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Tesi di Dottorato

Time, Events and Temporal Relations: an Empirical Model for Temporal Processing of Italian Texts

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To my family.
To my friends, for their help and support.
To Habibi.

Chapter 1

Introduction

The aim of this work is the elaboration of a computational model for the identification of temporal relations in text/discourse to be used as a component in more complex systems for Open-Domain Question-Answers, Information Extraction and Summarization. More specifically, the thesis will concentrate on the relationships between the various elements which signal temporal relations in Italian texts/discourses, on their roles and how they can be exploited. This introductory chapter is meant to outline the motivations behind the research and its main aspects, and to present an overview of the thesis.

1.1 It is or it was.

Consider the dialogue in the comics in Figure 1.1.

Figure 1.1: *The misfunctioning of a juicer: is it or was it defective?*

Going through the dialogues we discover that an electric juicer was bought in a period of time which precedes the moment of utterance of the child, and that, according to the child, the juicer "is defective". The most natural interpretation is that the juicer is defective *now* because it is the first time that it has been used since it was bought. Nevertheless, if we keep reading the strip we come to know that a particular action, or event, has taken place, namely that the juicer has been used to extract juice from bubble gums (quite weird, indeed). Clearly, the mother asks for a clarification to know if the juicer *was* already defective at the time of buying or it *is* defective now, i.e. it has become defective, after the fuzzy action of juice extraction from bubble gums (and we fear that the correct answer is the "it is"!).

Time is a pervasive element of human life. It is the primary element thanks to which we are able to observe, describe and reason about what surrounds us and the world. If we apply this trivial observation to the comics, we can easily observe that the absence of a correct identification of the temporal ordering of what is narrated and/or described may result in a bad comprehension, which can lead to a misunderstanding. In the example illustrated, the difference in tense, with respect to the property of the juicer to be defective, clearly codes two different temporal situations: one in which the juicer was defective at the moment of buying, which we know to be occurred in the Past, and the other in which the juicer is defective now, in the Present, after the boy has attempted to extract a particular kind of juice.

The fun of the comics is obtained by playing with times or, to be more correct, with the tenses associated with the defectiveness of the juicer. Normally, texts/discourses present situations standing in a particular temporal ordering. Whether these situations precede, or overlap or are included one within the other is inferred during the general process of reading and understanding a text/discourse. Nevertheless, to perform this seemingly easy task, we are taking into account a set of complex information involving different linguistic entities and sources of knowledge, in particular:

- we know, i.e we can recognize, the relevant situations, or eventualities, which are involved in a temporal relation and those which are not;
- we relate different entities with different ontological status, like eventualities, i.e. things that happen or obtain in the world, and temporal expressions, i.e. words denoting measures of time;
- we can recognize the relevant information which helps us in determining the actual temporal relation and it seems that we activate different processing strategies on the basis of the linguistic information available.

The big issue we are facing in front of these kinds of knowledge and capabilities is to understand *how* the contribution of these elements could be formally represented and, namely, what kinds of processing procedures an algorithm should perform in order to deal with the set of operations that we as humans seem to perform with relative ease. This has led us to find answers to five questions, namely:

Question 1 : What is the temporal information of a situation in isolation (e.g. state *vs.* event distinction)?

Question 2 : What are temporal expressions? How wide should be considered this class of words?

Question 3 : How much and what types of information are involved when we infer a temporal relation between two eventualities?

Question 4 : Is it possible to identify a set of necessary and sufficient conditions for each source of information involved in the inferencing process of determining the temporal relation between two entities? And if so, how can they be organized?

Question 5 : How fine grained should be the set of temporal relations in order to relate situations with each other and reason with them?

A wide variety of devices is used in natural languages to convey temporal information. Verb tense, temporal prepositions, subordinate conjunctions, adjectival phrases are some of the most obvious. Nevertheless even these obvious devices have different degrees of temporal transparency, which may sometimes be not so obvious as it can appear at a quick and superficial analysis. Other less obvious devices are at disposal which rely on commonsense knowledge or pragmatic inferences. Previous studies[1] have tried to provide an answer to these questions but all of them can be considered as partial answers not completely satisfying. One of the main shortcomings of previous research on temporal relations is represented by the fact that they concentrated only on a particular discourse segment, namely narrative discourse, disregarding the fact that a text/discourse is composed by different types of discourse segments and relations. A good theory or framework for temporal analysis must take into account all of them. In this work, we have concentrated on the elaboration of a framework which could be applied to all text/discourse segments, without paying too much attention to their type, since we claim that temporal relations can be recovered in every kind of discourse segments and not only in narrative ones.

The revision of previous works both in the field of Theoretical Linguistics and Computational Linguistics have provided us with a set of preliminary elements on the basis of which we have organized our work. This has led us to take into account different levels of analysis going from purely grammatical ones (tense and viewpoint aspect) to pragmatics (commonsense knowledge and discourse relations). Our purpose was to find reliable generalizations which, preserving the theoretical correctness of the linguistic analysis, could represent the key features to be implemented in an algorithm to automatically extract the temporal information from a text/discourse and make it available for further reasoning or manipulation. One of the main results we have obtained is the identification of a hierarchical order of application of the various sources of information which are involved in the process of inferencing temporal relations and on this basis we have proposed a general and unitarian model for automatically extracting them.

In addition to this linguistic exploration, the thesis also investigates the issue of how temporal information should be represented within a reasoning system. Time logic based on intervals such as that presented by Allen (1983) seems not to be adequate to account for the set of entities involved and namely for the too much precise temporal relations which are associated with it. On the basis of empirical data, we propose to enlarge it by including also coarse-grained temporal relations. Moreover, there could be cases in which we are not able to state in a reliable way if there exists a temporal relation or what the particular relation between two entities is. To overcome these issues: :

- we have enlarged the set of temporal relations, including both finely-grained and coarse-grained ones, so that the computation, even in absence of crucial information, will always produce a unique result and not a set of disjuncts of possible values; and
- we have adopted the proposal by Mani (2007) which allows the system to have differentiated levels of temporal representation on the basis of the temporal granularity associated with each discourse segment.

The importance of extracting temporal information from texts/discourses, and the difficulty of this task, suggest that a concerted effort should be performed in order to determine either the exact temporal order or the general temporal relation existing between two entities. The proposal of the model aims at representing a sound base which deals with those features and relations in texts/discourses which allow humans to perform this task.

[1] Partee (1973, 1984); Lo Cascio (1985); Dowty (1986); Hinrichs (1986); Passonneau (1988); Webber (1988); Blackburn & Lascarides (1992); Hwang & Schubert (1992); Kameyama et al. (1993); Kamp & Reyle (1993); Lascarides & Asher (1993); Hitzeman et al. (1995); Wiebe et al. (1997); Kehler (2000), among others

1.1.1 Methodological Note

The model we propose is obtained by mixing together theoretical assumptions and empirical data, collected by means of two tests submitted to a total of 35 subjects with different backgrounds. The subjects were asked to state the temporal relations between two adjacent eventualities previously identified in a text/discourse segment. In addition to this, they were also asked to state what was the source of information which had helped them mostly, i.e. what they perceived as the most salient, in the assignment of the temporal relation. The hypotheses predicting either the presence of a particular temporal relation or the salience of a source of information have thus been verified on the data collected from the subjects' judgments. In case a contradiction arises between the hypotheses and the data, these latter have been considered as the most relevant. One of the most interesting elements of the model is the fact that it is motivated on the basis of linguistic evidence and grounded on empirical data.

The lack of an annotated corpus for eventualities, temporal expressions and temporal relations in Italian represents the biggest shortcomings of this work which has prevented the implementation of the model and its evaluation. Nevertheless, we have been able to conduct a series of experiments for the validation of procedures for the further realization of a working prototype. In addition to this, we have been able to implement and validate a working prototype for the spotting of temporal expressions in texts/discourses.

This project was initially inspired by the adaptation of an annotation scheme for marking up time and temporal relations, namely TimeML (Pustejovsky et al., 2003c). However, the development of the model has not been conceived to be necessarily compliant with the scheme itself. The main advantage of the model is represented by the fact that it can be adapted to other languages in a very simple way and, most importantly, that it is output independent, i.e. that its output can be easily adapted to different representational formats, according to the required task for which it could be employed.

A further result of this work is represented by the creation of a corpus of Italian newspaper articles which is comparable in size and, most importantly, in content with the only available corpus annotated for temporal relations, the TimeBank. The collection of this corpus represents the first step for the creation of comparable resources which could be employed in multilingual tasks for Open-Domain Question-Answering or Information Extraction systems. Moreover, they can represent a relevant basis of data for comparable studies on the realization of the entities involved in temporal relations.

1.2 Overview of the thesis

The remaining of this work is organized in two main parts.

Part I comprises chapters 2-5 and is dedicated to the development of a computational model. Part II includes chapters 6-7 and illustrates two computational devices of the model, a working prototype of a tagger for Italian temporal expressions and a procedure for the implementation of the Event detector component and classifier.

Chapter 2 presents the so-called temporal entities, i.e. the ontological entities, their properties and relations, with which we are dealing when performing the task of recovering temporal relations in texts/discourses. A revision of the notions and conceptualization of time, both in physics and in language is accomplished. On the basis of the different conceptualization of time in the two domains, we have developed a general temporal ontology which presents a unitarian formal framework for the analysis of natural language data. The notions of **eventuality** is introduced and defined as a cover term for all things that happen, occur or obtain in the world. A principled distinction of the notions of event and state is illustrated together with their intrinsic temporal properties. Time is described as well and formalized exploiting already existing ontologies developed for the Semantic Web, which represent fundamental starting points for modelling and reasoning with time. A way of connecting these two different ontological entities is represented together with a formal description of how to compute, in an abstract situation, temporal relations.

The analysis of the linguistic realizations of the entities and properties of the temporal ontology is carried out in chapter 3. In this chapter we also present a deep revision of the contributions that the language subsystems, grammatical (tense and viewpoint aspect), lexical (lexical aspect, temporal prepositions and conjunctions) and pragmatic (discourse relations), have at disposal to code and signal temporal relations. One of the main interesting results of this section is represented by the identification of the different roles and contributions of these elements in the process of recovering or determining a temporal relation.

Chapter 4 presents a revision of the previous approaches in literature on systems and frameworks for the temporal analysis of texts. The chapter is divided into two main parts. In the first one, we analyze linguistic approaches, both formal and discourse based ones. We highlight their limits and good insights. As already stated, the main shortcomings of all these approaches is that they lack a unitarian framework to deal with all the devices natural languages have at disposal, thus providing partial pictures and mechanisms which are liable to failure when facing instances of real language data which are unable to deal with. In the second part we will present a brief state of the art of the computational applications developed so far for automatically extracting temporal information in texts/discourses. The main advantages of these approaches is related to the fact that they have been elaborated on real language data obtained by annotated corpora. We point out, however, the limits of these computational solutions which, in the vast majority of cases, lack a formal model against which to evaluate incorrect annotation and output of the system.

Finally, chapter 5 is devoted to the presentation of the model. In the first part of the chapter the results of the two experiments conducted on the subjects are illustrated and commented in details. The main results we have obtained from these empirical studies are:

- a general evaluation of the difficulty of the task of recovering temporal relations;
- information on the level of granularity of temporal relations;
- a saliency-based order of application of the linguistic devices used to express the temporal relations between two eventualities;
- the proposal of tense temporal polysemy, as a device to identify the set of preferences which can assign unique values to possibly multiple temporal relations.

On their bases we have developed the model which has a modular organization and reflects the constraints and preferences identified in the process of data analysis. With respect to previous frameworks, our model can be considered complete since it can be employed in the analysis of every type of text/discourse segments and, moreover, is able to overcome the limitations of the previous approaches.

Following a general introduction on the application of the model, chapter 6 presents a working prototype of a temporal expression tagger for Italian compliant with the TimeML specifications, which are becoming an international standard for representing temporal information in texts/discourses. The tagger has been implemented using rule-based techniques which take in input chunked or shallow parsed texts providing in output an annotated text for temporal expressions. An evaluation has been performed on a set of purpose annotated data and have reported an f-measure of 86.41 on identification of temporal expressions and of 75.86 for the identification of modifiers of temporal expressions. Unfortunately, no comparison is possible due to the fact that no other tagger for temporal expression available for Italian implements the TimeML specifications.

In chapter 7 a general procedure for automatically detecting and classifying eventualities is presented. The procedure shows how this complex task can be facilitated by exploiting a semantic lexical resource, namely PAROLE/SIMPLE/CLIPS. To show the reliability of the procedure we have conducted two annotation experiments using the lexical resource as an active interface. The results obtained are encouraging and promising. As for the event classification task our proposal is twofolded: on the one hand, in order to facilitate the recovering of temporal relations, we need to classify eventualities in terms of their lexical aspect values, but, on the other hand, since the identification of eventualities may be relevant for subsequent systems which need to perform reasoning with eventualities, we have also included a semantic classification of them which makes the modality of the eventualities explicit.

The thesis is finally completed by three appendices. In appendix A we report on the results of a corpus study on the identification of the semantics of temporal prepositions and conjunctions, classified with the cover term of signals. The meanings of these special class of words is represented by the temporal relation (or relations) they code. Appendix B is dedicated to the illustration, in a formal format, of the set of rules we have implemented for the temporal expression tagger. Finally, appendix C presents the adaptation to Italian of the TimeML guidelines, which we have conducted within the ISO project on Semantic Annotation Standard.

Part I

Chapter 2

Temporal Ontology: Modeling Time, Events and Temporal Relations

In this Chapter we will illustrate the entities involved in order to perform a temporal analysis of texts, and how we want to represent them. In an intuitive way, we are dealing with time and what happens or obtains in time, so we need to provide a formal framework for describing and modeling the entities we suppose exist or are relevant to our purpose. Usually, time is modeled using *instants* and *intervals*, and *events* and *states* correspond to what happens or obtains. In comparison with previous approaches, we will keep the descriptive issue separated from the modeling and interpretative one. This means that first we will shift to an abstract and formal level of description, i.e. an ontological level, where the entities involved are described, and then we will provide a formal model to connect the two ontological levels. The model is the first step for the elaboration of a robust computational model for a temporal analysis of text/discourse.
The chapter is organized as follows: in the first sections, (2.1 and 2.2), we will present a review of the cognitive basis of time since it represents a core element to fully understand the patterns of the linguistic encoding of temporal relations. The remaining of the chapter is devoted to the formalization of a general framework, what we call a Temporal Ontology for time, events and temporal relations.

2.1 Introduction

Reference to time is a pervasive phenomenon of human communication, and it is reflected in natural language. Consider, for instance, the following sentences:

(2.1) Marco comprò un libro.
Marco bought a book.

(2.2) Marco comprerà un libro.
Marco will buy a book.

The only difference between example 2.1 and the one in 2.2 is in the verb morphology. Such a minimal morphological difference has an important counterpart at the semantic level. As competent speakers of Italian (or English), we are able to claim that in the example 2.1 the "event", i.e. the buying of the book by Marco, is described as something which has *already* happened, while in 2.2 the same "event" has *not yet* occurred.

These are very trivial observations but introduce a first interesting observation. Provided the structure of a language such as Italian, where verb morphemes are compulsory when writing or uttering a sentence, temporal information is always present. Even when no exact temporal location is used (i.e. a date like "Tuesday, 29th February 2008"), we are always able to determine in which of the main temporal domains the described state of affairs must be located. So, we can correctly claim that example 2.1 is in the Past while example 2.2 is in the Future[1].

It is worth noticing that the pervasiveness of time has no counterpart in other cognitive domains. Consider, for instance, the domain of *space*, which represents a further core element in the elaboration of our experience. If we observe, again, examples 2.1 and 2.2, one can notice that no spatial information is provided but this does not avoid the acceptability of the sentences as being "grammatically" correct. Generalizing this observation, as Bonomi & Zucchi (2001) suggest, and exploiting our experience of readers, we could claim that the absence of spatial information characterizes lots of Italian (declarative) sentences, while (a minimum of) temporal information is always present[2]. In addition to this, temporal location, i.e. the identification of the temporal dimension of Past, Present and Future, is intimately different with respect to spatial location. An event or a state of affairs can be described as happening in front of, next to or behind us. Or even on the left or on the right. Nevertheless, none of these positions is more important than the others, i.e. none of them is presupposed as stable and unique and used as pivotal point of reference. Spatial location is dependent on the particular *point of view* which has been chosen by the speaker. On the contrary, temporal location is considered *independent on the point of view* of the speaker. What characterizes a point of view is the possibility of being arbitrarily chosen, and, thus, changed. This is impossible for time. Stating that a state of affairs is in the Past, Present or in the Future does not depend on an arbitrarily chosen point of view, but on the actual temporal location of the speaker which, usually, coincide with its moment of utterance. Combining the semantic information of the tenses and the reference to this moment of utterance, we are able to locate the event in example 2.1 in the temporal dimension of the Past, i.e. what is described precedes the moment of utterance, while the event in example 2.2 is located in the temporal dimension of the Future, i.e. what is described follows the moment of utterance.

The temporal location of the speaker cannot be freely chosen but is subject to constraints. One of them is represented by the observation that moving in time is not as free as moving in space. While we can ascribe to things and events properties such as being *on the right*, or *on the left*, *behind* or *in front of*... according to our point of view, we cannot describe, for instance, a past event (with respect to a given moment) as a future one. Another important constraint is the principle of internal directionality of time (Bonomi & Zucchi, 2001). It is a truism that the notion of *past*, *present* and *future* have an indexical nature, since, as already stated, they depend on the moment of utterance of the speaker and his/her temporal location. This implies that what is considered at a moment t a future event can shift in the past with respect to a different moment, say, t'. As time passes by, events shift from the Future, to the Present and then to the Past. However, when something is in the Past, it is there for ever. We can reformulate this principle in an axiom which we will call the Axiom of Internal Directionality of Time:

[1]With Past, Present and Future we are referring to the temporal dimension denoted by the verb morpheme and to the grammatical tense. Tenses will be referred by using simple Roman, e.g.: simple past, present, simple future. . . .

[2]Possible exceptions are sentences describing mathematical or physical statements, like "the earth is round", which cannot be located in a temporal dimension, however, we can consider these kinds of statements as tensed statements as well by claiming that they express a truth value which is valid in every time.

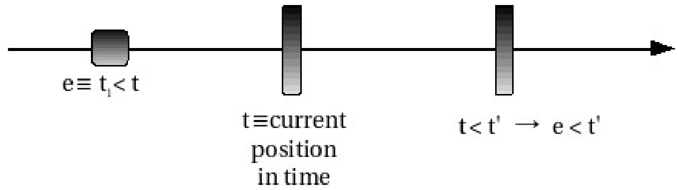

Figure 2.1: *Representing Time as an oriented line.*

A1. **Axiom of Internal Directionality of Time**: if it is true of my current position in time, *t*, that the event *e* occurred in the past of *t*, then it is true of any future position *t'* that *e* is in the past of *t'*.

The axiom of internal directionality introduces a well-known and successful metaphor for representing time and the temporal ordering of events, that is that of an oriented line whose points represents the internal instants, as illustrated in Figure 2.1.

To clarify the importance of the axiom A1., consider an event x which has happened at a time t, and an event y which has happened at a time t', which is posterior to t, i.e. $t' \succ t$. Then, claiming that "the event x happened before the event y" is always true, no matter the temporal location of the speaker. Once this utterance can be uttered, there is no way to modify its truth values by changing the relation between the two events. This allows us to claim that temporal relations have, with respect to other relations like, for instance, spatial relations, a certain degree of stability.

What we have stated so far is not to be considered as a contradiction but it represents two properties of time in language. On the one hand, the fact that lots of temporal notions are expressed by indexical expressions, like for instance verb tenses, which are dependent on the actual temporal location of the speaker and that, consequently, the temporal location of the event may vary according to the different temporal locations of the speaker. In this sense, time passes by, and the property of an events of being past, present and future is transitory. On the other hand, time has a directionality and the temporal transitory properties of events can be frozen: if on a certain occasion an utterance states that an event x is before another event y, or a time t, then this temporal relation is valid (or true) on every other occasion.

On this subject an insightful distinction is the one proposed by McTaggart (1927) between A-series, which represent the transitory properties of events and time, and B-series, which represent stable and permanent relations[3]. We will keep this distinction as relevant, since from a strict linguistic point of view it calls for a more general opposition, that is that between indexical expressions and expressions whose meaning is given by "classical" semantic rules, independent from the context.

From examples 2.1 and 2.2 we can observe that there is a big difference between

[3]McTaggart (1927) goes even further by claiming that the B-series are based on relation like precedence (succession) or simultaneity. We are not interested in this point, however, we only want to point out the two different ways in which time and temporal relations are encoded and represented in language.

linguistic time and physical time. As Steedman (1997) points out "the particular conceptualization of temporality that underlies language is by no means obvious" [Steedman (1997): 897]. Linguistic time is not primarily concerned with measuring intervals or instants, but, on the contrary, it relates different entities with respect to three dimensions: *earlier than*, *during*, *after*, corresponding to the temporal dimensions of Past, Present and Future respectively. In addition to this, if we zoom on the behavior of linguistic time in a text/discourse the picture gets more complicated, since it is responsible not only of identifying a temporal dimension for the entities involved but it also provides a set of cues to order these entities one with respect to the other.

These preliminary and quite intuitive observations lead to a question which needs to be answered before any attempt to formalize and describe the entities involved in a temporal analysis of texts is performed:

Question 6 : How is time conceptualized in our mind/brain?

2.2 The Psychology of Time

In discussing the cognitive basis of time, one may think that this represents a much simpler affair than discussing about the nature of the physical concept of time. After all, "*tempus fugit*", and we only have to perceive this flow, what has been called "the moving now"[4]. Unfortunately, the picture is much more complicated. Our conscious representation of time is a construction, which is dependent on two elements: the operations of the memory systems and perception. Three are the distinguishing aspects of the cognitive basis of time, in particular:

- time as duration;
- the temporal perspective;
- time as succession.

The durative aspect of time is twofolded: from the one hand, it deals with lexical expressions like "*one year*", "*10 minutes*", "*three o'clock*" which identify precise durations, and, on the other hand, it refers to several characteristics of the events. Every event persists for a certain duration, which an individual may encode and remember. Normally events are separated by time periods, which may contain other events, and the length of this time period plays a role in the cognitive aspect of time as duration. For instance, if an event lasts for a few millisecond, it is perceived as instantaneous, without duration. If, on the other hand, an event or episode lasts or persists for a longer period, then a person experiences, remembers and is able to judge duration. When speaking of duration an important distinction is that between experienced duration, which refers to the experience of time in passing, and remembered duration, which refers to the remembered duration of a time period. Fraisse (1963) proposed that "direct time judgements [are] founded immediately on the changes we experience and later on the changes we remember" [Fraisse (1963): 624]. An interesting aspect of Fraisse (1963)'s proposal is the emphasis on the fact that psychological time involves changes. Changes, in fact, serve as referents, or cues, to use in experiencing, remembering and judging time. As Gibson (1975) points out time in itself is not a stimulus, "there is no such thing as the perception of time, but

[4] "*[...] I can't say "now" quick enough for being exactly now [...]*", Vlado Radnovic, "Voice from the loudspeaker (tape-art 1)" (1975).

only the perception of events and locomotions" [Gibson (1975): 295]. Different models have been proposed for treating and explaining the cognitive basis of time as duration, like attentional models, memory-storage models and internal clock models. However, experimental data and changes in the cognitive paradigm provide evidence in favour of a different model or family of models, i.e. memory-change models, according to which we perceive a flow of change from the outside world and it is this flow which influence our perception and recollection of duration. In addition to this, the estimation of how long an event lasts or persists is essential to perform correct reasoning about the world. For instance, the perception of whether two events overlap or are in sequence often depends very much on their durations. A very interesting experiment on this cognitive aspect of time is represented by the creation of a corpus of typical duration of events, as performed by Pan et al. (2006). As we will see in the next sections, this aspect of time as duration is highly relevant in modeling our ontological representation of events and states.

Temporal perspective is the aspect of time most relevant to natural language. It represents the various attitudes that people adopt in relation to past, present and future. These issues are uniquely psychological in that modern physics has no need for a conception of time's passage from past to present to future. Temporal perspective is responsible for the temporal location of the events since it introduces a vantage point, the deictic "now", which coincides with the moment of utterance of the speaker, to which all events not co-temporaneous are related either as past or future. It is important to differentiate and keep separate the notions of temporal perspective and that of time as succession. The temporal ordering of events or instants is most likely computed from temporal perspective, rather than by the conceptually simpler notion of time as a succession. An interesting aspect which emerges from cognitive studies (Trabasso & Stein, 1994) is the intimate connection between the cognitive ability of temporal perspective and its being goal-oriented. In their work the authors defend the thesis that "the plan unites the past (a desired state) with the present (an attempt) and the future (the attainment of that state)" [Trabasso & Stein (1994): 120] by means of data from a set of experiments whose purpose was to investigate what linguistic devices, in particular temporal expressions, children use to narrate a story, as a function of age.

Finally, the notion of time as succession is related to the idea that time is simple, since" we only have to attend to the succession of events in the outside world" [van Lambalgen & Hamm (2005): 9]. Observations like the former have contributed to the idea that the progression of time can be represented as an ordered line or an arrow (see Figure 2.1 on page 11). Considerable cognitive research on this aspect of psychological time has investigated the temporal resolution of perceptual systems. Various phenomena are involved if brief stimuli are presented in such a way that the stimulus-onset asynchrony (i.e. the time span between the onset times of two stimuli) is very brief. Perceptual systems, like audition and vision, differ somewhat in this regard. Although some differences due to the perception system in analysis and the particular sensory receptor areas involved, it has been observed that with a very brief stimulus-onset asynchrony people experience apparent simultaneity, rather than succession. The encoding of succession of events occurring over larger time span, in all probability, makes use of temporal perspective, rather than simple linear succession. As Block (1990) claims:

> [...] in interaction with human cognitive processes, information relating to the ordering of events from earlier to later gives rise to the common idea that the progression of time may be represented as a line or an arrow. The continuously integrated functioning of perceiving, remembering and anticipating processes apparently produces a relatively automatic awareness of the successive ordering of events. This is

> a fundamental aspect of all temporal experiences beyond those that merely produce an experience of successiveness without the ability to discriminate temporal order. The primary psychological basis for the encoding of order relationships between events relates to the dynamic characteristics of information processing: in the process of encoding an event, a person remembers related events which preceded it, anticipate future events, or both [Block (1990): 6].

From the previous citation we can observe that the expression of relations such as "event A *precedes* now" and "event B *follows* now" are operationally, respectively, as: "If I *recall* event A, it must have taken place before now and is located in the past", while "If I *anticipate* event B, it must take place after now and is located in the future". Moreover, a relation like "A precedes B" is obtained by applying the above operational definition compositionally. According to this point of view, temporal perspective is overlayed with recollections and anticipations and, generally, with contextual material. A further observation which emerges from Block's claim is that succession, in general, is not automatically encode in memory, since it requires conscious attention for explicit encoding. Nevertheless, succession, i.e. precedence relation, seems to have a privileged position with respect to the other temporal relations, like "overlap", "includes", "begins" ... in the sense that it tends to represent the focus of conscious attention to temporal structure. However, with respect to previous theoretical approaches, in particular in the field of discourse semantics (Lascarides & Asher, 1993), we are not claiming that the temporal relation of succession is a general default between two subsequents sentences. No temporal relation can be assumed as a default, but they are the result of a complex process of inferencing based on linguistic and (relevant) contextual cues, such as tense, temporal adverbials, aspectual meaning, world knowledge and discourse structure.

Summing up what we have stated so far, we have a conscious perception of time, and this is the primary condition for its grammaticalization in language. This implies that time is a construction, "a product of the processes that allow [human beings to organize their lives so that their behavior remain] tuned to the sequential (i.e. order) relations in [their] environments" [Micheon (1990): 90]. The experience of time is developed through age and it is this constructive representation of time that allows humans not to live in an aeternuous present. Temporal perspective seems to have cognitive primacy over other cognitive aspects of time, in particular over time as succession. But this does not allow to claim that there exist a default temporal relation of succession, at least we can claim that succession is a preferred temporal relations in the sense that it may result easier to process. The idea that temporal perspective is essentially goal oriented seems to be supported by experimental data (Trabasso & Stein, 1994), and is interpreted as a consequence of the fact that we, as humans, are goal-oriented agents. A fascinating, but quite risky, hypothesis which can be formulated from these statements on the cognitive nature of time is that the *linguistic* encoding of time is mainly driven by the future-oriented nature of our cognitive make up.

This brief review of cognitive models of psychological time has introduced issues of which we have to be aware in order to conduct a temporal analysis of a text/discourse. In particular, the fact that temporal experience, as it is represented at the conceptual level and encoded in language, exhibits different levels of organisation, where at least three cognitive models for time are involved. This is a level of organisation in which various concepts are integrated together in order to provide complex, yet coherent, representations for time. It is this level of organisation that, for the most part, we employ in our everyday lives when we think and reason about time, and which we employ when we co-ordinate cultural and interpersonal activities such as scheduling meetings, moving meetings ‘forwards’ or ‘backwards’, when we prepare for ‘approaching’ events, and so forth. Such observations are crucial for the elaboration of a computational model for the temporal ordering of events; the complex organization of time at a cognitive level calls for a computational model of language which should be able to organize this information in an ordered and hierarchical way, so that algorithms for its processing may be developed.

2.3 Representing Time, Events, States and Temporal Relations in Natural Language

The question of how to model time, events and states in natural language has been the subject of a long debate for many decades now. Although this dissertation is not the place for a throughout review of the history of ontological issues on representing time and events and their relationships to Logic and Linguistics some references are compelling to better understand our approach to the Temporal Ontology.

In literature, it is possible to identify two distinct approaches on the modeling issue: time dependent models based on classical *Temporal Logic* (Prior, 1968), and time independent models, based on the davidsonian *event-based semantics* formalism (Davidson, 1967).

Classical temporal logic approaches, first establish a temporal framework, a model for time itself and then superimpose the different types of change that can occur in it, i.e. events and states. According to this ontological perspective, events and states are properties of times: temporal instants or intervals during which certain statements holds (van Benthem, 1983). Their ontological status is, thus, subordinated and derived from the modeling of time and reflects the properties of their propositions with respect to their evaluation time. On this view, sentences are no more logically represented by propositional variables with no reference to any particular time, (e.g. ϕ), but they are an *ordered* pair of the form $< i, \phi >$, where i is the relevant time period with respect to which the truth-values of the sentence are evaluated and ϕ is its propositional content. Verb tenses are considered as semantic operators which help the hearer/receiver to identify the temporal,location of i with respect to the moment of utterance.

The latter approach, the event-based semantics, represents a sort of ontological counterpart of the former approach. The idea of assuming events as a basic notion from which time can be derived and represented time is motivated, as already stated, by a philosophical tradition initiated by Davidson (1967). He introduced an autonomous notion of event by formalizing the famous sentence:

(2.3) Jones buttered the toast in the bathroom at midnight.

as

(2.4) $\exists e \exists x \exists p \exists t (butter(e, Jones, x) \wedge toast(x) \wedge bathroom(p) \wedge midnight(t) \wedge in(e, p) \wedge at(e, t))$

Events and states are assumed as primitives with distinctive properties and they are explicitly represented in logic formulas. Introducing these entities in logic representations can be backed up by evidence given by the anaphoric reference we can make to them. In the following examples we have used the classical notational convention by means of co-referring indices to illustrate the anaphoric link:

(2.5) John [buttered the toast]$_i$. He did it$_i$ in the bathroom. He did it$_i$ at midnight.

(2.6) John [buttered the toast]$_j$. That$_j$ was good.

According to this approach, instants and intervals are constructed as derived entities. The most classical treatment of this sort proceeds by construing temporal instants as maximal sets of pairwise simultaneous - or partially simultaneous - events. Tenses are no more simple semantic operators but they are functors which have the role of specifying the (temporal) relation between a time of evaluation i, usually the moment of utterance, and the time i' at which the event (state) occurred (held). Treatment of time as proposed in event-based semantics provides a reduction of time in terms of relations among events and are therefore germane to a relational conception of time, as illustrated in section 2.2.

Besides the theoretical and formal differences, the great innovation of these approaches is represented by what has been termed as *the tensed view of semantics*. This new perspective in semantics innovates the old classical first-order logic paradigm, by claiming that:

a. Propositions have truth values **at times** rather than having truth values *simpliciter*; thus, temporal distinctions expressed by tense are worth being studied;

b. The main semantic locution now is:

$$\phi \text{ is } v \text{ in } \mathbf{M} \text{ at } t$$

where v refers to truth values, **M** represents a model for the evaluation and t refers to a time;

c. a proposition may have different truth-values at different times.

These new epistemic paradigms represent the core elements for the development of our computational model and for the elaboration of its semantics, both theoretically and from a more applicative point of view, in particular, for temporal question answering, summarization or information retrieval tasks.

The two approaches illustrated so far have another common point, that is, time, events and states are defined inside a unique descriptive and modeling framework, either subordinating the properties of events and states to time, as in the priorean approaches, either conceiving time as derived from events and states, as in the davidsonian ones. Although such choices may be favoured since they try to represent the intimate connection between time and events, at the same time, they are a drawback for building formal ontologies whose aim is that of describing the most general features of the entities identified and how they are related to each other in the metaphysically most general ways. For instance, classical Temporal Logic does not do justice to a series of intuitive commitments to events, in particular the fact that events are perceived and time is constructed, and, on the other hand, its modeling of time, i.e. the use of either instants or intervals as ontological primitives, is in large part inadequate to represent the way in which speakers use language, as Kamp & Reyle (1993) suggested. In addition to this, deriving time from events and states, though it seems to reflect some cognitive issues as we have illustrated in section 2.2, introduces complex questions and complicated formalisms which may lose efficiency in modeling the way speakers conceive time and temporal relations in discourse. To avoid these shortcomings and to obtain the clearest possible "ontological" representation, we postulate that time, events and states are all ontological primitives, and that none of them can be derived or conceived in terms of the other. This means that under what we call

Temporal Ontology we are going to present two distinct ontologies[5]: one for time, and the other for events and states. The Temporal Ontology we are presenting is a general descriptive framework of the entities involved when doing a temporal analysis of a text/discourse, which aims at being independent of the various models and theories of temporal analysis[6]. Under this perspective, temporal relations between events are obtained as an extension of the time ontology, and they can be modeled as first-order predicates, i.e. they are functions, over the entities of the two ontologies. In addition, avoiding the introduction of temporal relation in the event ontology mirrors the intuitive observation that events and states are intimately anchored to time, and that, as a consequence of this anchoring, they can be ordered. Although these entities are strongly interrelated, we claim that their description must be kept separated. As a consequence of this approach, we should reach a more uniform treatment of the semantics of these entities and fix some elements for the elaboration of a general computational model for temporal analysis of text/discourse.

2.3.1 Eventualities: Events and States

Broadly understood *events* are things that happen - things such as "explosions", "weddings", "death", "walk", "thunders"...- while *states* are identified as the existing conditions or positions of an entity. As a matter of facts, it is not easy to provide an uncontroversial characterization of these entities. Whether events and states form a genuine ontological class has been a subject that has attracted the questions of philosophers, especially in the second half of the 20^{th} century. Nevertheless, human perception, action, language and thought manifest a commitment to entities of this sort. For instance, the fact that pre-linguistic infants appear to be able to discriminate and count events, or the fact that dedicated linguistic devices (i.e. verb tenses and aspects, nominalizations...) are tuned to events, states and their structures as opposed to entities and structures of other sorts, or, finally, when thinking about the temporal, causal, and intentional aspects of the world seems to require parsing those aspects in terms of events and their descriptions. Accepting as valid these *prima facie* commitments and following the great intuition behind the event-based semantic approach, we consider every sentence of natural language, or better every proposition of natural language, as expressing the occurrence of an *eventuality* in time. This term, first used by Bach (1986), is a cover term to identify both events and states[7]. Formally, this statement can be represented by the following formulas (where the symbol $\supset$ means inclusion):

E1 $\forall(\phi) \longrightarrow Event(e) \vee State(s)$

E2 $Event(e) \supset Eventuality(\varepsilon)$

E3 $State(s) \supset Eventuality(\varepsilon)$

Events and states represent the only two subclasses of eventualities, and, as already stated, they are considered as ontological primitives, thus:

[5]Hobbs & Pan (2004)

[6]For instance, we will not follow Kamp & Reyle (1993)'s or Schilder (1997)'s proposal by presenting a time logic model. On the contrary, we want to present general formal parameters for describing what are the entities involved, their properties and how they interact on a general abstract level. As it will appear in the following paragraphs, we are not assuming structures of eventualities or structures of time inside an interpretative model. The Temporal Ontology is an abstract, formal description of the entities. The interpretative model is a device which can be elaborated in a second moment.

[7]It is interesting to note that Bach (1986) speaks of "quantities of processes" when presenting states, as if they were derived from events; however we are following his distinction.

E3 $\forall(\varepsilon) \supset Event(e) \vee State(s)$

So far, nothing has been said about the nature of states and events; in particular, we need to find a set of features which allow us to distinguish in a clear-cut way the differences between these two entities. We are speaking of a *clear-cut distinction* but this is a possibility we confine to this abstract ontological level, things in real natural language are a bit more fuzzy, as we will see. The use of features is part of a long tradition in semantic analysis as they represent a good device to explain the behavior of different entities and, in particular, to identify and describe ideal or prototypical types - the task we are aiming to in this section. In addition, modeling entities in terms of features is also a good device to preserve the compositional hypothesis of meaning and to explain some phenomena, like type coercion, in natural language. One of the main shortcomings of a feature-value analysis is represented by the number of features one chooses to uniquely identify the entities under analysis. With respect to this issue, we adopt an empirical approach which mixes together observations based on intuitions from linguistic data and analyses from previous accounts (Vendler, 1967; Dowty, 1979, 1986; Bach, 1986; Bertinetto, 1986; Moens & Steedman, 1988; Pustejovsky, 1991).

As already stated, eventualities occur in time. As a consequence of this quite naïve philosophical view of the world, eventualities pertain in *reality* (e.g. the crashing of the planes on the Twin Towers on the 11th of September 2001) and "occupy" the portion of time where they occur or obtain, thus, eventualities are spatio-temporal entities. However, as it is illustrated by the following examples, their behavior is quite different. Consider, for instance,:

(2.7) Marco ha disegnato un cerchio.
Marco has drawn a circle.

(2.8) Marco ha fame.
Marco is hungry.

It is clear, with no need of complex logic formalisms or representations, that the propositional content of example 2.7 involves a change while the one in 2.8 not. To state that it is true that Marco has drawn a circle, it is a necessary condition that an entire circle has come to exist. It is interesting to note that if Marco stops before its completion, i.e. no complete circle has been drawn, then the sentence cannot be said to be true; however, we still register a change with respect to an hypothetical initial situation (for instance, a situation where Marco took a pencil and a sheet of paper). On the other hand, in example 2.8 this idea or perception of change, of movement is totally lacking. It describes a property of Marco, namely that of being hungry. To clarify these statements, imagine that we assign an arbitrary duration to the two propositional contents by claiming that both 2.7 and 2.8 last for 5 minutes. If we split these five minutes in three different moments, i.e. beginning - intermediate - final, it is easy to observe that only 2.7 has a dynamic evolution towards the end, while 2.8 does not, it is static. If by means of a special device we could stop the time at the intermediate point, we will observe that in 2.7 something which looks like a circle was drawn, and marks a change from the beginning point when the sheet of paper was completely blank. Moreover, from the beginning point to the intermediate point we cannot say that Marco has drawn a circle[8]; on the contrary, in 2.8 Marco has still the same property as at the beginning point, no change has occurred. Going a little

[8]In this case we could say that "Marco is drawing a circle", or that "Marco has drawn something which looks like a circle".

bit further we can claim that change involves movement. Borrowing a term from physics, we can say that the propositional content of 2.7 identifies a dynamic eventuality, while that in 2.8 identifies a static (i.e. non dynamic) eventuality. The presence or absence of **dynamicity** seems, then, to be a core feature to identify events and states. Re-analysing our examples by means of the feature of dynamicity, we are in a position to state that 2.7 is an instance of an event, while 2.8 is a state. A first, though rough, definition of events and states can now be formulated:

Definition 1 (event) : an event is a dynamic entity, describing a change in the reality;

Definition 2 (state) : a state is a static, i.e. non dynamic, entity, describing a property or a relation which is ongoing over a time span.

It is interesting to note that the nature of the first feature we have introduced, i.e. dynamicity, is temporal. This element reflects the observations that eventualities are spatio-temporal relations and suggests us a primary "dimension" to look for other features to refine our distinction.

Two consequences, or if we want to be more formal two corollaries, derive from the feature of dynamicity. The first, is that if an event is a change in reality, it must have a definite beginning and end, while a state describes an indefinitely extending "state of affairs" or conditions that are constant throughout their duration. To avoid misunderstandings, it is important to point out that we are not referring to which actors or in what ways an event or a state may be initiated or terminated, but only to some general properties which, in our framework, are thought as deriving from being dynamic or static entities. In a formal way we can represent these statements by means of the following axioms:

E4 $Event(e) \longrightarrow (begin(x) \wedge end(y))$

E5 $State(s) \longrightarrow \neg(begin(x) \wedge end(y))$

where x and y are two undefined time variables representing the beginning and the ending points or moments. The presence or absence of beginning and ending points is a further element for differentiating events from states, but it also represents a relevant element for the computation of temporal relations and also to obtain a more logical representation of eventualities and their constraints in time.

The second important consequence related to dynamicity is represented by the behavior in time that states and events have. As pointed out in an informal way above, if an event lasts for a time t, the internal points (or moments) into which this time can be divided do not represent points (or moments) in which the event happens, but at least stages of it. This is not true for states: the indeterminate relationship with the time a state "occupies" means that a state is true, or holds, also for every single internal points or moments of time it lasts. If in one of these internal moments, a state does not hold anymore, we are in presence of a change, a dynamic situation, that is, an event. These last observations can be better described by means of the properties of homogeneity and heterogeneity (Krifka, 1989). An entity x is homogeneous if for every entity y_1, y_2, y_n which is a subpart of the entity x, the subpart is a denotation or an instance of the entity x, i.e.:

- $\forall x[X(x) \longrightarrow \forall y(y \sqsubseteq x \wedge \neg y = x \wedge X(x))]$

On the other hand, an entity is heterogeneous if and only if for every subpart of it, *no* subpart is also a denotation or an instance of that entity, i.e.:

- $\forall x[X(x) \longrightarrow \neg\forall y(y \sqsubseteq x \wedge \neg y = x \wedge X(x))]$

These two properties have some corollaries as well. One of them, and maybe the most important, is the fact that heterogeneous entities give rise to special predicates. These predicates do not apply to any part of an entity in their extension, and they separate each entity they apply to from any other entity. Consequently, they individuate the entities in their extension. As a matter of fact, in virtue of being subject to a heterogeneous predication these entities are like individuals and, furthermore, can be counted. We may then say that an event is a heterogeneous type-predicate, which does not apply to any proper temporal part of the event in its extension. As such, it includes the criterion of individuation and counting for the event it applies to. Each event carries its own criterion of individuation and counting. This means that, one and the same event can be viewed as being composed of a different numbers of events. Take for instance the event of "building a house": this event may be viewed as a single atomic event, or as composed by different events like "digging the ground", "building up the walls".... Counting and individuation instantiate another property of events at the ontological level, that is, events are subject to part-of (mereological) relations for which the notions of identity, atomicity, proper subpart, overlapping as well as the operation of product and sum holds. We symbolize the primitive mereological property of parthood by 'P', so that '$P(x, y)$' reads "x is a part of y":

P1. x=y $\equiv$ P(x,y) $\wedge$ P(y,x) $\Longrightarrow$ x is identical with y

P2. O(x,y) $\equiv$ $\exists$z (P(z,x) $\wedge$ P(z,y)) $\Longrightarrow$ x overlaps y

P3. PP(x,y) $\equiv$ P(x,y) $\wedge$ $\neg$P(y,x) $\Longrightarrow$ x is a proper subpart of y

P4. $\neg$PP(x,y) $\equiv$ $\neg$(P(x,y) $\wedge$ $\neg$P(y,x)) $\Longrightarrow$ x is an atom

P5. x$\bigoplus$y $\equiv$ σz (P(z,x) $\vee$ P(z,y)) $\Longrightarrow$ sum of x and y[9]

P6. x$\bigotimes$y $\equiv$ σz (P(z,x) $\wedge$ P(z,y)) $\Longrightarrow$ product of x and y[10]

On the other hand, states hold homogeneously and they must be considered to have an indefinite number of proper parts which are also instances of those states. Homogeneity is clearly incompatible with counting and individuation: "one could not make sense of specifying a definite number of possible applications of a predicate to something which has an indefinite numbers of parts, each of which can be characterized by the same predicate" [Herweg (1991): 370]. In addition, states are closed with respect to the mereological properties: if an homogeneous predicate applies to an entity, it applies to all of its part as well.

We can now restate and refine our previous definitions of state and event by introducing these two properties, so that:

Definition 1′ (event) an event is a dynamic heterogeneous entity, describing a change in the reality, with a beginning and an end;

Definition 2′ (state) a state is a static (non dynamic) homogeneous entity, describing a property or a relation which is ongoing over a time span.

[9] z is the sum of x and y iff the parts of z are just those objects which are parts of **either** x **or** y

[10] z is the product of x and y iff the parts of z are those objects which are parts of **both** x **and** y.

2.3.1.1 Distinguishing Event Types

Having stated that events are heterogeneous entities which can be counted and identified suggests that inside the event category is possible to make further distinctions, i.e. to identify ontological sub-types. A feature often used in literature, and linked to the observation that states and events occupy a portion of time when they are realized or uttered, is that of **durativity**, i.e. their internal temporal duration[11]. This feature seems quite trivial, the idea of durativity is implied in our definitions of events and states ("having a beginning and an end"; "a relation which is ongoing over a time span"), and, at the same time, it applies to both these entities. This could lead to a contradiction with what we have stated above about homogeneous and heterogeneous entities. By applying durativity *tout court*, we are not able to better distinguish events and states. As a result, we will find out that some events are similar to states, since they last over a variable time span, and that other events seem to be instantaneous. To avoid such a confusion and possible contradictions, we claim that the "scope" of this feature is constrained and that it cannot apply freely. From our point of view, the identification and use of new features is now constrained by the properties of heterogeneity and homogeneity. This means that, although on a general level, events and states last, i.e. have a duration, the use of this parameter at the level of homogeneous entities is useless since, by definition, no further ontological type can be identified. Trying to be clearer: claiming that states can be differentiated on the basis of their duration, i.e. permanent and non-permanent ones, does not introduce ontological differences, the ontological properties of permanent states are exactly the same of those of non-permanent ones, the only difference is that non-permanent states may end if other external elements occur. On the contrary, applying the durativity feature to events is useful since the distinction between durative and instantaneous, or punctual, events is a relevant distinction. Durative and punctual events realize different ontological properties, in particular "how big" (in time) is the distance between the beginning and end point. It is important to notice that when speaking of punctual events we are not saying that these events are really instantaneous. Punctual events do have some duration, though we as human are not able to perceive the time span between its beginning and end point. Once again, a feature which is intimately related to time, i.e. durativity, has been used as a distinguishing element for identifying internal properties of a subclass of the eventualities, thus reinforcing the claim that they qualify as spatio-temporal entities.

As linguistic data show, the distinctions inside the primitive category of event are not exhausted with the identification of different durations. Consider the following examples:

(2.9) Marco corse.
Marco ran.

(2.10) Marco corse al negozio.
Marco ran to the store.

(2.11) Marco tossì.
Marco coughed.

(2.12) Marco raggiunse la vetta della montagna.
Marco reached the top of the mountain.

[11]To indroduce a parallel with the cognitive models of time (section 2.2) durativity corresponds to time as a duration.

What should strike an attentive reader is the fact in examples 2.10 and 2.12 the events terminate, i.e. their end points are perceived as naturally occurring, and the events are considered to have taken place only after the end point is reached, on the contrary, this is not the case in 2.9 and 2.11: these events do not terminate, but they end. This behavior of events with respect to their end points represents a further feature to describe them, known as **telicity**.

Following Krifka (1989), telicity is conceived and formalized as a consequence of having part-of relations. Thus, an event is said to be telic if it is a quantized event, that is if for any choice of x and y, if x can be described by an expression ε, and y can also be described by ε, then x is not a mereological proper part of y. An event is considered as atelic if it is a strictly cumulative one, that is if for any choice of x and y, if x can be described by an expression ε, and y can also be described by ε, then the mereological sum of x and y can also be described as ε and it does not denote a union with just a single element. To clarify these statements, consider 2.10: if we divide the entire event in two subparts, for instance going from Marco's house to the zebra crossings and then going from the zebra crossings to the store, none of this subpart can be understood and described as an event of going to the store, and thus 2.10 is a telic event. Similarly, in 2.9 if we divide the event of running in three subparts, all of them can also be described as an event of "Marco ran". In fact, if they are summed up together they can still be described as an event of "Marco ran" as well. The same observation holds for 2.12 and 2.11 identifying a telic and an atelic event, respectively. Note that atelic events seem to have a behavior similar to states, as cumulativity seems to be realized as a consequence of being homogeneous entities[12]. We do not agree with this observation and reject such analyses of atelic events on the following arguments:

- intuitions: descriptions or predicates like 2.9 are conceived as events, as things that happen or occur, and not as states;
- heterogeneity still holds: atelic events are recognized after a certain amount of time has passed. Considering example 2.9 as a paradigmatic case, an interval of time too short in which a person has just raised up a foot cannot be identified as an interval of time in which the event of "running" takes place[13], at least, it can be identified as a subpart which summed up with other parts instantiate an event of running;
- strict cumulativity: as we have stated in the definition above, atelic event are *strictly cumulative*; this is the key property which differentiates them from states and homogeneous entities, which, on the other hand, are simply cumulative i.e. the merological sum of two expressions denote a union with just a single element.

Telicity has a further effect. When a telic event has terminated, we can observe that both an end point and a transition to a new state of the world have occurred. Consider 2.10: in the first case, the event is perceived to have occurred only when/after Marco has terminated his run and has reached the store (i.e. the end point), and as soon as he has reached the store, we can claim that Marco *is at* the store (i.e. the new state of the world). A similar behavior can be observed for 2.12: the event has terminated when Marco has reached the top, and, consequently, he *is on* the top of the mountain. Examples 2.9 and 2.11 do not give rise to such a state. This property of telic events can be explained by means of the notion of **contingency** (Moens & Steedman, 1988).

[12]With a different argument this kind of analysis is proposed in the DRT framework (Kamp & Reyle, 1993).

[13]For a similar argument see Dowty (1986).

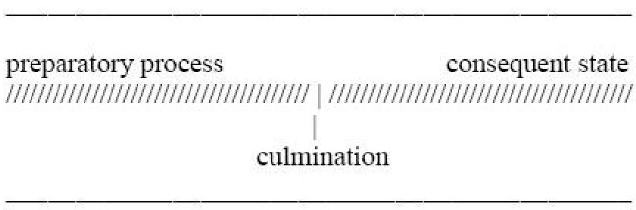

Figure 2.2: *The tripartite structure of telic events.*

Contingency, a non-temporal relation, relates to the organization and representation of events and states of affairs in episodic memory. In particular, contingency is a cover term to refer to a very general class of dependencies between events, which reflects the fact that the speaker's predications about events are "coloured by the fact that [...] events are involved in sequences that are planned , predicted, intended, or otherwise governed by *agencies*[14] of one kind or another" [Moens & Steedman (1988): 16]. The new state of the world that telic event creates, usually called consequent state, exists because it is contingently related to this event type. Telic events are then a complex ontological type, since with respect to other events, i.e. the atelic ones, they have a beginning point, a (natural) ending point and a consequent state. As Moens & Steedman (1988) and Passonneau (1988) point out telic events can be associated with a tripartite structure, called nucleus, comprising a preparatory phase (the beginning point and the period of time necessary to reach the end point), a culmination (the end point) and an associated consequent state (the new state of the world). Graphically, it can be represented as in Figure 2.2.

Combining together the features described so far, i.e. durativity and telicity[15], we can easily identify four subcategories of events, namely:

Definition 3 (activities) a class of events with extended duration and atelic (strictly cumulative), which can be labelled as *activities*;

Definition 4 (semelfactives) a class of events with (almost) instantaneous duration and atelic (strictly cumulative), which can be labelled as *semelfactives*;

Definition 5 (accomplishments) a class of events with extended duration and telic (quantized), which can be labelled as *accomplishments* ;

Definition 6 (achievements) a class of events with (almost) instantaneous duration and telic (quantized), which can be labelled as *achievements*.

Summing up, we have recognized that in the universe of discourse there is a class of eventualities, whose ontological primitives are states and events. These two entities have been described and formalized autonomously, and not as being derived from properties of other entities; time is present only indirectly since it has contributed to the identification of distinguishing features, like dynamicity, durativity, and heterogeneity, and reflects the fact that eventualities are spatio-temporal entities. In addition, each of the eventuality types presented above can be associated with a general temporal schema, representing

[14] Italics by the authors.
[15] $2^2 = 4$

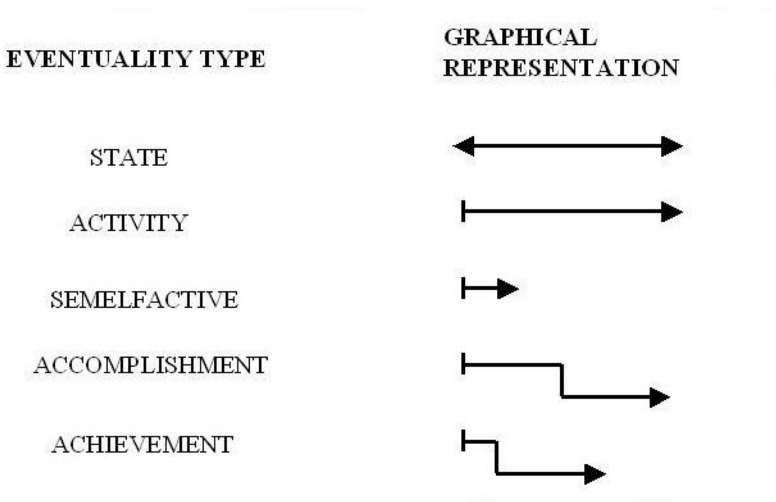

Figure 2.3: *State, Events and Associated Temporal Schema.*

their intrinsic temporal properties. Figure 2.3 is an informal representation, while a formal and logical account will be presented at the end of the chapter.

As already stated, states are static homogeneous entities, (normally) without beginning or end points. They can have different duration but this does not represent, as far as we are concerned, a distinctive ontological characterization since their behavior is always the same. Events, on the other hand, are heterogeneous dynamic entities; they involve a change in the state of the world. Heterogeneity entails the identification of sub classes of events, and the fact that events are subject to mereological properties. Mereological properties, on the one hand, allow the analysis of events both as atomic and complex entities, and, on the other hand, identify the parameter of telicity, which is realized by what we have defined as quantized events. Atelic events are described as strictly cumulative entities. Events have a beginning and end point, before and after which they are no more valid. Duration plays a different role in the class of events since it is a feature which helps to distinguish event subclasses, in particular between extended and (almost) instantaneous ones. Such a distinction has, as we will see, a fundamental role when computing the temporal ordering of events since it will restrict the set of of possible temporal relations between two eventualities.

2.3.2 Time: Instants and Intervals

In section 2.2 we have gone through the way time is conceptualized at a cognitive level. In this section, we will try to present from an abstract point of view which kind of temporal entities are involved when speaking of time and what are their main properties[16]. As for events, it is possible to identify a macrocategory, that of the *temporal entities* which, on the one hand, is sympathetic with the way we conceptualize time, and, on the other hand, represents a strategy to describe and formalize time.

Temporal entities can be interpreted as “special” measures of time, to which it is possible to associate what happens in time and in the world. For instance, spatio-temporal entities, like events, may have different temporal extension or duration. Usually, two main

[16]We are particularly indebted to the work of Hobbs & Pan (2004) for this section.

subcategories of temporal entities are identified, i.e. interval and instants:

T1 $Instant(t) \supset Temporal\_Entity(\tau)$

T2 $Interval(T) \supset Temporal\_Entity(\tau)$

T3 $\forall(\tau) \supset Instant(t) \vee Interval(T)$

Intervals and instants are both considered as ontological primitives. This is an innovative element of our ontology, and of the general semantic model, since it avoids choosing either the instant or the interval as the core temporal unit to be used to construct the other concept, as it has been done in previous approaches (instant-based *vs.* interval based structures). Intervals are conceived as things with extent, while instants are point-like. This, however, does not mean that instants are durationless, but that they do not have interior points.

According to what Hobbs & Pan (2004) propose, temporal entities may have a beginning and an end, which are unique and are instantiated by a relation between instants and temporal entities in general:

T4 $begins(t, \tau) \supset Instant(t) \wedge Temporal\_Entity(\tau)$

T5 $end(t, \tau) \supset Instant(t) \wedge Temporal\_Entity(\tau)$

T6 $Temporal\_Entity(\tau) \wedge begins(t_1, \tau) \wedge begins(t_2, \tau) \longrightarrow t_1 = t_2$

T7 $Temporal\_Entity(\tau) \wedge end(t_1, \tau) \wedge end(t_2, \tau) \longrightarrow t_1 = t_2$

It is important to notice two aspects: firstly, that the beginning and end of an instant is itself but this does not imply that instants are totally lacking of duration, and, secondly, that the presence of a beginning and an end is not compulsory. This allows us to define some key notions for temporal analysis, in particular those of open/unbounded interval, i.e. a temporal entity without beginning and end points, semi-open/bounded interval on the right, i.e. a temporal entity without an end point, semi-open/bounded interval on the left, i.e. a temporal entity without beginning point and that of closed/bounded or proper interval, i.e. a temporal entity whose beginning and end points are not identical. Notice that an open (or semi-open) interval identifies an infinitive stretch of time:

Definition 7 (unbounded interval) $(\forall T)OpenInterval(T) \equiv$
$Interval(T) \wedge (\forall t_1, t_2) \neg [begins(t_1, T) \wedge ends(t_2, T)] \wedge (t_1 \neq t_2]$

Definition 8 (right semi-open interval) $(\forall T)RightSemi-OpenInterval(T) \equiv$
$Interval(T) \wedge (\forall t_1, t_2)[begins(t_1, T) \wedge \neg ends(t_2, T)] \wedge (t_1 \neq t_2]$

Definition 8 (left semi-open interval) $(\forall T)LeftSemi-OpenInterval(T) \equiv$
$Interval(T) \wedge (\forall t_1, t_2)[\neg begins(t_1, T) \wedge ends(t_2, T)] \wedge (t_1 \neq t_2]$

Definition 9 (closed/proper interval) $(\forall T)Closed/ProperInterval(T) \equiv$
$Interval(T) \wedge (\forall t_1, t_2)[begins(t_1, T) \wedge ends(t_2, T) \wedge t_1 \neq t_2]$

Time also expresses duration. In our descriptive model durations are represented and measured by intervals. For instance, linguistic expressions like "from 2 p.m. to 3 p.m.", which implicitly express a duration contained between two instants, give rise to an associated interval.

Instants may be contained inside intervals, for instance, a temporal expression like

"Friday evening at 8 p.m" signals that an instant ("8 p.m.") is contained in an expression having a temporal extent, i.e. an interval ("Friday evening"). This relation can be expressed by a binary predicate: $Inside(t, T)$ Hobbs & Pan (2004). In addition to this, since we are building a time ontology and since we will deal with calendar and clock terms as well, it is useful to have a relation, named *begingsOrInOrEnds*, between instants and intervals which expresses the fact that an instant may be the beginning, or inside or the end of an interval:

T8 $(\forall t, T)[beginsOrInOrEnds(t, T)] \equiv$
$[begins(t, T) \vee Inside(t, T) \vee ends(t, T)$

2.3.2.1 Internal Directionality of Time

As stated in section 2.2, one of the most important cognitive aspect of time is that of time as succession. This aspect of time seems to have a privileged position in our mind/brain because it seems to be the focus of conscious attention to the temporal structure. In addition to this, we have also introduced the Axiom of Internal Directionality of time (axiom A1., section 2.1). In our ontology, this aspect is represented by introducing a relation which gives directionality to time. Thus, temporal entities are ordered according to the *before* relation, which is defined as follows: a temporal entity τ_1 is before a temporal entity τ_2 if the end of τ_1 is before the start of τ_2. This relation is considered to be basic both to instants and intervals, and it satisfies the following axioms, that is, it is antireflexive (TA1.), asymmetric (TA2), and transitive (TA3):

TA1. $before(\tau_1, \tau_2) \longrightarrow \neg\, before(\tau_2, \tau_1)$ antireflexive

TA2. $before(\tau_1, \tau_2) \longrightarrow \tau_1 \neq \tau_2$ asymmetric

TA3. $before(\tau_1, \tau_2) \wedge before(\tau_2, \tau_3) \longrightarrow before(\tau_1, \tau_3)$ transitive

The introduction of the precedence relation by means of the predicate *before* states that time is ordered. Time can be seen either as linearly ordered, i.e. a continuous line with no beginning and end stretching from the past to the future, or as branching. The most important time-branching model is forward branching time where each point has a unique past but more that one future. At this level of description we remain silent on the type of ordering of time since this is a modeling issue. Note that both approaches on time-ordering are compatible with this ontology. At this level of description we prefer to remain silent on the issue of time density.

It is straightforward that the *after* relation is obtained by the inverse of *before* and, moreover, that the relation instantiated by *before* is clearly a temporal one.

By means of the *before* relation we can refine some relations and notions previously introduced, in particular:

- the fact that the end of an interval is not before the beginning of the interval;
- the fact that there is always a duration when an instant is before another;
- the fact that the principal property of the *Inside* relation is that of stating that if an instant t is inside a proper interval, then the beginning of the interval is before instant t, and that the instant t is before the end of the interval.
- the fact that every instant which is in the *Inside* relation with an interval identifies a duration which has the same properties of an interval and represents a sub-interval of that interval:

Definition 10 (sub-interval) $subInterval(T) \equiv$
$(Interval(T) \wedge Inside(t, T) \longrightarrow [\exists(Interval(T_1) \wedge [begins(t_1, T_1) \wedge ends(t, T_1) \wedge (t_1 \neq t)]]$

2.3.2.2 Relations between Instants and Intervals

The property of time of being intrinsically ordered allows us to extend the set of relations between temporal entities. This a core difference between eventualities and time. As already stated, the aim of this chapter is that of providing a formal description of the entities involved when doing a temporal analysis of a text/discourse and not an interpretative model. It is for this reason that we have not described in the eventuality ontology any further relation but that of parthood. We have not assumed an eventuality structure, i.e. an interpretative model of how eventualities are organized in the world and which temporal relations can be assumed on inherent dependencies between eventualities. We claim that these kinds of relations are not properties of eventualities but of the concepts which may be associated with one of the different types of eventualities. For instance, stating that the event of "*getting married*" is before a state of "*being engaged*" does not depend on the properties of the types of eventualities (in this case an achievement and a state) but it is related to the knowledge of the world we have of these two concepts. It would be absurd to claim that a state is always before an achievement only for the fact of being a state. Eventualities are not intrinsically oriented like time. It is for this reason that we include in the ontology for time a set relations between the temporal entities. These relations are purely temporal.

As far as relations between time entities are concerned, it is possible to identify three main sets: relations between intervals, relations between instants and, finally, relations between instants and intervals. All these relations can be conceived as derived from the before relation and they can be formalized as derived from this relation and in terms of identity on the beginning and end points.

Relations between intervals can be described and defined following Allen (1983)'s standard interval calculus[17]. Excluding the *before* (and *after*) relation that we have already defined, Allen (1983) identifies 11 other relations, 5 of which - *overlap*, *meets*, *during*, *starts* and *finishes* - are binary, i.e. one can be expressed as the inverse of the other. The following interval temporal relations are formalized as axioms and are taken from [Hobbs & Pan (2004): 69]; t_1 and t_2 are the beginning and end of interval T_1 while t_3 and t_4 are the beginning and end of interval T_2; Figure 2.4 on the following page illustrates graphically these relations:

Definition 11 (equal/simultaneous) $\forall(T_1, T_2)[Equals/Simultaneous(T_1, T_2) \equiv$
$(\forall t_1)[begins(t_1, T_1) \equiv begins(t_1, T_2)]$
$\wedge(\forall t_2)[ends(t_2, T_1) \equiv ends(t_2, T_2)]]]$

Definition 12 (overlap) $\forall(T_1, T_2)[Overlaps(T_1, T_2) \equiv$
$(\exists t_2, t_3)[ends(t_2, T_1) \wedge begins(t_3, T_2) \wedge before(t_3, t_2)$
$\wedge(\forall t_1)[begins(t_1, T_1) \longrightarrow before(t_1, t_3)]$
$\wedge(\forall t_4)[ends(t_4, T_2) \longrightarrow before(t_2, t_4)]]]$

Definition 13 (meets) $\forall(T_1, T_2)[Meets(T_1, T_2) \equiv$
$(\exists t)[ends(t, T_1) \wedge begins(t, T_2)]]$

[17] Allen's classical formulation of interval calculus assumes that all intervals are proper intervals. We do not follow with respect to this point the author.

Definition 14 (before) $\forall(T_1, T_2)[Before(T_1, T_2) \equiv$
$(\forall t_2, t_3)[ends(t_2, T_1) \wedge begins(t_3, T_2) \longrightarrow before(t_2, t_3)]]$

Definition 15 (during) $\forall(T_1, T_2)[During(T_1, T_2) \equiv$
$(\exists t_1, t_2)[begins(t_1, T_1) \wedge ends(t_2, T_1)$
$\wedge(\forall t_3)[begins(t_3, T_2) \longrightarrow before(t_3, t_1)]$
$\wedge(\forall t_4)[ends(t_4, T_2) \longrightarrow before(t_2, t_4)]]]$

Definition 16 (starts) $\forall(T_1, T_2)[Starts(T_1, T_2) \equiv$
$(\exists t_2)[ends(t_2, T_1) \wedge (\forall t_1)[begins(t_1, T_1) \equiv begins(t_1, T_2)]$
$\wedge(\forall t_4)[ends(t_4, T_2) \longrightarrow before(t_2, t_4)]]]$

Definition 17 (finishes) $\forall(T_1, T_2)[Finishes(T_1, T_2) \equiv$
$(t_1)[begins(t_1, T_1) \wedge (\forall t_3)[begins(t_3, T_2) \wedge before(t_3, t_1]$
$\wedge(\forall t_4)[ends(t_4, T_2) \equiv ends(t_4, T_1]]]$

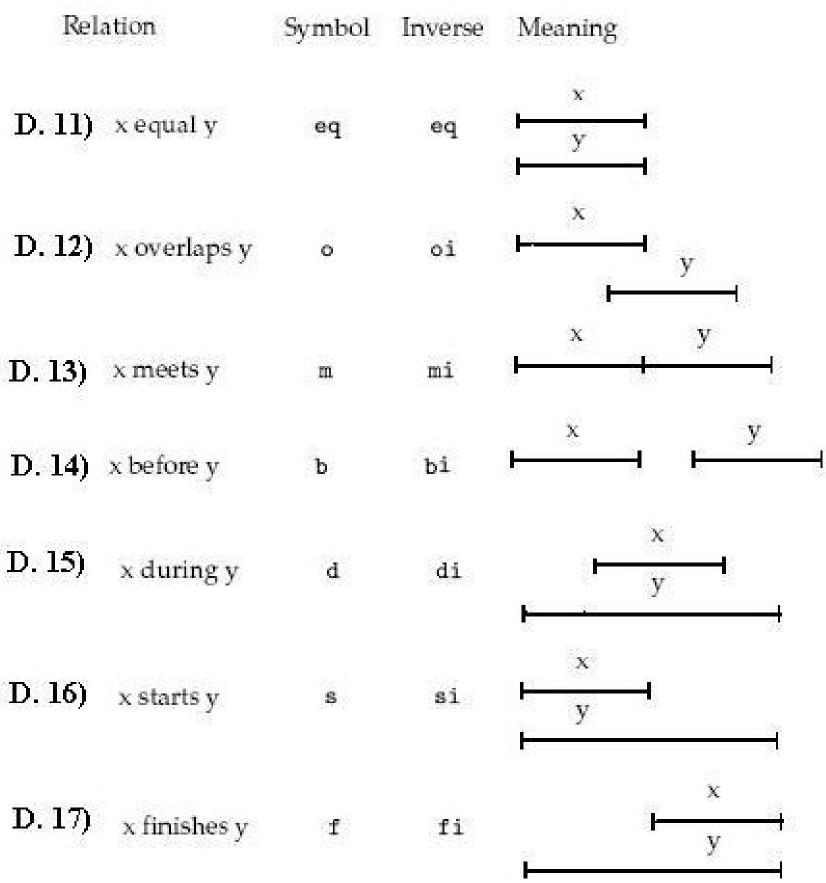

Figure 2.4: *Allen's interval relations.*

Table 2.1 on the next page summarizes the relations which hold between the beginning and end points of the intervals for all the 13 relations, where $\prec$ stands for before, $\succ$ for after and, finally, $\equiv$ for coincidence or simultaneity.

A reduced set of relations holds for instants. The way to define these relations is exactly the same as for intervals, with the difference that now we are dealing with instants. This reflects the idea that "instantaneous" moments of time do have a duration but also that their beginning and end points are the instants themselves (see axioms T4-T7). Instead

Table 2.1: *The 13 intervals' beginning and end point relations.*

	t_1, t_3	t_2, t_4	t_1, t_4	t_2, t_3
eq	$\equiv$	$\equiv$	$\prec$	$\succ$
o	$\prec$	$\prec$	$\prec$	$\succ$
oi	$\succ$	$\succ$	$\prec$	$\succ$
m	$\prec$	$\prec$	$\prec$	$\equiv$
mi	$\succ$	$\succ$	$\equiv$	$\succ$
b	$\prec$	$\prec$	$\prec$	$\prec$
bi	$\succ$	$\succ$	$\succ$	$\succ$
d	$\succ$	$\prec$	$\prec$	$\succ$
di	$\prec$	$\succ$	$\prec$	$\prec$
s	$\equiv$	$\prec$	$\prec$	$\succ$
si	$\equiv$	$\succ$	$\prec$	$\succ$
f	$\succ$	$\equiv$	$\prec$	$\succ$
fi	$\prec$	$\equiv$	$\prec$	$\succ$

of 13 relations, the set of possible relations between instants is reduced to 5[18], i.e. *equal* or *simultaneous*, *meets/is_met_by* and *before/after*. These restrictions prevents the rising of contradictions: in fact, if all the other relations held, then instants would be conceived and derived from intervals, a choice we have excluded by postulating that instants and intervals are ontological primitives.

It is interesting to notice that even the relations between instants and intervals are reduced. As Vilain (1992) points out, we have 5 irreducible relations: an instant may precede or follow an interval, or may start or end an interval or may be included into (i.e. during) an interval. Except for the before relation, all the other relations are not binary. These relations reflects what we have stated in axiom T8 in section 2.3.2. Again, all the relations can be expressed in terms of the privileged *before* relation and identity of beginning and end points. The axioms expressing these relations are derived from the interval relations; intervals are conceived as proper intervals and instants have a beginning and end points, as they are temporal entities. Figure 2.5 on the following page illustrates graphically the relations:

Definition 14′ (before) $\forall(t,T)[Before(t,T) \equiv$
$(t_1,t_2,t_3,t_4)[begins(t_1,t) \wedge ends(t_2,t)] \wedge [begins(t_3,T) \wedge ends(t_4,T)] \wedge before(t_2,t_3)])$

Definition 15′ (during) $\forall(t,T)[Contains(t,T) \equiv$
$(\exists t)[Inside(t,T)] \longrightarrow begins(t_1,T) \wedge ends(t_2,T)$
$\wedge before(t_1,t) \wedge before(t,t_2)]$

Definition 16′ (starts) $\forall(t,T)[Starts(t,T) \equiv$
$(\exists t_2)[ends(t_2,t) \wedge (\forall t_1)[begins(t_1,T) \equiv begins(t_1,t) \wedge t_1 \equiv t_2]$
$\wedge(\forall t_4)[ends(t_4,T) \longrightarrow before((t_1 \wedge t_2),t_4)]]]$

Definition 17′ (finishes) $\forall(t,T)[Finishes(t,T) \equiv$

[18]See also Allen & Hayes (1989).

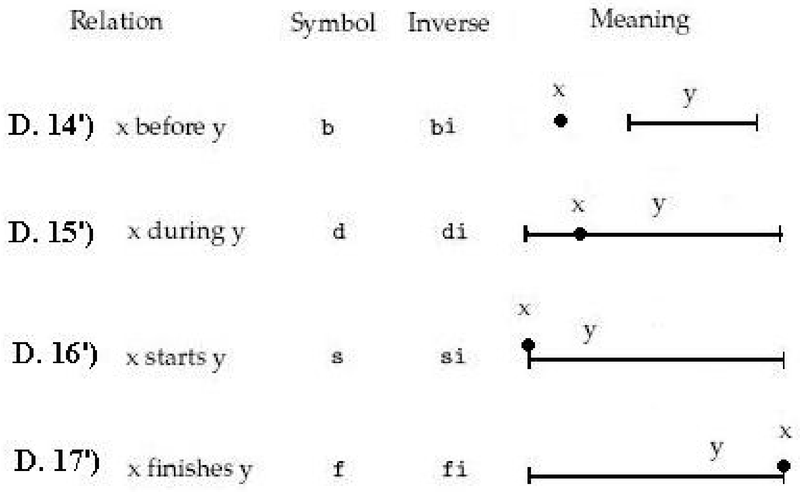

Figure 2.5: *Instant-interval relations.*

$(t_1)[begins(t_1, t) \wedge (\forall t_3)[begins(t_3, T) \wedge before(t_3, t_1]$
$\wedge(\forall t_4)[ends(t_4, T) \equiv ends(t_4, t)]]]$

Finally, relations between the temporal entities allow to perform inferencing processes to compute the whole set of possible relations which may be involved. We are aware that presenting an inferencing mechanism in a section which aims at describing the general properties of the temporal entities may seem out of place since it would be more suitable as a part of an interpretative model of time. However, we do not agree with this observation. Our counterargument to support the introduction of a reasoning mechanism on temporal relations in this section is very simple and already stated: this set of "complex" temporal relations is not due to the particular values of the temporal entities involved, or based on mechanisms exploiting world knowledge but it is derived from a property of time itself, i.e. its being intrinsically ordered. Moreover, time order is expressed by the *before* relation, which satisfies the axiom of transitivity. All other possible temporal relations between two temporal entities can be expressed by means of the *before* relation. This allows us to claim that the property of transitivity is satisfied by every temporal relation. Thus, if a temporal relation R holds between the temporal entities τ_1 and τ_2, and a different temporal relation R_1 holds between the temporal entities τ_2 and τ_3, by exploiting the property of transitivity, we are able to infer which or which set of possible temporal relations may hold between τ_1 and τ_3. Figure 2.6 on page 35, from Allen (1983) illustrates how these inferencing mechanisms work. It is necessary to clarify a point: according to the temporal entities involved not all transitions are allowed; thus if R holds between an instant$_i$ and an interval$_j$ and R_1 between the interval$_j$ and another interval$_k$, then the set of transitions is constrained to the possible temporal relations which can hold between an instant and an interval.

2.3.3 Connecting Time and Eventualities: introducing modeling issues

To compute temporal relations between eventualities in a text/discourse and more in general in the world, it is necessary, on the one hand, to define the way eventualities and time connect and, on the other hand, to introduce some interpretative constraints on time. We have already stated that eventualities pertain to reality and that they "occupy" time. This calls for the identification of a device to connect time to eventualities. Such a device has to be able to keep the distinctions introduced when describing the entities and, at the same time, to provide a "description" of how to extend the temporal relations defined for the temporal entities to eventualities.

To perform such a task we believe that it is compelling to introduce some interpretative or modeling elements. The first of them concerns a choice with respect to the temporal ordering of time, in particular we constrain the directionality of time to be strictly linear, i.e. a continuous line with no beginning or end, stretching from the past to the future. This property can be formalized by introducing the following axiom (TA4.):

TA4. $\forall \tau \longrightarrow before(\tau_1, \tau_2) \vee before(\tau_2, \tau_1) \vee (\tau_1 = \tau_2)$ strict linearity

We also assume that the time line can be represented by the set of real numbers, $\Re$, and that, in order to express and recover temporal relations between eventualities, time should be dense, i.e. between two instants it is always possible to identify another instant:

TA5. $\forall t, t_1(before(t, t1) \longrightarrow \exists t_2(before(t, t_2) \vee before(t_2, t_1))$ time density

Axiom TA4 and TA5 serves as an abstract representation of time.

In order to link time and eventualities we introduce a special predicate: *holds*[19]. The predicate *holds* is responsible for assigning a proper temporal representation to each eventuality and represents a formalization of the intuitive notion that eventualities "occupy" time. We postulate that no eventualities can be represented by an instant as it has been defined and described in section 2.3.2, since even punctual or instantaneous events do have a duration. The predicate *holds*, thus, maps each eventuality to a corresponding interval. Recalling **Definition 7-9** for intervals, we introduce two constraints to allow them to apply to eventualities, in particular:

- we assume the existence of two functions α and ω (Schilder, 1997) which allow the accessibility of beginning and ending points of all types of intervals, including open and semi-open ones. In addition, beginning and ending points of intervals are instants;
- open and semi-open intervals do not identify anymore infinitive stretch of time but a time span whose boundaries do not belong to the interval itself.

Assuming the functions α and ω will help us to better illustrate the meaning of axioms E4 and E5 of section 2.3.1 on beginning and end points for events and states. We have claimed that as consequence of the dynamicity feature states do not have beginning and end points (axiom E5). We are going to reformulate this axiom by claiming that states do have beginning and end points but they (normally) do not belong to the intervals

[19]There are several proposals which stipulate a function or a relation which connects the eventualities to time. For instance, Schilder (1997) introduces a relation called *LOC*. See also Shoham (1987) and Hobbs & Pan (2004).

which the *holds* predicate assign to them. It is quite trivial to reformulate axiom E4 for events now, that is an event is an interval whose beginning and end point belong to the interval itself. Thus, the predication $holds(\varepsilon, T)$ relates the beginning and end points of an eventuality to instants, and then maps each eventuality to a corresponding interval according to its type.

2.3.3.1 Eventualities to Intervals: a Time Logic Representation

A time logic representation of eventualities is obtained by taking into account both the features of dynamicity, durativity and telicity which, together with the distinction between homogeneity and heterogeneity, describe the properties and types of eventualities and temporal notions and representations. Such a representation is essential to compute temporal relations.

We have already seen that dynamicity, which is the core feature to distinguish between states and events, can be reformulated in terms of bounded and unbounded intervals, so that we obtain the following representation; i_1 and i_2 represent the beginning and ending points of the intervals; $\prec$ reads as before and $\preceq$ reads as $i_1 \prec i_2$ or $i_1 = i_2$:

Representation 1 (state) : $]i_1, i_2[\equiv \{i | i_1 \prec i \prec i_2\}$

Representation 2 (event) $[i_1, i_2] \equiv \{i | i_1 \preceq i \preceq i_2\}$

Homogeneity and heterogeneity apply as well, but now they provide the following readings: an eventuality which denotes a state may be true for all sub-intervals inside the open-interval representing the state down to every instants, while an eventuality denoting an event may be true only for eventualities with temporal extension $[i_1, i_2]$ and not for every sub-intervals in it.

We need now to provide the representations of the different types of events identified in section 2.3.1. To achieve this purpose we will take into account the feature of durativity. We have stated that events differentiate with respect to their internal temporal duration between durative - activities and accomplishments - and instantaneous, or punctual, - semelfactives and achievements - events. A property punctual events is that they are categorised as elements which still possess a duration. However, the intervals denoted by punctual eventualities are very different from those denoted by durative ones, since their intervals are more similar to instants than to real intervals. When we have introduce the entities of the time ontology in section 2.3.2, we have claimed that a distinguishing property of instants is that they have *no interior points*. Since we cannot allow eventualities to be represented by instants, because otherwise we will not have beginning and end points, we constrain intervals representing punctual events to be intervals without internal structure, i.e. between their beginning and end point no further instant can be found. In this sense we can speak of instantaneous events:

Representation 3 (punctual event) $[i_1, i_2] \equiv \{i | (i_1 = i) \vee (i_2 = i)\}$

Representation 4 (durative event) $[i_1, i_2] \equiv \{i | i_1 \prec i \prec i_2\}$

Telicity is the last feature we have to reformulate, so that we can distinguish between activities and accomplishments and semelfactives and achievements. To achieve a temporal representation of this feature we have to concentrate not on the fact that a telic event has a naturally ending point, but on the observation that these events can introduce a consequent state, which begins immediately after the end of the bounded event. The temporal extension of this resulting state is an open interval over which the restriction of contingency still holds:

Representation 5 (telic event) $[\, \mathrm{i}_1, i_2]i_3[\equiv \{i|i_1 \preceq i \preceq i_2\}$
$\wedge \{i|i_2 \prec i \prec i_3\}$

Finally, we can now associate a temporal representation to the four types of events we have identified:

Representation 6 (activities) $[i_1, i_2] \equiv \{i|i_1 \prec i \prec i_2\}$

Representation 7 (semelfactives) $[i_1, i_2] \equiv \{i|(i_1 = i) \vee (i_2 = i)\}$

Representation 8 (accomplishments) $[i_1, i_2]i_3[\equiv \{i|i_1 \prec i \prec i_2\}$
$\wedge \{i|i_2 \prec i \prec i_3\}$

Representation 9 (achievements) $[i_1, i_2]i_3[\equiv \{i|(i_1 = i) \vee (i_2 = i)\}$
$\wedge \{i|i_2 \prec i \prec i_3\}$

2.3.3.2 A Formal Way of Computing Temporal Relations

The introduction of the predicate *hold* and the representation of eventualities as intervals is pivotal to present an abstract and formal way of computing temporal relations between eventualities. In this way we can extend the temporal relations introduced and defined in section 2.3.2.2 to eventualities in an direct way according to their temporal representation. However, the picture is not as simple as it appears. If we can claim without problems that the 13 relations between intervals may hold between states and durative events and that the 5 relations between instants may hold between punctual events, we cannot claim that the 5 relations between instants and intervals apply to relations between punctual events and, states and durative events. This is due to the fact that though similar to instants for some properties punctual events are still intervals. Following Allen & Hayes (1989), we claim that the possible relations between a punctual event and a state or a durative events is represented by 8 relations, only two of which are binary, namely: *before/after*, *meets/is_met_by*, *simultaneous*, *during*, *starts*, *finishes*. No other temporal relation is possible.

By applying this strategy temporal relations assumes the status of functions between the entities. A further advantage of this modelization is that the way of computing temporal relations is exactly the same for all kinds of entities, and we are able to compute temporal relations between eventualities, between temporal entities and further between eventualities and temporal entities. Consider, for instance, two activities A and B, the former holding during the interval T and the latter during the interval $T^{'}$. On the base of the temporal representations associated with each entity type as presented in section 2.3.3.1, the temporal relations between A and B is computed through the temporal intervals associated with the eventualities. So if we state that A DURING B, it means that:

(2.13) $DURING(A, B) \equiv holds(A, T) \wedge holds(B, T^{'}) \longleftrightarrow$
$[\exists(t_1, t_2, t_3, t_4)[begins(t_1, T) \wedge begins(t_3, T^{'}) \wedge ends(t_2, T) \wedge ends(t_4, T^{'}) \wedge$
$before(t_3, t_1) \wedge before(t_2, t_4)]$

Similarly, if we state that an instant t starts an accomplishment C, i.e t STARTS C, it means that:

(2.14) $STARTS(t, C) \equiv holds(C, T) \longrightarrow$
$\exists(t_1, t_2, t_3)[begins(t_1, T) \wedge ends(t_2, T) \wedge begins(t_3, T) \wedge t_3 \equiv t_1]$

2.4 Conclusion

In this chapter we have presented what are the entities involved when performing a temporal analysis of a text/discourse.

We have shown that the set of eventualities can be described independently, since eventualities denotes situations and not times. Two sets of primitives are present in the class of eventualities: events and states. Due to the heterogeneity property, it is possible to identify 4 different types of events: activities, semelfactives, accomplishments and achievements. Their identification is instantiated by two features: durativity and telicity. Instantaneous or punctual events are not conceived as timeless entity, but they are perceived as such by human beings. Temporal relations need not to be assumed when presenting eventualities, because they are derived by, or better inferred from, the concepts associated with the eventualities.

Temporal entities are abstract entities which represent special measures for time. Two primitives are postulated: intervals and instants. Both these entities have durations but instants, with respect to intervals, do not have an internal structure. Temporal relations are a direct consequence of time, which is conceived as intrinsically ordered by means of the relation of precedence (i.e. *before*). Three sets of temporal relations can be identified between the temporal entities: relations between intervals, relations between instants and relations between instants and intervals. In addition to this, we have shown that it is possible to perform temporal reasoning as a consequence of the *before* relation which is assumed as the basic temporal relation from which all others relations can be derived.

Finally, we have introduced a small formal interpretative model to connect eventualities and time. This interpretative model represents the first step to elaborate a more complex computational model. To do this, we have postulated the existence of a special predicate, i.e. *holds*. By means of this predicate, and introducing two constraints on time - the axioms TA4 and TA5 - we can perform a temporal representation of eventualities. We have also shown how at this abstract level temporal relations can be performed between eventualities. In this way, temporal relations assume the status of functions between the entities. In addition to this, we have claimed that temporal relations as defined for time apply (almost) directly to eventualities, thus providing a uniform way to compute them.

In the next chapter, we will consider how the entities illustrated at this abstract representational level are realized in natural language.

B r2 C A r1 B	<	>	d	di	o	oi	m	mi	s	si	f	fi
"before" <	<	no info	< o m d s	<	<	< o m d s	<	< o m d s	<	<	< o m d s	<
"after" >	no info	>	> oi mi d f	>	> oi mi d f	>	> oi mi d f	>	> oi mi d f	>	>	>
"during" d	<	>	d	no info	< o m d s	> oi mi d f	<	>	d	> oi mi d f	d	< o m d s
"contains" di	< o m di fi	> oi di mi si	o oi dur con =	di	o di fi	oi di si	o di fi	oi di si	di fi o	di	di si oi	di
"overlaps" o	<	> oi di mi si	o d s	< o m di fi	< o m	o oi dur con =	<	oi di si	o	di fi o	d s o	< o m
"over-lapped-by" oi	< o m di fi	>	oi d f	> oi mi di si	o oi dur con =	> oi mi	o di fi	>	oi d f	oi > mi	oi	oi di si
"meets" m	<	> oi mi di si	o d s	<	<	o d s	<	f fi =	m	m	d s o	<
"met-by" mi	< o m di fi	>	oi d f	>	oi d f	>	s si =	>	d f oi	>	mi	mi
"starts" s	<	>	d	< o m di fi	< o m	oi d f	<	mi	s	s si =	d	< m o
"started by" si	< o m di fi	>	oi d f	di	o di fi	oi	o di fi	mi	s si =	si	oi	di
"finishes" f	<	>	d	> oi mi di si	o d s	> oi mi	m	>	d	> oi mi	f	f fi =
"finished-by" fi	<	> oi mi di si	o d s	di	o	oi di si	m	si oi di	o	di	f fi =	fi

Figure 2.6: *Transitivity Table for the Temporal Relations (omitting simultaneous) [Allen (1983): 836.]*

Chapter 3

Temporal Entities in Language

The task we address in this thesis is the elaboration of a computational model for ordering events and temporal expressions in time. In chapter 2 we have discussed and illustrated the ontological framework and the entities which are involved. In this chapter we will describe how the temporal entities are actually realized in natural language, with a particular attention to Italian.

An important aspect that previous works, Setzer (2001) among others, have pointed out is that the text genre may influence the way in which temporal relations are expressed. For this reason, we will briefly describe some idiosyncrasies of the genre which form our corpus, i.e. newspaper articles, as far as temporal ordering is concerned.

3.1 Eventualities

Recalling the ontological definition of eventuality we presented in chapter 2, section 2.3.1, in this section we concentrate on the linguistic coding of the concept of eventuality. Following Jezeck (2003), we agree on the existence of an intermediate level, corresponding to the *conceptualization* of the event, between the ontological concept of eventuality and its linguistic realization, thus preventing a direct relationship. The absence of a one-to-one relationship between the notion of eventuality and its linguistic realization leads to claim that eventualities are not realized by a single part-of -speech entirely devoted to this goal. It is a truism that it is possible to identify sorts of universal tendencies according to which eventualities are expressed by verbs, as Levin & Hovav (2005) state:

> Happenings in the world, unlike most physical objects, do not come perceptually individuated [...] rather they are individuated by language. Verbs lexicalize properties of happenings in the world; we use the term EVENT[1] for happenings, whose properties are lexicalized by verbs. Verbs, then are predicates of events and phrases containing verbs can be considered 'event descriptions'. [Levin & Hovav (2005): 19]

As the following examples show, verbs, both at finite and non-finite forms, do in fact express eventualities, i.e. an *event* or a *state*, (eventualities are underlined)[2]:

(3.1) I pompieri <u>hanno isolato</u> la sala.
The firefighters <u>isolated</u> the room.

[1] The authors use the term "event" as a general cover term; in this context it can be considered a synonym of "eventuality"

[2] In the English translations there may be a discrepancy with respect to the Italian realizations of the eventualities. In these cases the realizations of the eventualities are not signalled.

(3.2) Fim-Cisl e Uilm-Uil hanno annunciato oggi una conferenza stampa.
Fim-Cisl and Uilm-Uil unions announced a press conference for today.

(3.3) La città mostra i segni della battaglia: cassonetti incendiati o rivoltati.
The city shows the signs of the fight: garbage bins on fire or upsidedown.

(3.4) Andare per negozi il sabato è un'abitudine ormai.
Going shopping on Saturdays has become a habit.

(3.5) Giovanna sa il francese.
Giovanna knows French.

(3.6) Marco ama Giovanna.
Marco loves Giovanna.

Verbs, however, are not the only part-of-speech which natural languages use to code eventualities. As a superficial and intuitive analysis of a text shows nouns often realize eventualities[3]. Nouns represent a complex linguistic entity since they can be used to classify concepts, i.e. refer to objects and people in the world, like *dog*, *tree*, *Marco*, *book*... or to express relational concepts, like *travelling*, *meeting*, *party*, *hit*... In this section we will take into account only a subset of *relational* nouns, which we will call event nominals, following Pustejovsky (1995). Event nominals are nouns characterized by a temporal dimension in which the eventualities take place and realize the ontological distinctions of states, activities, accomplishments, achievements and semelfactives (chapter 2, section 2.3.1). Nouns can realize eventualities in three different ways (Gross & Kiefer, 1995):

- through a nominalization process from verbs, i.e. deverbal nouns; e.g.:
  fuga [escape], *arrivo* [arrival], *corsa* [run], *bevuta* [drink], *accordo* [agreement]...
- nouns which are not derived from a verb and which have an eventive[4] meaning in their lexical properties; e.g.:
  guerra [war], *uragano* [hurricane], *assemblea* [meeting], *cerimonia* [ceremony]...
- nouns which normally denote objects but which are assigned an eventive reading through the process of type-coercion induced by verbs' selectional preferencies or by temporal prepositions (Pustejovsky, 1995); (the eventive noun is underlined, the co-textual elements which give rise to the type-coercion phenomenon are in bold); e.g.:

  (3.7) Ho **interrotto** il libro.
  *I've **interrupted** my book.*

  (3.8) Vengo a casa **dopo** la pizza.
  *I'll come home **after** the pizza.*

  (3.9) La scuola **è durata tutta la mattina**.
  The school lasted all morning.

[3]For a comprehensive reading on the issue of event nominals see Mazzariello (2008).
[4]"Eventive" here is used as a synonym of eventualities, thus covering both events and states.

The range of linguistic devices used to code eventualities is, however, much bigger. Other common strategies are represented by constructions which do not correspond to a unique part-of-speech but to clauses realized by copular constructions (examples from 3.10 to 3.12), VPs, realized by light verb constructions (examples 3.13 and 3.14) or idioms (3.15), PPs (examples 3.16 and 3.17) and even cases of AdjPs (example 3.18) (again, the eventualities are underlined):

(3.10) Marco è stanco.

Marco is tired.

(3.11) Marco sembra stanco.

Marco seems tired.

(3.12) I cani restavano sempre liberi.

The dogs always remained free.

(3.13) Una giovane turista, è morta sabato mentre faceva una doccia.

A young tourist died on Saturday while she was having a shower.

(3.14) L'assemblea ha preso visione del bilancio.

The board examined the budget.

(3.15) Tutte le questioni principali sono rimaste sul tappeto.

All main issues remained unresolved.

(3.16) Una giovane turista in vacanza nel villaggio "Kartitubbo" è morta ieri.

A young tourist on holiday in the "Kartitubbo" resort died yesterday.

(3.17) Tutte le persone a bordo sono morte nell'impatto.

All people on board died in the impact.

(3.18) La giovane coppia, residente a Milano, stava trascorrendo un periodo di vacanza in Sicilia.

The young couple, resident in Milan, was spending a vacation in Sicily.

All these different types of realizations point to an important issue for automatic identification and extraction of events in a corpus or in texts in general, that is, that we need a combination of syntactic and semantic criteria. In particular, as far as the latter element is concerned it calls for the elaboration of complex strategies which combine information from lexical resources with the use of dynamic strategies, which are able to compute and recognize type-coercion phenomena.

3.2 Time: Temporal Expressions

As for eventualities, the expression of time is realized in lots of different ways. For instance, if we take a lexical resource like PAROLE/SIMPLE/CLIPS[5](Ruimy et al., 2003) and we search for entries which correspond to the semantic type of TIME, we will get these results:

(3.19) anno;

year

(3.20) assessorato;

councillorship

[5]Refererred to as SIMPLE/CLIPS in the remainder of this work

(3.21) infanzia;

childhood

(3.22) durata;

duration

(3.23) giorno;

day

(3.24) maggio;

may

(3.25) scuola;

school

All these words express, in a way or another, time. By observing them we can notice that there is a difference between words that are used to measure time, or purely temporal words i.e. words denoting instants and intervals, like in 3.19, 3.22, 3.23 and 3.24, and those which get a temporal reading only if they are in an appropriate linguistic context, like 3.20, 3.21 and 3.25. As far as we are concerned, we will restrict the set of words expressing time only to the purely temporal words, or, as stated in Ferro et al. (2001) "the flagging of temporal expressions is restricted to those temporal expressions which contained a reserved time word, called **lexical trigger**" [Ferro et al. (2001): 2]. The restriction of temporal expressions to reserved time words, corresponding to instants or intervals, like the example 3.19 and those from 3.22 to 3.24, is highly important since, on the one hand, it reduces temporal expressions to a closed set of words and a limited range of parts-of-speech, and, on the other hand, it prevents mismatches and biases between possible eventive nouns and temporal expressions. To clarify this latter point consider this sentence :

(3.26) Vengo dopo la *scuola*.

I'm coming after the school.

As the example shows, the possible and available readings of the word *scuola* [school] are double in particular:, on the one hand, we will obtain an eventive reading, where *scuola* is type-coerced to an event by the temporal preposition "*dopo*" [after], and, on the other hand, a temporal reading if *scuola* is interpreted as "*the period of time* during which the school activities take place". Even by extending both the linguistic and extralinguistic context we are not in a position to discriminate in a consistent way what is the "proper" reading. As we have illustrated in section 3.1, a context like the one in the example 3.26 is usually identified as an eventive reading context for nominals. But, according to what we have stated above, in this case the noun *scuola* would also bear a temporal value. This way of reasoning, which could be correct from a purely descriptive point of view, is extremely problematic. Firstly, expressions of this kind pose a big issue about their ontological nature: in contexts similar to the example 3.26 a single word is overloaded with information since it can be considered both as an event and as a period of time. Secondly, temporal expressions like *scuola* are non-referring temporal expressions. Non-referring temporal expressions are expressions which cannot be anchored in a clear-cut way on the time axis and it is not possible to associate them with a specific calendar date. Finally, from a strictly computational point of view, these expressions are difficult to annotate and may lead to an inconsistency in the data, thus preventing the possibility of creating robust algorithms. On the basis of these observations and the definition of "lexical trigger" proposed by Ferro et al. (2001), words like *scuola* and similar are not considered as temporal expressions.

The linguistic realizations of temporal expressions present a reduced set of variations with respect to the eventualities and is, in a certain way, more regular. In Table 3.1 we report some results we obtained from a corpus study[6] on possible lexical triggers of temporal expressions in Italian and their corresponding parts-of-speech.

Table 3.1: *Temporal expression triggers and corresponding POS.*

Timex Lexical Triggers	**POS**
agosto, alba, anniversario, domenica, estate, giornata, serata, futuro, lustro, stagione...	Nouns
Natale, Pasqua, Capodanno, Ferragosto	Proper Nouns
25/07/2007, 1980, 13:11...	Calendar/Time Patterns
annuale, primaverile, estivo, recente, mensile...	Adjectives
annualmente, oggi, ora, allora, adesso, finora, ieri, tutt'ora...	Adverbs
primo, secondo, 1, 31, 28...	Numbers

The analysis of the corpus data revealed other important information on the properties of temporal expressions, in particular, the fact that they have a two-folded function in text/discourse. On the one hand, their primary function is that of referring to a parcel of the time axis by denoting an interval or an instant which provides an anchor in time to the eventualities to which they are linked, i.e. they tell us *WHEN* something (has) happened, and, on the other hand, they are a source of information for computing the temporal order of eventualities.

The data collected have shown that most temporal expressions refer to times relative either to the publication date or to some other date or temporal expressions in the article. The use of absolute calendar pattern, like *25/07/2007* or *5 maggio 2006*, are very rarely found and used. In addition to this, an entire class of temporal expressions refers to durations, i.e. expressions like *circa 3 anni* [about 3 years], *un paio di mesi* [a couple of months]. Duration are often realized without making their beginning and/or end points explicit. This makes impossible to assign a calendar date which corresponds to the beginning and to the end point of the interval denoted by the duration and sometimes it is not even possible to state how long the interval lasts; e.g.:

(3.27) per mesi. = how many months? on which date did it begin and end?
for months.

The corpus-based observations, on the one hand, confirm the distinction between referring and non referring expressions, and, on the other hand, offer a solution to the issue of how to classify and treat temporal expressions. This last issue is extremely important because finding the proper way of classifying temporal expressions is the first step to perform a robust automatic recognition of them. Instead of using the granularity level of the temporal expressions, i.e. the fact that they may denote a year, a day, a month..., we propose to use reference as the discriminating cue. Reference allows us to treat in a more uniform way different types of temporal expressions, and it avoids the use of *ad hoc* classifications. In this way, four types of temporal expressions can be identified:

[6]The corpus consists of 179 newspaper articles, for a total of 62K words, from the PAROLE corpus and the Italian TreeBank, both available at the ILC-CNR of Pisa.

- specific: all temporal expressions whose meaning or value with respect to a calendar time is self-evident; e.g.: *24/02/2008*; *il primo maggio 1947* [May 1st 1947]...
- deictic or non-contiguous: all temporal expressions whose meaning or value in terms of calendar date is obtained by using an external contextual element; e.g.: *oggi* [today]; *ieri* [yesterday]; *il prossimo mese* [next month]...
- anaphoric or contiguous: all temporal expressions whose meaning or values is obtained by the value of a previous co-textual temporal expression which works as an anaphoric anchor[7]; e.g.: *pomeriggio* [afternoon]; *il giorno dopo* [next day]; *due anni fa* [two years ago] ...
- durations: all temporal expressions which denote intervals of time of any kind and with different levels of precision; e.g.: *tre mesi* [three months]; *parecchi giorni* [several days]; *ogni settimana* [every week]...

The relative regularity of the temporal expression realizations, both in terms of parts-of-speech and vocabulary, suggests that these kinds of expressions may be automatically recognized and treated by means of strategies and tools based on finite states automaton (FSA) transducers, giving rise to what is known in literature as temporal grammars. We will present solutions for its elaboration and the results of its implementation in the second part of this thesis (see chapter 6).

3.3 Temporal Relations

The encoding and signalling of temporal relations in a natural language is realized by a variety of devices. Temporal relations have an inferential nature, they are not real linguistic entities but, as we have pointed out in chapter 2, they are functions which can be associated to the entities of our ontology. Their identification by speakers/readers is accomplished by reasoning processes which are initiated by pure linguistic input and augmented with other kinds of information, non-linguistic in nature, such as common sense knowledge. In addition to this, it is important to point out that the identification of temporal relations is subordinated to the identification of a discourse sequence, i.e. a unitary - coherent and cohesive - message that forms a unified whole.

In order to obtain a comprehensive picture of temporal relations in natural language, we have to take into account three distinguished components (Móia, 2000), in particular:

TR1. the relation itself, which can be of different sorts:

TR1(a). *temporal location*: it involves a relation between a given entity - the located entity - and a parcel of the time axis - the locating entity. This relation to the time axis can be direct, if the locating entity is a part of the time axis, or indirect, if the locating entity can on turn be connected to to time axis. The relation between located and locating entity may vary, according to the set of possible (temporal) relations we have identified in sections 2.3.2.2 and 2.3.3.2 in chapter 2; e.g.:

(3.28) Marco si è sposato nel 1980.

Marco got married in 1980.

[7]The difference between indexical and anaphoric temporal expressions is due to the type of anchor chosen, if it is external element part of the context, is considered indexical, while if it is an internal co-textual element is considered anaphoric. In this sense, we may claim that they are similar to indexical and anaphoric pronouns.

[direct temporal location; Temporal Relation: **inclusion** between the *located entity* - the event of Marco getting married - and the *locating entity* - the temporal expression 1980]

(3.29) Marco si è sposato durante la guerra.
Marco got married during the war.

[indirect temporal location; Temporal Relation: **during** between the *located entity* - the event of Paolo getting married - and the *locating entity* - the event of the war]

TR1(b). *duration*: it is independent of the localization of the entity on the time axis and it represents a quantification of the length of an entity and an amount of time; e.g.:

(3.30) Marco ha lavorato per 3 ore.
Marco worked for 3 hours.

[the event of working lasted for an amount of time equals to 3 hours]

TR1(c). *frequency*: normally, it deals with the explicit counting of eventualities with respect to a time unit; e.g.:

(3.31) Marco va al cinema 3 volte a settimana.
Marco goes to the cinema 3 times per week.

[the event of going to the cinema happens 3 times in week]

Notice that the term frequency is applied also to constructions where no explicit counting of eventualities seems to be expressed. These involve adverbials like *frequently*, *every morning*, *whenever + CLAUSE* and similar. These kinds of constructions do not directly count eventualities but express a relation between eventualities and intervals, i.e. they quantify over times. This entails quantification over the described eventuality which necessarily iterates. Following Kamp & Reyle (1993), we consider these adverbials as adverbs of temporal quantification, which, with respect to purely frequency constructions, "**characterize the location times** of the described eventuality [...] (and) act as bound variables, ranging over sets of possible location times" [Kamp & Reyle (1993): 635, my bold]. In other words, they involve a quantification over the location times, which, in turn, entails a quantification over the located eventualities;

TR2. the entities involved in the relation: following what we have stated in chapter 2, temporal relations may hold between all the entities introduced in the ontology i.e. eventuality - eventuality; time - time, and time - eventuality;

TR3. the object of the relation which is necessarily a temporal entity, i.e. the located area of the time axis or the amounts of times.

All these concepts are marked in language by different devices, which represent the sources of temporal information in a natural language discourse. We propose to divide these devices into two broad categories: pure lexical items and a specialized sub-system. The following sections are devoted to their presentation and description, with a particular focus on Italian.

3.3.1 Lexical items encoding Temporal Relations

Lexical items signaling temporal relations are commonly identified in literature with temporal adverbials. The linguistic realizations of this category is quite varied as it includes: temporal PPs (examples 3.32 and 3.33), adverbs of time (examples 3.34 and 3.35), temporal clauses (example 3.36) and NPs (example 3.37) (the expressions realizing temporal adverbs are underline):

(3.32) Marco è a Boston da ieri.

Marco is in Boston since yesterday.

(3.33) Marco ha vissuto a Boston per 3 anni.

Marco has lived in Boston for 3 years.

(3.34) Marco si sposato oggi.

Marco got married today.

(3.35) Marco è uscito. Poi ha comprato un dolce.

Marco got out. Then he bought a cake.

(3.36) Lo aspettai finché non tornò.

I waited for him until he came back.

(3.37) Marco annaffia il giardino ogni lunedì.

Marco waters his garden every Monday.

The class of temporal adverbials is commonly considered to provide the reader with **explicit signals** of the temporal relations which hold between the two entities involved (in the examples we have cases of a temporal relation between an eventuality and a temporal expression, like in examples 3.32, 3.33, 3.34, 3.37, and between two eventualities, like in examples 3.35, 3.36). In literature[8], temporal adverbs are commonly classified into three main categories:

- adverbs which locate the described eventuality in time or respect to another eventuality, like in examples 3.32, 3.34, 3.35, 3.36;
- adverbs which measure the duration of the described eventuality, like in example 3.33;
- adverbs which express the frequency or number of times the described eventuality occurs, like in example 3.37.

In addition to this, most authors identify a forth category of ambiguous temporal adverbs as "adverbs which simultaneously serve as location and as measure of the described eventuality" [Kamp & Reyle (1993): 612–13]. Following Móia (2000), we do not agree on the existence of such a class.

Instead of proposing a survey of previous approaches to the treatment of temporal adverbials, their classification and properties, we are going to introduce a novel distinction which, from a certain point of view, breakes up with previous descriptive approaches in literature. Our choice is mainly based on corpus-based observations on the way temporal adverbs are realized and also on the definition of temporal expressions we have adopted (section 3.2). Taking these two points as pivotal, it is possible to identify two classes of lexical items which are responsible for the signaling of temporal relations: the macroclass of **signals** and that of **bare temporal expressions**. To clarify our statement consider the following examples, taken from our corpus:

(3.38) Guerriglia ad Hannover dove **da** giovedì sera sono accorsi circa 1.500 punk.

*Guerrilla in Hannover where **since** Thursday night 1.500 punks have reunited.*

(3.39) Abbiamo offerto di restare solo a quelli che non hanno compiuto massacri **in** questi anni di occupazione.

*We have offered to remain only to those who did not take part to the massacres **in** these years of occupation.*

[8] Bennett & Partee (1978); Quirk et al. (1985); Bertinetto (1986); Smith (1997); Móia (2000)

(3.40) L'accordo è stato firmato **ieri** al Pentagono.

*The agreement was signed **yesterday** at the Pentagon.*

(3.41) **Subito dopo** la strage di Bhopal il suo nome era rimbalzato sulla carta stampata.

***Immediately after** the Bhopal massacre, its name appeared on the press.*

In the examples we have underlined the classical temporal adverbs while put in bold our new distinction. By observing the actual linguistic realizations of these adverbs we can notice one important element, that is that they all present one of the following structures:

(i.) TEMP. ADVERB = [ADVERB/PREPOSITION/CONJUNCTION [TEMPORAL EXPRESSION/EVENT]]

(ii.) TEMP. ADVERB = [TEMPORAL EXPRESSION]

The first construction is represented by examples 3.38, 3.39 and 3.41, where the expressions in bold correspond to signals, while the second by example 3.40, where the expression in bold corresponds to a bare temporal expression. The advantages of such a new classification are multiples, both from a theoretical and an applicative point of view. Firstly, and most importantly, we maintain separated the different conceptualizations of the entities which contribute to the realization of a temporal adverb (being a locating or a durative one). Such a distinction is very useful to provide a proper semantic description of such entities and, in addition to this, it explicits the role of elements such as prepositions, connective adverbs, like *poi* [then], *intanto* [meanwhile], and temporal conjunctions, like *mentre* [while], *quando* [when], by recognizing their contribution to the recovering of a temporal relation. Secondly, it provides a sort of parallelism with human cognitive abilities to build up temporal relations between different entities. We have already stated that temporal relations are inferencing mechanisms which are built from linguistic input and augmented, when and if necessary, with contextual (i.e. non-linguistic) one. Instances of temporal adverbs which are realized by constructions like those in (i.) provide the reader with all the necessary linguistic information to accomplish the inference process to retrieve the temporal relation. Stated in a different way, realizations of temporal adverbs of this sort offer a compositional way of determining the temporal relations, since the elements introducing the temporal expressions are the explicit linguistic means which, in combination with semantic information from what precedes and follows them, denote a temporal relation between two entities. On the other hand, realizations of bare temporal expressions, i.e. (ii.), are cases where the contribution of the linguistic information is limited since the recovering of the temporal relation is not made by explicit linguistic information but by exploiting inferencing mechanisms which may make use of contextual evidences. Their primary role, as already stated in section 3.2, is that of providing a temporal anchor for the eventuality or time expression to which they refer. Finally, a difference in functions corresponds to these two types of constructions: bare temporal expressions always realize temporal locating adverbs, i.e. they provide the answer to the question "when did something happen?", or locate a temporal expression with respect to another. On the contrary, signals can either locate an entity or express its duration, which, under the perspective of our work, both represent instances of a temporal relation. We want to point out that each signal realizes only one of the proposed functions, according to its semantics or asserted meaning. In this sense we agree with Móia (2000)'s claim that there are no ambiguous temporal adverbs which express both the location and the duration of the eventuality or temporal expression. Those cases where such ambiguity seems to arise are instances where one of the two functions, normally duration, is not part of the meaning but it is inferred. These inferences are implicatures, and not part of the meaning of the linguistic form, i.e. of the signal.

3.3.1.1 The semantics of signals

The[9] aim of this section is that of presenting a formal semantics for signals, which can provide relevant benefits both from a theoretical point of view and an applicative perspective, in particular for Information Extraction and Question-Answering systems.

The proposed semantics is based on three previous formal accounts, namely those of Schilder & Habel (2001); Pratt & Francez (2001) and Schilder (2004) on temporal prepositional phrases, which we have extended to temporal signals in general. In general, signals are predicates of the form $< e, < e, t >>$, denoting a relation between times, either temporal expressions or eventualities. One of the most challenging issues related to the formalization of such a compositional semantics for signals is represented by the rather high variability both in meaning (i.e. temporal relations) and in linguistic realization (i.e. parts-of speech). On the basis of this variability it is possible to split the class of signals into two groups:

Definition 18 (semantically explicit signals) a set of signals whose meaning is self-evident and stable, and can be represented as $Rel(X, Y)$, where X and Y refer to a temporal expression(s) or eventuality(ies) description(s), and *Rel* corresponds to the associated temporal relation or the semantics of the signal; e.g.:

(3.42) I "patron" della Candy preferiscono acquisire solo **dopo** trattative lunghe e laboriose.

Candy's owners prefer to buy only ***after*** *long and toilsome negotiations.*

dopo [after] = AFTER;
preferiscono acquisire [prefer to buy] = X;
trattative [negotiations] = Y $\longrightarrow$
AFTER (X, Y)

Definition 19 (semantically implicit signals) a set of signals whose meaning is highly abstract and gets specialized according to the semantic properties of the elements which precede and follow the signal. The semantics of this set of signals needs abstraction and thus can be represented as $Rel(\lambda(X), \lambda(Y))$, where $\lambda(X)$ and $\lambda(Y)$ refer to a temporal expression(s) or eventuality(ies) description(s), for which a proper semantic description is needed, and *Rel* to the associated temporal relation or the semantics of the signal which is determined by the interaction between the co-textual element X and Y; e.g.:

(3.43) Ahmad Butt è morto **nel** 1984.

Ahmad Butt died ***in*** *1984*

nel [in] = $Rel(\lambda(X), \lambda(Y))$;
è morto [died] = X $\wedge$ X = $Perf(_{achievement}e)$;
1984 [1984] = Y $\wedge$ Y = $_{date}$I $\longrightarrow$
$Rel[\lambda\ Perf(_{achievement}e),\ \lambda(_{date}I) \equiv$
DURING $(_{achievement}e,\ _{date}I)$

[9]The core content of this section was presented at the 4th ACL-SIGSEM Workshop on Prepositions, Prague, June 2007, (Caselli & Quochi, 2007).

As it appears from example 3.43, the semantics of the co-textual elements, i.e. $\lambda(X)$ and $\lambda(Y)$, plays a major role in determining the semantics of the implicit signal. In particular, the semantic information which needs to be taken into account is the aspectual information (i.e. type of eventuality and viewpoint information) for eventualities and the type of temporal expression. To deal with these elements, we have adopted here a representation to describe the eventuality type, the *Perf* operator for viewpoint and a novel representation for temporal expressions which takes into account its ontological status, i.e. either an interval, I, or an instant, i, and its type, i.e. whether it denotes a date, a clock time, a pure time slot, a duration or a set. These two kinds of semantic information are pivotal to assess the meaning of implicit temporal signals.

An interesting aspect of signals is that they may give rise to entailments which denote the "associated temporal expressions", and, consequently, associated temporal relations. To illustrate this kind of implicatures we will present a further example:

(3.44) Dall'inizio dell'anno l'euro ha guadagnato l'11% sul dollaro.

Since the beginning of the year the euro has gained 11% compared to the dollar.

da [since] = $Rel(\lambda(X), \lambda(Y))$

ha guadagnato [has gained] = X $\wedge$ X = $Perfect({}_{accomplish.}e)$;

l'inizio dell'anno [the beginning of the year] = Y $\wedge$ Y = ${}_{date}$I $\longrightarrow$

$Rel[\lambda\ Perfect({}_{accomplish.}e),\ \lambda({}_{date}\mathrm{I}) \equiv$

NO T.REL $({}_{accomplish.}e,\ {}_{date}I) \wedge$ [**EQUAL** $({}_{accomplish.}e,\ {}_{duration}I')$]

$\wedge$ (**START** $({}_{accomplish(e)}s,\ {}_{date}I^S)$

As example 3.44 shows, the semantics of the temporal signal *da* [since] in this case is null, i.e NO T.REL. However, the combination of this signal with an accomplishment event at the perfect viewpoint gives rise to an associated temporal expression, ${}_{duration}I'$, which denotes a period of time which starts at the beginning of the year, ${}_{date}I$, and finishes at the moment of utterance of the sentence, ${}_{date}I^{S}$[10]. This entailed temporal expression, ${}_{duration}I'$, represents a duration associated to the event of gaining which expresses its temporal extension. It's quite easy to imagine the consequences: first, a temporal relation of EQUAL between the associated temporal expression and the event can be inferred; and then, it is possible to infer additional temporal relations between the event of gaining and all other eventualities which can be temporally located in this period of time. In addition to this, there is one more entailed temporal relation, the START relation between the contingent state of the event,${}_{accomplish(e)}s$, and the moment of utterance, ${}_{date}I^S$. Nevertheless, when computing these entailed temporal relations it is important to keep in mind the ontological type of the eventuality. For instance, the event in our example is an accomplishment, and of a particular kind since it denotes an incremental event; due to its internal temporal properties, as we have illustrated in chapter 2, section 2.3.1, the temporal relation of EQUAL does not represent how long the event lasted but, on the contrary, how long its preparatory process before the culmination point, which in our sentence coincides with the 11% gain of the euro, is.

In appendix A we will present a comprehensive list of temporal signals and of their semantics based on a corpus study, together with a description of the methodology used. The main advantage of our approach is that the general formal framework is language independent. This means that although the specific meaning of each signal is clearly (and trivially) language specific, the procedure to identify them is not dependent on the language in analysis but can be applied to any natural language where such a class of

[10]The moment of utterance of a sentence can always be associated with a temporal expression, which if not explicitly stated in the text, usually corresponds to the date when the sentences is uttered.

linguistic items can be identified. In Table 3.2, we present a reduced list of signals extracted from our corpus and belonging to both groups together with their corresponding part-of-speech.

Table 3.2: *Explicit and implicit signals and corresponding POS.*

Signals	**Type**	**POS**
poi, intanto, all'inizio, contemporaneamente...	Explicit	Adverbs
quando...	Implicit	Conjunction
in, per, tra...	Implicit	Preposition
dopo, fintanto...	Explicit	Conjunction
dopo (di), durante, entro...	Explicit	Preposition

3.3.2 Sub-system expressing Temporal Relations

In a language like Italian the temporal-aspectual system is the other big device used to express temporal relations. This system is composed by:

- tense; and
- aspect, which, in turn, and following Smith (1997)'s proposal, is composed by:
  - viewpoint or grammatical aspect; and
  - lexical aspect (*Aktionsaart*).

These components of the temporal-aspectual system must not be mixed up together as it often happens in literature. Although they are deeply interrelated one with each other, they need to be kept separated on a conceptual level so that it would be easier to describe in a compositional way what is their contribution to the recovering of temporal relations. The following sections will be devoted to a critical examination of the contribution of the linguistic devices composing the sub-system.

3.3.2.1 Tense

Tense is a grammatical device which is not present in all existing natural languages. Italian, with respect to Chinese - for instance - is considered a tensed language, a language in which all sentences have a direct temporal information. In Italian, tense is realized by verb morphemes (inflectional morphemes) and, following Comrie (1985), it represents the "grammaticalised expression of location in time" [Comrie (1985): 9]. In much of traditional grammars tense is considered as a category of the verb on the basis of its morphological attachment to it. We do not agree with this statement, and we argue, following Lyons (1977); Comrie (1985) and Smith (2004), that tense is a category of the clause or of the sentence as a whole, or, in logical term, of the entire proposition.

If tense locates entities, i.e. eventualities, in time it is necessary to establish an arbitrary reference point. Since language is speaker-oriented, the speech situation is usually assumed as offering this reference point, which for tense is represented by the "present moment" [Comrie (1985): 14] or the "speaker's time (*now*)" [Smith (2004): 597]. As we have stated chapter 2, tense locates the eventualities into one of the three temporal dimensions according to reference point: either in the Past, if the eventuality is prior to the speaker's time, or in the Present, if the eventuality is at the same time as the speaker's time (or including it), or in the Future, if the eventuality is subsequent to the present moment. Such a property characterizes tense as being a deictic system. This statement needs clarifications: the speaker's time, or in other words, the moment of speech is the most basic deictic center, but it is possible to have other deictic centers, or reference points, provided that these are clarified by the context (both linguistic and extralinguistic).

So far we have stated that the role of tense semantics is that of locating eventualities in time. This is possible by exploiting the relationships which may be obtained by combining the meaning of tense morphemes with the chosen deictic center. However, on the way of representing tense's semantics there is no much agreement in literature. In fact, we argue that it is possible to identify three main approaches:

- classical priorean and neo-priorean approaches (Prior, 1968; Blackburn & Lascarides, 1992; Blackburn, 1994; Bonomi, 1995): tense is represented as an operator which quantifies over temporal structure;
- reichenbachian and neo-racheinbachian approaches (Reicheinbach, 1947; Hornstein, 1977; Vikner, 1985; Brent, 1990; Kamp & Reyle, 1993; Nelken & Francez, 1997; Smith, 2004): tense codes a relation between three times, namely: a speech time, S, a reference time, R, and an event time, E;
- descriptive approaches of tense meaning without a formal framework or specific linguistic theory (Comrie, 1985; Bertinetto, 1991).

For the purpose of our work we have chosen to represent tense semantics in a way similar to the raichenbachian and neo-rachiebachian approaches. Such a choice is dictated by the conviction that this framework and its elaborations are optimal to describe the role of tense as the primary source of information to retrieve temporal relations both in sentences and in texts/discourses.

As already stated, the key idea of Reicheinbach (1947) work is that tense meaning can be represented not as a relation between two points or moments, the deictic center and the time when the eventuality occurs, but between three. As Reicheinbach (1947) states:

> Let us call the time point of the token [uttered] the *point of speech*. Then the three indications, "before the point of speech", "simultaneous with the point of speech", and "after the point of speech", furnish only three tenses; since the number of tenses is [...] greater we need a more complex interpretation. From a sentence like "Peter had gone" we see that the time order expressed in the tenses does not concern one event, but two [...], whose positions are determined with respect to the point of speech. We shall call these time points the *point of the event* and the *point of reference*. In the example the point of the event is the time when Peter went; the point of reference is a time between this point and the point of speech.[Reicheinbach (1947), in Mani et al. (2005): 71]

The point of speech, S, represents the core element of the reichenbachian theory and corresponds to the speaker's "here-and-now". The point of reference, R, represents the temporal standpoint of a sentence, and it may work as a temporal anchor in a complex sentence or in a sequence of sentences (i.e. a text). The point of event, E, is the time interval or instant when the eventuality takes place or is situated. It is important to point out that the point of event is temporally independent of the eventuality itself. In the original approach, tenses's semantics are represented by a one three-place relation between the different points, according to this scheme. First, the relation between the speech point and the reference point are established, and then the same operation is performed to establish the relation between the reference point and the event point. On this basis, nine fundamental tense forms ($3X3 = 9$), are identified[11] which are illustrated in Figure 3.1. The position of R with respect to S is indicated by the words like "past", "present" (i.e. simultaneous) and "future", while the position of E relative to R is indicated by the terms "anterior", "simple" (i.e. simultaneous) and "posterior". Note that the "," stands for simultaneity "-" for precedence.

Structure	**New Tense Name (Reichenbach, 1947)**	**Corresponding Italian Tense**
E – R – S	Anterior Past	Trapassato I - II
E, R – S	Simple Past	Passato Semplice, Passato Composto & Imperfetto
R – E – S **R – S, E** **R – S – E**	Posterior Past	Futuro nel Passato Composto
E – S, R	Posterior Past	Passato Composto
S, R, E	Simple Present	Presente
S, R – E	Posterior Present	Futuro Semplice
S – E – R **S, E – R** **E – S – R**	Anterior Future	Futuro Composto
S, R – E	Simple Future	Futuro Semplice
S – R – E	Posterior Future	Futuro nel Passato

Figure 3.1: *Reichenbach (1947)'s fundamental 9 tense forms and corresponding Italian ones.*

One of the most important insights of this analysis is represented by the identification of the moment of reference. The introduction of R has acknowledged a property of tense which, on the contrary, classical priorean analysis is unable to account for, that is the fact that tense has referential properties. This means that in a sentence like:

(3.45) Marco ha corso.
Marco ran.

tense does not only locate the event of Marco's running in an unspecified past time with respect to the moment of speech, but that this event occurred at R, i.e. a particular, **contextually determined**, past time. In addition to this, the presence of R is used by Reicheinbach (1947) to provide a principled account of what in classical descriptive grammars is called the *sequence of tenses*. According to the author these rules should

[11] The possibility of ordering the three points should provide 13 possible relations. As the author himself claims "[f]urther differences of form result only when the position of the event relative to the point of speech is considered; this position is usually irrelevant" [Reicheinbach (1947), in Mani et al. (2005): 77].

be interpreted as the principle which demands the *permanence of the reference point.* Although the events referred to in the clauses may occupy different time points, the reference point should be the same for all the clauses, so for instance, the tenses of the sentence in 3.46 (cited in [Reicheinbach (1947) in Mani et al. (2005): 74], can be represented as follows:

(3.46) *I had mailed the letter when John came and told me the news.*
1st clause: $E_1 - R_1 - S$
2nd clause: $R_2 \equiv R_1, E_2 - S$
3rd clause: $R_3 \equiv R_2, E_3 - S$

If someone said "I had mailed the letter when John has come", this sentence would be considered as incorrect because of a change in the R of the second clause. In this way, the R provides a *locus* for relating events in a principled manner, i.e. ordering them, thus realizing a further property of tense, namely that **tense orders eventualities** along the hypothetical time axis. Finally, the presence of R offers a way for a proper treatment of the phenomena of shifted deixis. Deictic adverbs like *ora* [now], *tra 3 giorni* [in 3 days] and similar may shift the actual point of speech to a past or a future one. R is responsible for correctly **anchoring these shifted moments of speech**.

Criticisms and modifications to Reicheinbach (1947)'s original proposal have been suggested mainly on two aspects of his theory: on the way the three points or moments should relate one with respect to the other, and on the notion of reference time itself. However, after detailed readings of the literature[12] on these subjects we concluded that all these criticisms are fuzzy and mix up together different aspects of Reichenbach's analysis which is in itself fuzzy on these two points. In the next paragraphs, we will provide a comprehensive critic to Reichenbach's semantics of tense in order to obtain a clearer picture which can help us to point out what the contribution of tense in signalling and recovering temporal relations in texts/discourses is.

On the issue of a moment of reference Reichenbach introduces this notion for a proper treatment of the semantics of some tenses, in particular of the past perfect. This third element is, in fact, necessary otherwise core temporal differences between this tense and a tense like the simple past would be lost. In addition to this, a further justification for introducing this new element is found by analyzing the behavior of temporal (locating) adverbs:

> When a time determination is added, such as is given by words like "now" or "yesterday", or [..] "November 7, 1944", it is referred not the event but to the reference point of the sentence. [...]. When we say, "I had meet him yesterday", what was yesterday is the reference point, and the meeting may have occurred the day before yesterday. [...] the reference point is used here as the carrier of the time position [Reicheinbach (1947), in Mani et al. (2005): 75]

Thus, at the same time, this notion of moment of reference is also used to refer to a general property of tense, i.e. the fact that it has a referential property[13]. Such a property of tense is not directly stated by Reichenbach, but it can be inferred when he speaks of the permanence of the moment of reference (see example 3.46). It is our opinion that

[12] Vikner (1985); Bertinetto (1985, 1986); Brent (1990); Kamp & Reyle (1993) and Giorgi & Pianesi (1997)

[13] The first who clearly stated this property of tense was Partee (1973). We will come back on this issue in the following chapters.

these two aspects of the moment of reference must be kept separated and distinguished since their contribution is different according to the perspective we adopt when speaking of tense semantics. We are referring here to a pivotal distinction proposed by Comrie (1985) and well known in modern semantics theory, that is the distinction between basic and inferred meanings. If we need to state what is the basic temporal meaning that each tense encode in a natural language, the notion of reference time we need is clearly the first one. On the other hand, if we want to develop a theory of tense semantics, we must first acknowledge the type of discourse context in which the tensed clause appears. This kind of analysis needs, in our opinion, to make use of the second notion of moment of reference and must find a representational device to distinguish it from the first one, which, as we stated, is part of the basic meaning of the tense form.

Basic Tense Semantics: from a one three-place relation to two-place relations
The basic temporal information of tense forms is that of providing information on **where** to locate the E, the moment or point of event, on the time axis with respect to a deictic center, which is normally assumed to be S. As Reichenbach noticed, not all tense forms and their semantics can be described according to the relation between these two points. However, the solution he proposed, i.e. to introduce a third moment, R, for all tense forms is somehow difficult to accept.

Our ri-analysis of the reichenbachian system develops from Comrie (1985) seminal work. We claim, following in part Comrie, that tenses can be classified into two broad categories:

Definition 20 (absolute tenses) : tenses where the R is not necessary to describe their basic temporal meaning which can be obtained by the relations between E and S;

Definition 21 (absolute/relative tenses) : tenses where the R is necessary because it is part of the basic temporal meaning of the tense form which can be expressed, formally, by the relations between E, R and S.

Before going on, we feel necessary to restate what these three points represents under our perspective. S represent a deictic center which normally coincide with the moment of utterance of the speaker. We say "normally" because the value of S can be shifted: for instance, if we are reading a newspaper, S does no more coincide with the moment of utterance but, accordingly, with the publication date of the newspaper itself. Independently from the way S is recovered, it represents a fixed point, or moment, in time from which the basic temporal meaning of the tense forms is determined and described. The E is the time of occurrence of the eventuality. It tells us that eventualities occur in time. It is important to point out that E does not correspond to the location time of the eventuality but simply states that there is a time span in which a certain eventuality occurs. Using a terminology from classical tense semantics (Prior, 1968), the E represents the existential quantifier of the tense forms. Finally, the R is no more the temporal standpoint of a sentence, but a second deictic center which is necessary to describe the temporal meaning of some tense forms. As it appears from what we have stated so far, the value we assign to R is completely different from the original proposal of Reichenbach. In addition to this, we claim that R is an optional element since it is not necessary to describe the temporal meaning of absolute tenses. Nothing prevents us from modifying its representation and even rename it as S_1. If R is ri-analyzed in this way, we must also acknowledge the fact that there may be tense forms which need more than an R to express their basic meaning, for instance when an eventuality is located "relative to a reference point which is in turn located relative to a reference point which is located relative to the present moment"

[Comrie (1985): 128]. A tense form of this kind is represented by the future perfect in the past:

- E relative to R_1 relative to R_2 relative to S

To represent tense meaning in a uniform way we can no more rely on the one three-place relations proposed by Reichenbach. We propose to shift to two-place relations[14], one between E and S and the other, when present, between R and S. Consequently, absolute tenses will be represented by a one two-place relation between E and S, where E can be simultaneous, anterior or posterior to S, while absolute/relative tenses are represented by at least two two-place relations: one between E and R, where, in principle, E can be simultaneous, anterior or posterior to R and the other between R and S, where R can be either posterior or anterior to S. A simultaneous relation between R and S would be in contradiction with what we have stated so far. If R, which in our account is interpreted as a second deictic point or center, were simultaneous to S, the two points would coincide and be the same thus representing an instance of an absolute tense.

With respect to previous works which argued for two-place relations, we have not introduced substantial differences except for the fact that we have a direct relation between E and S which is, however, restricted to absolute tenses only. On the contrary, and in agreement with these works, we claim that in absolute/relative tenses such a direct relation is not allowed. The reasons for this choice are not arbitrary but are well grounded in a semantic analysis of tense meaning, since in absolute/relative tenses the position of S relative to E is **inferred** and mediated by the context. To justify this claim we take in analysis the future perfect (corresponding to the Italian *futuro composto*). The representation proposed for this tense in the classical reichenbachian framework is left open with three possibilities:

Definition 22 (Reichenbach's future perfect) : $S-E-R$ or $S,E-R$ or $E-S-R$.

The position of E relative to S is considered by Reichenbach to be irrelevant and the three possible representations of this tense are all the same fundamental form. From a semantic point of view allowing a similar representation means to mix up different level of semantic information. Stating the position of E relative to S is an implicature which is made by exploiting contextual information. As a justification to this claim consider these examples[15]. When someone claims "Marco will have finished his work by tomorrow" he is clearly unaware of the fact that Marco may have already finished the work (otherwise he would be devious and would violate general principles of conversation). So if the relation between E and S was part of the meaning of the future perfect we should agree with the classical reichebachian representations and consider this tense form as inherently ambiguous in its interpretation, that is it will always activate the three possible combination we have illustrated in **Definition 22**. Now suppose this different scenario with someone asking "Will Marco have finished his work by tomorrow?" and suppose that, although the speaker knows that Marco has already finished his work, the answer is "Yes, in fact he has already finished it". The first part of the answer maintains the truth-conditions of the future perfect. On the other hand, if part of the meaning of the future perfect was that Marco has finished his work between the moment of utterance and the reference point ($S-E-R$) then the second part of the answer would be a contradiction, but it is not so. The second part of the answer serves to cancel the implicature which is generated by the "yes" that the manuscript is not yet finished. A possible counterexample to this

[14]Vikner (1985); Brent (1990); Giorgi & Pianesi (1997)

[15]An extended argumentation on this issue may be found in Comrie (1985): 69–75.

argument may be represented by the analysis of the past perfect (*trapassato I* in Italian) which has a unique way of ordering the three moments, i.e. $E - R - S$ and the claim that the E is anterior S as a part of the meaning of this tense form seems to hold. However, a closer analysis shows that even in this case this relation is not a direct one but is obtained by a form of reasoning due to the fact all the three points stand in a precedence (i.e. **before**) relation one with respect to the other. Recalling a property of this relation, namely that of transitivity (chapter 2, section 2.3.2.1), it is easy to observe how even in this case the relation between E and S is inferred and it is not part of the basic tense semantics[16] The same type of analysis holds for the future perfect in the past (*futuro nel passato composto*) as well.

A further advantage of using two-place relations is represented by the possibility to stress the hierarchical nature of the relations between S, R and E: S is the most independent element, R is directly dependent on S and can be placed only in relation to it, and, finally, E is the most dependent element, as it can be collocated only in relation to R which, in turn, depends on S.

Having reinterpreted R as the second deictic center necessary to describe absolute/relative tenses, the analysis of temporal adverbials proposed by Reichenbach is no more correct. According to the author all temporal adverbials have the function of signalling the R. On the contrary, and in agreement also with Bertinetto (1985), temporal adverbs have different functions according to the tense forms with which they co-occur. Consider these examples:

(3.47) Ieri, Marco è partito alle 15.00.
Yesterday, Marco left at 15.00.

(3.48) Ieri, Marco era (già) partito alle 15.00
Yesterday, Marco had (already) left at 15.00.

In example 3.47 we are dealing with a *passato composto*, which we consider as an absolute tense[17] whose temporal meaning is represented by the relation between E and S,

[16]The mechanism works in this way: E is before R, R is before S, then E is before S. As it appears, the relation between E and S is inferred exploiting the transitivity property of the precedence relation (see also Table 2.6 on page 35).

[17]This claim may be considered wrong or strongly unacceptable since, in literature, the *passato composto* is analyzed as having a R as part of its meaning. We do not agree with this approach and argue for the correctness of our proposal presenting the following arguments:

Argument 1 (basic temporal meaning) : as we have already stated, it is important to keep separate the notions of basic and inferred temporal meanings of tense. In addition to this, we claim that most analyses of the *passato composto* take into account its contribution and interpretation in discourse when explaining the semantics of this tense form, which we consider to be a secondary meaning of tense.

Argument 2 (tense *vs.* aspect) : the analyses which claim the necessity of a R to describe the semantics of the *passato composto* do not distinguish, in our opinion, between the contribution of tense and that of aspect. Three-points analyses of the *passato composto* represent it as $(E - R) \bullet (R, S)$ by specifying, however, that this schema holds only for the **perfect** reading of this tense form. The perfect is an aspectual value, which must be kept conceptually distinct from tense. R is then not interpreted as a further deictic center, but as expressing an aspectual value which provides other kinds of temporal information on the eventuality than its temporal location. Thus, the semantic status of this R is completely different from the one we have claimed to exist to describe absolute/relative tenses. In addition to this, the relation between R and S should be interpreted as expressing the aspectual values which may be associated with the different tense forms. If it so, then a contradiction arises when representing tenses like the *trapassato I* or the *futuro anteriore* which may be associated with perfect aspectual value (in the past and in the future, respectively).

namely $(E - S)$. The two temporal adverbials, *ieri* [yesterday] and *alle 15.00* [at 15.00], correspond to a bare temporal expressions and to a signal plus a temporal expression which have the role of providing a temporal anchor for the event *è partito* [left]. They restrict E, or better, they offer an external reference to locate in a very precise way E on the time axis and with respect to S. In addition to this the first temporal expression *ieri* [yesterday] also works as a temporal anchor for the second one, *15.00*, whose relation is recovered by means of the signal *alle* [at]. Generalizing these observations, we can state that temporal adverbs which occur in conjunction with absolute tenses always correspond to temporal locating adverbs, i.e. external means for locating an eventuality on the time axis.

On the other hand, things are more complicated when we analyze example 3.48. The two temporal adverbials have different functions which get specialized according to the tense semantics. In comparison with the temporal adverbs in example 3.47, they do not represent both instances of temporal anchors. Recalling the semantic representation for the Italian *trapassato I*, i.e. $(E - R) \bullet (R - S)$, we claim that the second temporal adverb, realized by a signal plus temporal expression, *alle 15.00* [at 15.00], represents an instance of the R while the first, *ieri*[yesterday] has the function of providing the temporal anchor for locating E. To support this analysis consider this argument: the semantics of the *trapassato I* states that there exists a time t where an eventuality occurred (E). t is prior to another time, $t\prime$ (R), which in turn is prior to a fixed time n (S). The adverb *alle 15.00* [at 15.00] cannot represent a specification of the time t since it does not provides us with information on when the event of leaving occurred, but states that, at the particular time that it denotes, the event of leaving had already occurred. In addition to this, its denotation is dependent on the particular time n. The conclusion we can draw form this argumentation is that *alle 15.00* [at 15.00] corresponds to $t\prime$, i.e. R. On the other hand, the temporal adverb *ieri* [yesterday] tells us when in the Past the event occurred, it anchors the time t (E) on a (more or less) precise moment on the time axis. Interpreting these adverbs the other way round is highly implausible and will lead to unnatural and impossible readings. Summing up, analyzing example 3.48 we can observe a new function of temporal adverbs that they may represent also explicit instances of intrinsic temporal reference (R) of tense forms. Thus, temporal adverbs which co-occur with absolute/relative tense may signal either R or specify the location of E.

A final remark on this issue is necessary: R is always present with absolute/relative tenses, it is not an optional element. If it is not explicitly stated, it is always recoverable from the context otherwise the interpretation of the tense is not possible. On the contrary, temporal anchors which specify the location of E (what in A.I. is known as the time-stamping of an event, that is associating each event with a precise date/time in which it

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According to this interpretation, the semantic values of the *trapassato I* would be $(E - R) \bullet (R, S)$, like the *passato composto*, and that of the *futuro anteriore* would be $(R - E) \bullet (R, S)$. Such an analysis is a nonsense, since the temporal meaning of these two tense forms are different and cannot be formalized by using this conceptualization of the R. Moreover, notice how in this way the temporal meaning of the *passato composto* and that of *trapassato I* are identical which is totally incorrect and counterintuitive.

Argument 3 (missing *R*) : let's accept that the representation of *passato composto* needs a second deictic center, i.e. R, and which corresponds to this schema $(E - R) \bullet (R, S)$. Now, this R stands in a precedence relation with E and in a simultaneous relation with S. Then, if R and S are simultaneous, they are in an equal relation (see Figure 2.4 on page 28, chapter 2). If the two deictic centers coincide, then they can be thought as being the same, so $R = S$. In this way, R is unnecessary to formalize the semantics of the *perfetto composto* which can be represented by the simpler relation between E and S.

occurs) are not compulsory elements required by the tense semantics but additional and optional ones which may be provided if it is necessary to locate E in a more precise way with respect to the location which is offered by tense.

In Table 3.3 we illustrate the representation of the basic temporal meaning of the tense forms for the Italian indicative mood. As notational devices we will represent the relation of simultaneity with "$\equiv$", the relation of precedence with "$\prec$", and that of succession with "$\succ$"; the "$\bullet$" represents a conjunction when more than a two-place is required, E represents the time span in which the eventuality occurs, S is the main deictic center, normally associated with the moment of utterance and R is the second deictic center.

Table 3.3: *Basic temporal meaning of Italian tense forms.*

Tense Type	Tense Forms & Semantics
Absolute Tense	**Presente**: $(E \equiv S)$ **Passato Semplice**: $(E \prec S)$ **Imperfetto**: $(E \prec S)$ **Passato Composto**: $(E \prec S)$ **Futuro Semplice**: $(E \succ S)$
Absolute/relative Tense	**Trapassato I**: $(E \prec R) \bullet (R \prec S)$ **Trapassato II**: $(E \prec R) \bullet (R \prec S)$ **Futuro Composto**: $(E \prec R) \bullet (R \succ S)$ **Futuro nel Passato**$(E \succ R) \bullet (R \prec S)$

Tense and temporal relations As already stated, the breaking innovation of the reichenbachian approach to tense semantics is represented by the acknowledgement that tense has a referential property. To distinguish this notion of reference from the one we have presented above we will use a different notation, namely *Rpt*[18]. This new temporal reference point should be the bulk of any good theory whose aim is that of providing a principled way to describe the role of tense in creating and signaling temporal relations between eventualities. Its interpretation is dependent on the type of textual domain[19] the tensed clauses or sentences occur in. Independently from the domain of occurrence, the *Rpt* is always simultaneous with *E*.

As far as the first type of textual domain, i.e. sentence in isolation, the temporal relations are signaled by the relation between *E*, *S* and, when present, *R*. The *Rpt* can be introduced in the description only as a representational device to point out the fact that tense has a referring property.

In the textual domains of complex sentences and discourse sequence, tense has a double function: on the one hand, it locates the eventualities on the time axis, and, on the other hand, it provides the reader/listener with a set of cues, sometimes necessary and sufficient, to order eventualities, i.e. to reconstruct their proper temporal order. To perform such a complex task, we need to introduce, next to the *Rpt*, a further concept which we will call *textual temporal anchor* (Bertinetto, 1986), and represents it with an A. A is not a new entity[20], but it is a technical device which is required to account for the behavior of

[18]The same notation has been proposed for the first time by Kamp & Reyle (1993).

[19]By textual domain of occurrence we refer to the type of linguistic context a sentence or a clause may appear in. We identified three types of textual domain of occurrence: sentence in isolation, complex sentences (i.e. main clause plus embedded clause) and discourse sequence. We are particularly indebt to Smith (2004) for this distinction.

[20]*Entia non sunt multiplicanda praeter necessitatem.*

the tense forms in textual environments other than sentences in isolation. The presence of the A gives rise to further relations, in particular: a relation between the Rpt and the A and a relation between Rpt and the deictic centers, S and R. The first relation, that between the Rpt and the A, represents what we call the *textual interpretation of tense*, while the second relation expresses the relation between the specific referred time where the eventuality occurred (Rpt) and the deictic centers. Being a parameter, the A needs to be set and offers a method to account for the role of tense in computing the temporal ordering of eventualities. The relationship of the A with the reference point, Rpt, is dependent on the textual domain of occurrence of the tensed eventuality and its position (being in the first sentence, or in a dependent clause or in a subsequent main sentence). The default value of the A is always the main deictic center, S. To illustrate the functioning of the A, consider the following examples:

(3.49) Marco ha detto che Giovanni non verrà. [complex sentence domain]
Marco said that Giovanni won't come.

(3.50) Marco entrò nel bar. Indossava un abito scuro. [text/discourse domain]
Marco entered a bar. He was wearing a dark suit.

In example 3.49 we are facing an instance of a complex sentence textual domain formed by a main clause (e_1) plus an embedded clause (e_2). The basic temporal meaning associated with the verb forms involved is the same we have illustrated in Table 3.3 on the preceding page. In addition to this, we also explicit the relation between Rpt and E, which, as already stated, is always a simultaneous relation:

(i.) e_1: $(E_1 \prec S_{e_1}) \wedge (Rpt_1 \equiv E_1)$ [main clause]

(ii.) e_2: $(E_2 \succ S_{e_2}) \wedge (Rpt_2 \equiv E_2)$ [subordinated clause]

We introduce now the relation between the Rpts and the As (*textual interpretation of tense*) and that between the Rpts and the deictic centers, S. The final temporal relation between the main clause eventuality and that in the subordinated one can be expressed by the exploiting the A parameter, in particular by the conjunction of the relations between the reference point of the main clause eventuality and its A, Rpt_1 and A_1, and that between the subordinated clause eventuality and its A, Rpt_2 and A_2:

(ia.) e_1: $(Rpt_1 \prec S_{e_1}) \wedge (Rpt_1 \prec A_1)$ [main clause]

(iia.) e_2: $(Rpt_2 \succ S_{e_2}) \wedge (A_2 \prec Rpt_2)$ [subordinated clause]

Setting the various parameters and putting the representations in (ia.) and (iia.) into a unique formula, we will obtain:

(iii.) $(S_{e_1} = S_{e_2})\wedge$
$(A_1 = (S_{e_1})\wedge$
$(A_2 = Rpt_1)$

(iiia.) $[((E_1 \prec S_{e_1}) \wedge (Rpt_1 \equiv E_1) \wedge (Rpt_1 \prec S_{e_1})) \wedge ((E_2 \succ S_{e_1}) \wedge (Rpt_2 \equiv E_2) \wedge (Rpt_1 \prec Rpt_2))]$

from which the following temporal relation can be obtained:

(iiib.) $(Rpt_1 \prec S_{e_1}) \wedge (Rpt_1 \prec Rpt_2)$

which corresponds to the temporal relations between the two eventualities, i.e. $E_1 \prec E_2$.

Tense's interpretation in example 3.50, text/discourse domain, is very similar to the one we have seen in example 3.49. Thus, tense information linked to the two eventualities will provide us with the following information and set of relations:

(iv.) $[(E_1 \prec S_{e_1}) \wedge (Rpt_1 \equiv E_1) \wedge (Rpt_1 \prec S_{e_1}) \wedge (Rpt_1 \prec A_1)] \wedge$ [first sentence]
$[(E_2 \prec S_{e_2}) \wedge (Rpt_2 \equiv E_2) \wedge (Rpt_2 \prec S_{e_2}) \wedge (Rpt_2 \equiv A_2)]$ [second sentence]

setting the parameters we will obtain:

(iv.a) $(S_{e_1} = S_{e_2}) \wedge$
$(A_1 = (S_{e_1}) \wedge$
$(A_2 = Rpt_1)$
$\longrightarrow (Rpt_1 \prec S_{e_1}) \wedge (Rpt_2 \equiv Rpt_1)$

Some observations are compulsory to explain how the mechanism illustrated works. First, it is important to point out that in complex sentences like in 3.49 the relations between *Rpt* and A differ consistently according to the type of clause we are analyzing, in particular: in the main clause the relation is always (*Rpt relative A*), while in the embedded one we claim that the relation is a different one, i.e. (*A relative Rpt*). This shift in relation represents the way embedded clauses are to be interpreted temporally. On the other hand, the textual domain of text/discourse requires a different kind of interpretation, namely that for every eventuality the relation between *Rpt* and A is always (*Rpt relative A*), independently of the order of presentation of the sentences forming the text/discourse sequence. As a consequence, in the text/discourse domain A may remain underspecified for lack of adequate context for its setting and maintaing the default value for every tensed eventuality. Finally, from these examples it could be inferred that tense, interpreted as we have exposed, always provides all the necessary and sufficient cues for the ordering of eventualities. However, this is not true. Tense provides with a set of cues which, according to the textual domain of occurrence and the type of temporal sequences involved, sometimes may be necessary and sufficient, while sometimes just necessary. As an example of this second case consider again the example 3.50. The fact that we have identified a simultaneous relation between Rpt_2 and Rpt_1 does not represent the correct temporal order between the two eventualities, which can be assessed only with the contribution of other types of information like aspect and the lexical aspect associated with the eventualities. This observation lead us to formulate a claim and one hypothesis on the role of tense as a device for recovering the temporal order of eventualities:

Claim 1 (tense as necessary and sufficient) : tense is a necessary and sufficient device to retrieve the temporal order of events when it occurs in sentence in isolation and in complex sentences like the one illustrated in 3.49.

Hypothesis 1 (tense in text/discourse domain) in a text/discourse, tense may be a necessary and sufficient element for reconstructing the order of eventualities in a restricted set of cases, in particular when there is a deep shift in the temporal meaning of the different tense forms, i.e. when it is possible to set a value for A in a principled way and which does not correspond to the default. On the other hand, sequences of tenses with the same forms, i.e. meaning, keep the value of A set on the default, and the temporal order of the eventualities involved is not based on tense information, but on the type of aspect (grammatical and lexical) and contextual, pragmatic information.

Confirmation of Hypothesis 1 will be accomplished as part of the elaboration of the computational model together with the description of the mechanisms to set the A according to the textual domain. In Table 3.4 on the next page we present the complete set of relations which may hold between *Rpt*, *A* and the deictic centers for each tense form[21]:

Table 3.4: *Relations between Rpt, R, S and A.*

Tense	**Relations**
Presente: $(E \equiv S) \wedge (Rpt \equiv E)$	$(Rpt \equiv A) \wedge (A \equiv S)$
Passato Semplice: $(E \prec S) \wedge (Rpt \equiv E)$	$(Rpt \prec A) \wedge (A \prec S)$
Passato Composto: $(E \prec S) \wedge (Rpt \equiv E)$	$(Rpt \prec A) \wedge (A \prec S)$
Imperfetto: $(E \prec S) \wedge (Rpt \equiv E)$	$(Rpt \equiv A) \wedge (A \prec S)$
Trapassato I & II: $((E \prec R) \bullet (R \prec S)) \wedge (Rpt \equiv E)$	$[(Rpt \prec A) \wedge (R \equiv A)] \wedge (A \prec S)]$
Futuro Semplice: $((E \succ S) \wedge (Rpt \equiv E))$	$(Rpt \succ A) \wedge (A \succ S)$
Futuro Composto: $((E \prec R) \bullet (R \succ S)) \wedge (Rpt \equiv E)$	$[(Rpt \prec A) \wedge (R \equiv A)] \wedge (A \succ S)]$
Futuro nel Passato: $((E \succ R) \bullet (R \prec S)) \wedge (Rpt \equiv E)$	$[(Rpt \succ A) \wedge (R \equiv A)] \wedge (A \prec S)]$

3.3.2.2 Aspect: viewpoints and lexical aspect

The starting point of our analysis of Italian aspect and its contribution to the determination of temporal relations stems from the work by Smith (1997). She introduces a two-component theory of aspect based on a cross-linguistic investigation of five different languages, namely English, French, Russian, (Mandarin) Chinese and Navajo. This two-level approach provides an explanation for the difference between the two types of aspectual information which is understood as a view on the type of eventuality (viewpoint or grammatical aspect) and as expressed by the temporal properties/features of the eventuality itself (lexical aspect, *Aktionsaart*, or actionality). The former can be gained by applying a certain viewpoint chosen by the speaker and it is a property of the whole sentence, while the latter is obtained by exploiting the information obtained in the lexical entry stored in an event denoting lexeme. The following sections provide the reader with a critical description of these two elements composing the aspectual system in Italian and their role/influence for temporal relations.

Aspectual Viewpoints: visibility and quantification Aspectual viewpoint is, as tense, a grammatical category. However, with respect to tense, the viewpoint aspect is a non-deictic category and it has nothing to do, in its basic or primary meaning, with issues of temporal location or ordering of events. Viewpoint aspect is responsible for making explicit specific semantic values of the tense forms with respect to the different ways of viewing the temporal constituency of a situation, i.e. the speaker's view of the eventuality. To clarify this notion consider the lens of a camera. Their role is that of visualizing objects to make them available for pictures. In a comparable way, aspectual viewpoint is responsible for making visible the eventuality described in the sentence.

In Italian, the aspectual viewpoint is normally encoded by the same verb morphemes which codify tense. Notice that with respect to other languages, like English for instance, we claim that the relationship between verbal morphemes and aspectual values is not isomorphic, i.e. a verb morpheme may specify more than one aspectual value, due to

[21]Notice that when A is equal to S, all the relation between A and S are no more valid since the two elements are the same. This means that it is not possible to obtain from relations like $(A \equiv S)$ or $(A \prec S)$ contradictory statements like $(S \equiv S)$ or $(S \prec S)$

the influence of co-textual elements or to the type of discourse sequence/unit the tensed eventuality occurs in. As for tense, aspectual viewpoint applies to the sentence domain. All sentences have a viewpoint since the eventuality type information is not visible without one. It is interesting to point out a default pattern of interpretation which connects tense and viewpoint, which can be stated as follows:

- unbounded, i.e. open or semi-open, eventualities are located in the present;
- bounded, i.e. closed, eventualities are located in non-present tenses.

As we will see in the development of this section, these defaults can be overridden.

The information conveyed by the viewpoint constitutes part of the semantic meaning of an eventuality: viewpoint spans all or part of an eventuality, or better of the associated temporal schema of an eventuality, as we presented in chapter 2, section 2.3.3.1. An important issue which is sometimes misinterpreted in literature is the fact that the viewpoint is independent of the lexical aspect[22]. Although the information viewpoint presents is affected and limited by lexical aspect these two notions must be stated independently one of each other. We will claim that viewpoint has two levels of interpretations: a strictly semantic, or positive one, and a pragmatic, or inferred one.

Usually, the basic semantic meaning of viewpoint has been associated with the **visibility** of an eventuality. Only what is visible is asserted. It is this type of information which is available to the receiver for truth conditional statements and entailments and which provide indirect information on the temporal localization of eventualities. Thus, as a long tradition in literature has pointed out, the main semantic difference among viewpoints is in how much of the temporal schema of an eventuality they make visible. Following Bertinetto (1986) the viewpoint system of Italian can be described on the basic opposition between Perfective and Imperfective. To illustrate this opposition consider the following sentences:

(3.51) Marco attraversava la strada.
Marco was crossing the road.

(3.52) Marco ha attraversato la strada.
Marco crossed/has crossed the road.

The difference between the two sentences is not expressed by tense, since the events are both located in the Past, but, as we have already stated, concerns their visibility. In particular, in example 3.51 the event is presented as only partially visible, while in 3.52 it is the entire temporal span of the event, i.e. the event as a whole, which is described. In a more formal way, we can describe this difference by stating that, generally, an eventuality with the perfective viewpoint corresponds to a closed interval, i.e. both its beginning and end points are visible and part of the eventuality itself, while the imperfective viewpoint gives rise to open intervals. This means that the beginning and end points are not visible. In other words, what is visible with the imperfective viewpoint is just a part of the eventuality. Schematically, the eventualities in the two examples can be represented as follows, where the slashes correspond to the visible extent of the eventuality, and b and e are the beginning and end points, respectively:

(3.51a) b e
//////

[22] For a comprehensive revision on this issue see Bertinetto (1997).

(3.52a) *b..* *..e*
/////

Each viewpoint may specify more fine grained values. For instance, the progressive is a specification of the general imperfective value and similarly the perfect for the perfective. In addition to verb morphemes, aspectual viewpoint can be signaled also by what are called *lexical viewpoint morphemes* and aspectual periphrases. The first refers to an entire set of lexical items, such as *iniziare* [begin], *continuare* [continue/keep/go on], *finire* [finish] and many others, whose function is that of presenting a narrow view on a phase of the eventuality[23]. Thus, *iniziare* [begin] will narrow the view on the beginning point of the eventuality while *continuare* [continue/keep/go on] will focus on the internal stages of it. Their presence is a way of explicitly stating some "marked" readings of the general viewpoints like the ingressive viewpoint or the continuous. The second refers to a strategy of the Italian language which makes use of a free morpheme (called modifying verb) which carries temporal (i.e. tense) and viewpoint information, followed by a main verb inflected to one of the non-finite tense forms (i.e. gerund, infinitive or participle). These elements supply for the lack of inflected paradigms for some viewpoint values or explicit means of coding viewpoint values which normally are inferred from the context. Some of the most known instances are $stare + gerund_{MainVerb}$, for the progressive, or $andare/venire + gerund_{MainVerb}$ for the continuous.

The analysis of viewpoint aspect that we will present in this section follows only in part Smith (1997)'s seminal work. With respect to the original proposal of the author, we maintain the parameter of the visibility of the beginning and end points of the temporal schema of each eventuality as a good device for determining the semantic values but we introduce a further parameter which, in our opinion, is pivotal for the description of this sub-system of natural language, that is the parameter of quantificational information. Thus, in our perspective, the basic semantics of viewpoint is two-folded: it expresses the visibility of the beginning and end points of the temporal schema associated with the eventuality and, at the same time, it provides information on the quantificational interpretation which applies over the eventuality itself. Such an analysis of viewpoint is extremely useful since, on the one hand, is able to overcome some limits of Smith's proposal and, on the other hand, it introduces two major novelties, as Bonomi (1997a) points out, that is (i) the fact that different aspectual forms are explicitly connected with different types of quantification over eventualities, and (ii) that these quantificational properties of aspectual forms help to explain the nature of temporal relations between eventualities.

Another point of dissimilarity with Smith (1997) is the refusal of the neutral viewpoint as one of the basic values. The refusal of this value is based on the contradictory arguments the author introduces for its justification. One of the key element of Smith (1997)'s work is based on an assumption of a (quasi) perfect isomorphism between verb morphemes and viewpoint values. In her study of the French data she claims that two tenses, namely the simple future and the present, are aspectually zero-marked and they render the sentences aspectually ambiguous ruling out the application of the "classical" aspectual values. What distinguishes the neutral viewpoint, according to her proposal, is the fact that its basic semantic is undetermined for the imperfective or the perfective readings, which are licensed by inferencing mechanisms based on co-textual and con-textual information. In support to this argument, she presents a set of semantic tests, such as the co-occurrence of simple future and present in *when*-clauses which present the availability of imperfective or perfective readings, or the use of the present in sports reports or

[23]These types of lexical viewpoint morphemes are also known as phasal periphrases (Bertinetto, 1991)

similar text/discourse types which telescope time and have a perfective value, or the fact that performative verbs at present tense allow only a perfective reading. So far so good, or at least it seems. When analyzing the *imparfait*, which in her framework is always associated with the imperfective viewpoint, the author is forced to introduce the notion of "conventions of use" to explain some perfective readings of this tense. In our opinion, the notion of "conventions of use" is a contradiction in her framework and one of the first argument against the necessity of the neutral viewpoint. In fact, if we consider the perfective readings of present tense, all the cases that Smith points out, with the exception of *when*-clauses, are instances which can be associated to "conventions of use" of the present tense in a way very similar to the those that she introduces for the *imparfait*. This different treatment of the same phenomenon is hardly acceptable and linked to an idealistic analysis which is based on isomorphic, i.e. one-to one, relations between morphemes and viewpoint values. If we abandon such a point of view, nothing prevents us by claiming that the basic viewpoint meaning of the present is the imperfective, and that in appropriate contexts this value may be shifted to the perfective. These cases represent instances of "conventions of use". Thus, no neutral viewpoint is necessary.

Her analysis of *when*-clauses is debatable as well. Smith claims that in *when*-clauses French future tense may have a double reading:

(3.53) Jean chantera quand Marie entrera dans le bureau.
Jean will sing^{Fut} *when Marie will enter*^{Fut} *the office.*

The main clause may have either an imperfective (progressive) reading, that is that Jean will already be singing when Marie enters, or a perfective one (inceptive, i.e. a closed reading on the beginning point of the first eventuality), that is that Jean will start to sing at the time of Marie's entrance. She claims that this range of interpretation is not available for the "pure" perfective and imperfective and it is due to context influence and not part of the so called "conventions of use". She identifies a similar behavior also for the present tense:

(3.54) Marie sourit toujours quand Paul arrive à la maison.
Marie always smiles^{Pres} *when Paul gets*^{Pres} *home.*

Her comment on example 3.54 is "[t]he closed [i.e. perfective] reading is not only possible, but more natural than the open [i.e. imperfective] one'. This shows that the viewpoint of of the *Présent* is not imperfective." [Smith (1997): 201].

We are not going to argue for the availability of these readings for future and present tenses, but, on the contrary, we argue against the parallelism between these two tenses. In particular, we are going to show that her analysis does not take into account some semantic properties of the future tense, which allows us to explain such a double reading without making to much reliance on the context (or, in our terms, the con-text) but as a part of the "conventions of use". Moreover, we claim that her analysis of the perfective readings of present tense *when*-clauses is based on a bias on the status of habitual sentences, which, in our opinion, is a direct consequence of her restricted analysis of viewpoint semantics which excludes the contribution of the quantificational information.

As for the future tense, we can observe that Smith seems not to take into account a fundamental property of this tense form that is the fact that it may refer to possible, or probable, courses of events or validity of situations, i.e. it may have a modal value. Usually, the future is analyzed as the counterpart of the past and in terms of basic temporal semantics it refers to the fact that an actual E is to be located in a time which is successive to its S. All perfective readings of the future tense are made under the assumption that what counts is the occurrence in the future of the eventuality at issue, without taking into account alternative courses of events. What the speaker have in mind with the perfective reading of the future is only the **actual** course of the eventuality. On the contrary, we claim that the imperfective readings of the future tense actualize the modal values of this tense. In particular, when the imperfective reading is available the speaker does not only want to state the fact that an eventuality will occur in the future, i.e. in a time posterior to S, but also that the current state of affairs i.e. external, contextual elements, of which he is aware of, plays an essential role in the possible course of eventuality. Under this analysis the imperfective readings of the future may be associated with the expression of epistemicity, i.e. of the probability that a certain course of events will take place or hold. Since in Italian, the future tense is considered as a sort of grammatical device to code epistemicity and the quantificational information of the general imperfective is that of expressing modal quantification (i.e. quantification over eventualities and possible worlds), we consider these imperfective readings of the future tense as "conventions of use" for expressing epistemicity. The fact that a future sentence, out of a discourse/texts context, usually allows such an viewpoint ambiguity is a consequence of the fact that the future tense represents an instance of the grammaticalization of epistemicity. Thus, it is not the context *per sé*, as Smith claims, that specifies the viewpoint value of the future tense, but, on the contrary, it is the use in context of this form, in a way which can be compared to the perfective readings of the *imparfait* or of the present tense. The imperfective readings of the future are thus to be interpreted as shifted values due to "conventions of use".

As far the present tense is concerned, we have already argued for the fact that some of the examples Smith reports to justify the neutral viewpoint can be explained under the label of the "conventions of use" as well. However, this explanation cannot be used to account for her treatment of present tensed *when*-clauses. We claim that her analysis of sentences like 3.54 is based on a bias on the status of the habitual viewpoint. According to Smith this value should be considered as a "marked" reading of the perfective viewpoint. This statement is hardly acceptable. All grammars describes the habitual viewpoint as a reading of the imperfective, since it codes the indeterminate representation of a pattern of eventualities. To overcome Smith's arguments we need to make use of the quantificational information related to the viewpoint. We have already stated that the imperfective viewpoint has an added intensional/modal value. The natural interpretation of example 3.54 is that there is a systematic connection in the present between two eventualities. In terms of truth conditions, this sentence calls for a universal quantification which is intended to characterize an extended interval I by referring to the fact that there is a present period of time, made salient by the context, C, in which every time that Paul gets home (e), Marie smiles ($e^{'}$). The correct logic representation is the following (adapted from Bonomi (1997b,a, 1998b):

(3.55) $\forall e([C(e) \wedge paul - get - home(e)] \longrightarrow$
$[\exists e^{'}(marie - smile(e^{'}) \wedge (e \equiv e^{'})$

In addition to his, the habitual viewpoint has the well known property of introducing an eventuality type shift. To account for this property, we introduce here a suggestion by Chierchia (1995) that the whole implication can be rendered as a complex state, S, whose function is that of denoting Marie's habit of smiling when Paul gets home. Thus, we reformulate statement 3.55 as follows:

(3.56) $\exists S(\forall e([C(e) \wedge paul - get - home(e)] \longrightarrow$
$[\exists e^{'}(marie - smile(e^{'}) \wedge (e \equiv e^{'}))$

Under this perspective we are able to correctly account for the habitual aspect and to show that the proposal of Smith is incorrect, since the habitual is a specialized reading of the general imperfective viewpoint. In terms of visibility of beginning and end points we have to refer to the complex state S which is associated with the pattern of eventualities and not to the single instances of the eventualities which compose it. Smith's account is right on this point: in fact, if we consider, in terms of visibility, only the instances of the eventualities composing the pattern, they are clearly perfective, that is closed intervals, but the entire pattern is open with respect to its temporal dimension. Without taking into account the quantificational dimension of meaning of the viewpoint, this pivotal remark is lost and as a consequence incorrect analysis of temporal relations may be generated.

After this long digression, which we consider fundamental, we can present our analysis of viewpoint aspect. For clarity's sake and to avoid repetitions, we will present in Table 3.5 on page 72 the types of viewpoint in Italian, their associated temporal schema in terms of visibility of beginning and end points and their quantificational meaning. As a final remark on the relationship between viewpoint and tenses we state that there is generic tendency according to which to each tense form corresponds a "default" viewpoint value. However, as we have pointed out above, these tendencies may be overridden due to what we have called the conventions of use of a specific tense form in a particular discourse/text unit or segment which imposes a shift of the original value.

Finally, we are now in a position to state what is the role of viewpoint in terms of its contribution to the identification of temporal relations. Viewpoint has an indirect role respect to tense for locating eventualities in time or ordering them. In addition to this, the basic semantic of viewpoint concerns visibility of beginning and end point of the temporal schema associated with the eventualities and quantificational information on the asserted, or visible, portion of them. Thus, it provides the reader with a set of **indirect** information for the correct analysis of temporal relations. Formally, we claim that viewpoint introduces in the text/discourse an interval I, which represents the locus of the viewpoint information. I is always located at the moment of event, E. In addition, we claim that I instantiates a relation with Rpt, which can be either of inclusion, $\subseteq$, in case of the perfective viewpoint, or of overlapping, $\circ$, in case of the imperfective. I is a temporal entity which may have unique beginning and end points, t_1 and t_2 respectively (chapter 2, section 2.3.2). The presence or absence of these points is strictly related to the type of viewpoint. Recalling example 3.50 and its analysis of tense, represented here in 3.57, we will show the contribution of aspectual viewpoint semantics for temporal relations:

(3.57) Marco entrò nel bar. Indossava un abito scuro. [text/discourse domain]
Marco entered a bar. He was wearing a dark suit.
$(Rpt_1 \prec S_1) \wedge (Rpt_2 \equiv Rpt_1)$ [tense interpretation]
$Perf(I)[\exists I_1 \exists e((enter - the - bar - Marco(e)) \wedge (Rpt_1 \subseteq I_1) \wedge (t_1 \leq I_1 \leq t_2))] \wedge$
$Imperf(I)[\exists I_2(\forall J(C(e) \wedge J \subseteq I_2) \longrightarrow$
$\exists e(wear - jacket - Marco(e)) \wedge (Rpt_2 \circ I_2) \wedge (t_3 \prec I_2 \prec t_4)]$ [aspectual viewpoint semantics]
$((Rpt_1 \subseteq I_1) \prec S_1) \wedge ((Rpt_2 \circ I_2) \equiv (Rpt_1 \subseteq I_1)) \wedge (I_1\ TR\ I_2)$ [compositional analysis]

According to our perspective, the contribution of the viewpoint aspect is two-folded: on the one hand, it states what is the relationship between Rpt and I and points out the visibility of beginning and end points, and, on the other hand, it provides us with quantificational information of I over the eventualities. In addition to this, we claim that when integrating temporal semantics and viewpoint information, we give rise to a further relation, TR, which is a relation between the Is of each involved eventuality[24]. Such a relation does not help us very much in determining what is the actual temporal relation between the two eventualities. Nevertheless, recalling the functions α and ω and the constraints on open and semi-open intervals[25] (chapter 2, section 2.3.3) we can identify a set of possible temporal relations corresponding to Allen (1983)'s interval relations. The only narrowing of the values which can be stated is provided by the order in which the two eventualities are presented, avoiding the presence of inverse relations. As far as example 3.57 is concerned, provided the analysis of relations between intervals and their beginning and end points (see chapter 2, section 2.3.2.2), the order of the eventualities, that is bounded first, unbounded after, and the semantics of the viewpoint values, a set of seven possible temporal relations may hold between the two eventualities, namely, (I_1 eq, b, m, s, d, o, f I_2). Without the knowledge of the type of eventualities involved and further inferencing based on world knowledge, the temporal relation between the two eventualities is still undetermined.

Lexical aspect: the realization of the ontological eventuality types Lexical aspect, or actionality, is not, *strictu sensu*, a grammatical category like tense or viewpoint. Lexical aspect belongs to lexicon and it represents the intrinsic temporal structure associated with eventualities. From our perspective, lexical aspect represents the empirical support to the ontological distinctions we have introduced in chapter 2, section 2.3.1 on eventualities. Commonly, lexical aspect is associated with verbs since the range of linguistic tests elaborated so far in literature are based on syntactic criteria in the aim of identifying homogeneous classes. In fact, as Moens (1987) points out, what is needed as a starting point in an aspectual classification of *verbs* are tests based on co-occurrence possibilities of the verb with certain adverbial expressions or with the progressive and perfect viewpoint. However we want to depart from this perspective, and we claim that lexical aspect applies to all eventualities, independently of their realization. This means that non-deverbal eventive nouns, like *assemblea* [meeting], can be associated with a lexical aspect. However, the behavior of verbal eventualities and pure, i.e. non-deverbal, nominal ones is somehow different. In fact, if for verbs it is possible to postulate a basic lexical aspect value, we predict for pure nominals a major variability. From a certain point of view, we could state that pure nominals seem to have an underspecified, or neutral, aspectual value which gets specialized in a compositional way in the context and influenced by the temporal properties of the verb which elicits the eventive reading of the nominals[26].

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[24]Note that in the case of a temporal relations between an eventuality and a temporal expression, which do not have a viewpoint, we claim that this relation holds between I and the temporal interval/point of the temporal expression, and is always a relation of inclusion of I in the time interval/instant denoted by the temporal expression.

[25]From a mathematical point of view, the relation between an open and a closed interval cannot be determined. Having postulated the existence of the functions α and ω allows us to relax some well-known principles which are valid for maths. In this way, all types of intervals are always proper intervals allowing the computation of temporal relations even between an open and a closed interval.

[26]As a paradigmatic example of the behavior of pure nominal eventualities consider these examples with the noun *assemblea* [meeting]:

(i) L'assemblea è durata 3 ore.
The meeting lasted for three hours.

(ii) L'assemblea si è conclusa in 3 ore.
The meeting finished in 3 hours.

(iii) L'assemblea è finita alle 3.

The distinctions of the temporal properties which compose the various eventuality types have been illustrated and discussed in chapter, 2. With respect to that analysis, in this section we want to point out Smith's compositional framework for the identification of the "final" value of the eventuality types, some linguistic features associated with them and their role for the identification of temporal relations.

The key feature of Smith's framework is its high compositionality. We postulate that the lexicon provides all the relevant information, which combined together by means of a set of rules, participate in the assessment of the actual eventuality type value, i.e. its lexical aspect. The starting point for the success of such approach is represented by the identification of the default actionality value of a sentence. Such a value can be retrieved by taking into account what Smith calls the minimal verb constellation of a sentence (in her terms the "maximally simple sentence"): the verb and its basic argument structure. This represents the *locus* for the identification of the intrinsic temporal/actionality properties, which allows the correspondence of that linguistic realization into one of the five ideal eventuality types presented in the the ontology. The identification of this basic value is accomplished through a series of syntactic tests, which check for the acceptability (i.e. grammaticality) of that basic verb constellation with adverbial modification, mainly temporal adverbs (i.e. temporal expressions of the form SIGNAL + TEMPORAL EXPRESSION), and also with viewpoint values. The use of these devices is due to the fact that eventualities occur in time, i.e. they individuate a temporal interval in which something happens or holds. The temporal properties of an eventuality "indicate how the situation [eventuality] unfolds in time, and can be elucidated as a situation [eventuality] occurs over time." [Smith (1997): 124]. The grammaticality of a verb constellation with an aspectual viewpoint value or an adverb is strictly linked to a compatibility between the intrinsic temporal features of the eventuality and those which are made explicit by the "testing" devices. Thus for instance, an activity, which is a durative, atelic event, is not compatible, i.e. ungrammatical, with a temporal adverb realized by "IN + DURATION", which expresses a telic value, that is the time after which the culmination point of the event has been reached. Once the basic actionality value is assigned a set of rules which take into account the co-textual elements of the sentence applies. These rules have the function of computing the actual eventuality type, which may remain unchanged or shifted. An important device which characterize rules' application is the distinction between internal eventuality type shift triggers, like viewpoint values, and external ones, like adverbial modification, type of NPs or PPs.... As an example of how these rules work consider this sentence:

(3.58) Marco dipingeva un quadro.

Marco was painting a picture.

basic actionality value: $V^{[+telic][+durative]} \longrightarrow$ e_type: ACCOMPLISHMENT; basic interval repr.: $[i_1, i_2]i_3[\equiv \{i|i_1 \prec i \prec i_2\}$
$\wedge \{i|i_2 \prec i \prec i_3\}$

sentence structure: [[NP_Subj$_{count.}$] [Tense= Imperf.; Viewpoint=

The meeting ended at 3.

In example (i), the presence of a durative verb (*è durata* [lasted]) and of temporal expression expressing a duration (*3 ore* [3 hours]), assign lexical aspect to the event *assemblea* as **activity**; in a similar way the same value is assigned in (iii), with the verb *finire* [end], which has not a telic value. On the contrary, in (ii) the present of a telic verb like *concludere* [finish], together with a temporal expression introduced by the signal *in*, provides the noun with a telic value, as if after 3 hours the meeting has reached its natural ending point, assigning lexical aspect of achievement. However these are only intuitions, major research is needed and actually out of the scope of this thesis, although intimately connected.

Imperfective_Progr. $V^{[+telic][+durative]}$ [NP_D.Obj$_{count}$]]]

Compositional Rule a.): **If** [+ telic] *and* progressive viewpoint, **then** shift to [-telic].

actual actionality value after Rule a.): $V^{[-telic][+durative]} \longrightarrow$ e_type: ACTIVITY;
basic interval repr.: $[i_1, i_2] \equiv \{i | i_1 \prec i \prec i_2\}$

As it has been shown, the so called Rule a.) predicts that a telic verb is incompatible with a progressive or imperfective viewpoint, which, due to its temporal features, coerces a shift in the eventuality type (e_type) to have the feature [- telic]. Thus, the new eventuality type of sentence 3.58 has actionality value [- telic] [+ durative], which corresponds to the temporal properties of activity events. In case the sentence in 3.58 were part of text/discourse, the temporal relations should have been computed between this new eventuality type and the other eventualities.

A fundamental issue which has not been pointed out in the ontology, but which must be explicited to account for the role of lexical aspect in temporal analysis of text/discourse, is the description of a stage-by-stage development of the five eventuality types. We have already assumed that eventualities occur in a temporal interval, which can be identified with the I introduced to describe viewpoint aspect. We claim that such a description is extremely useful in the development of our computational model since it will provide a set of parameters which combined with the properties of viewpoint aspect can be formalized and implemented, thus facilitating reasoning mechanisms:

Definition 23 (temporal development of activities) : Activities occur at interval I, with the condition that for every instants $i_j ... i_n$ included in I, the event does not obtain at i_{j-1}; i_j is the beginning point; it obtains at i_{j+1}; and i_n following i_j, is the **arbitrary** end point; and at i_{n+1} the event does not hold;

Definition 24 (temporal development of accomplishments) : Acccomplishments occur at interval I, with the condition that for some $i_j ... i_n$ included in I, the event does not obtain at i_{j-1}; i_j is the beginning point; at i_{j+1} the internal stages of the event develop; and i_n following i_j, is the **natural** end point; at i_{n+1} the resultant (contingent) state of the event holds and the event does not obtain;

Definition 25 (temporal development of semelfactives) : Semelfactives occur at interval I, with the condition that for some i_j included in I, the event obtains; at i_{j-1} and at i_{j+1} the event does not obtain;

Definition 26 (temporal development of achievements) : Achievements obtains at interval I, with the condition that for some i_j included in I the culmination point obtains; at i_{j-1} and i_{j+1} the event does not obtain; and at i_{n+1} the resultant (contingent) state of the event holds

Definition 27 (temporal development of states) : States hold at interval I, with the condition that for every $i_j ... i_n$ included in I, the state does not hold at the beginning point i_j and at the end point i_n following i_j; it holds at i_{j+1}.

It is important to point out that the temporal developments illustrated in **Definition 24 - 27** represent a sort of idealized behavior. The influence of the viewpoint is fundamental. Once the actual, i.e. in sentence, actionality of an eventuality has been determined, the portion of the eventuality which is focused by a viewpoint inherits all the temporal properties of that eventuality type. This observation can be stated as a general principle of preservation of the actionality type properties (Smith, 1997) which can be enunciated as follows:

Principle of preservation of actionality type properties : Viewpoint is located at I; with the condition that the focused portion of the eventuality ε preserves all the actional/temporal properties of ε.

For instance, the default actionality of the verb *dipingere* [to paint] is an accomplishment. In the example 3.58 the actual actionality value is that of an activity. According to the principle of preservation of the actionality type, the focused portion of the event by the viewpoint has all the actionality property of activities (**Definition 23**) and not of accomplishments (**Definition 24**).

As far as temporal relations are concerned, the role of lexical aspect seems to be that of narrowing the set of possible temporal relations. If we accept the on-line metaphor of discourse/text processing by humans, that is that a discourse/text is analyzed by our mind/brain in an incremental way, sentence by sentence, we can predict, knowing their actional/temporal properties, how many possible temporal relations may hold between two adjacent eventualities in two different sentences. Recalling example 3.57, we can now add the actionality values of the two eventualities:

(3.59) Marco entrò nel bar. Indossava un abito scuro.

Marco entered a bar. He was wearing a dark suit.

$((Rpt_1 \subseteq I_1) \prec S_1) \wedge ((Rpt_2 \circ I_2) \equiv (Rpt_1 \subseteq I_1)) \wedge (I_1 \ eq, b, m, s, d, o, f \ I_2)$ [tense and viewpoint]

$I_1 = Achievement^{[+telic][-durative]} \longrightarrow$

$[(\mathrm{i}_1 \leq I_1 \leq i_2) \wedge (i_3 \leq I_1^{'}) \wedge (\exists i((i \subseteq I_1) \wedge ((i_1 = i) \vee (i_2 = i) \wedge (i_2 \leq i \leq i_3))))]$

$I_2 = State \longrightarrow [(i_4 \leq I_2 \leq i_5 \wedge (\forall i((i \subseteq I_2) \wedge (i_1 \leq i \leq i_2)))]$

$((Rpt_1 \subseteq I_1) \prec S_1) \wedge ((Rpt_2 \circ I_2) \equiv (Rpt_1 \subseteq I_1)) \wedge (I_1 \ \mathbf{eq, b, m, s, f} \ I_2)$

As it appears from the analysis, taking into account the temporal properties of the two eventualities we have reduced the set of relations from seven to five. Unfortunately, even the contribution of lexical aspect is not sufficient, in this case, to state the temporal relation which holds between the event and the state. To assess this unique value between the two Is we need a further level of information, which takes into account the semantic and pragmatic (i.e. world/commonsense knowledge) that we, as humans, have about the events under examination.

3.4 The influence of discourse structure and text genre

Before concluding this chapter some remarks on the issue of discourse structure and the influence of text genre are compelling.

One of main innovation in the study of discourse semantics is represented by the identification of the fact that different discourse segments or units are connected one to the other by means of rhetorical relations. Rhetorical relations are part of a set of linguistic devices which contributes to the internal cohesion of a text/discourse. We are not going to explain in details the mechanisms which give rise to rhetorical relations nor even theories which use rhetorical relations as a strategy to reconstruct the temporal ordering of a text/discourse (Lascarides & Asher, 1993, among others), but we will outline what we consider a general principle on the rhetorical relations influence, or contribution, to the identification of temporal relations between events. Since discourse units have different functions, i.e. different rhetorical relation connections, they can provide a sort of accessibility hierarchy of the most probable temporal relations. For instance, if we have a two sentence discourse sequence where each sentence is an instance of a discourse unit, and they are connected by the rhetorical relation of *Narration*, then according to this accessibility hierarchy, we can state that the most probable relation is *before* and that the least probable is *during*. We claim that being aware of the discourse structure is a necessary condition for the correct computation of temporal relations, but it represents a secondary source of information with respect to the devices which we have presented in the previous sections.

The way eventualities are ordered in a text/discourse is also dependent on its genre. Even without presenting a deep analysis of the different text genres, intuitively we are able to state that the ordering of events in a novel is very different from that of a news article. Since this work is concerned with the temporal ordering of eventualities in news articles, we will describe some characteristics of this text genre. Following Bell (1999), newspaper articles exhibit a non-chronological order of description of eventualities. The temporal structure is dictated by the relevance of the news instead of by narrative norms. This means that, usually, the latest event in a chronological order is presented first. Consider this excerpt from an article of our corpus:

(3.60) Aveva 13 anni la ragazzina di origine tunisina travolta e uccisa da un'auto pirata giovedì sera ad Ardea, in località Tor San Lorenzo, sul litorale a sud di Roma. [...] [paragraph 1]
Batute Oueslati, questo il nome della tredicenne uccisa, giovedì sera, quando è stata travolta dall'auto pirata stava gettando l'immondizia. Erano circa le 21.30. [...] Batute Oueslati, detta dagli amici Pasma, era andata a svolgere la piccola incombenza domestica come tante altre volte e, a quanto si è appreso, la mamma era nelle vicinanze. [...] [paragraph 2]
..La famiglia della vittima è molto conosciuta a Tor San Lorenzo, dove vive da circa 30 anni, dopo che il padre era immigrato dalla Tunisia in Italia. [paragraph 3]
The young Tunisian girl, bumped and killed by a car on Thursday night in Ardea, Tor San Lorenzo, a small town on the coast south of Rome, was 13 years old. [...] Batute Oueslati, that was the name of the teenager killed, on Thursday night, was throwing the garbage when she was bumped by the car. It was 9.30 p.m. more or less. [...] Batute Oueslati, called by her friends Pasma, had gone to do this small homely job as usual, and , as far as it has been reported, her mother was in the neighborhood.
..The family of the victim is well-known in Tor San Lorenzo, where it has lived for 30 years, after the father emigrated from Tunisia to Italy.

The first event reported by the article is that the young girl had been bumped and killed by a car, then in later paragraph other background information, such as the fact she was performing a homely job, which precede the event of being killed by a car is presented. In addition, this small excerpt presents an examplification of the so-called "instalment method", that is that after having introduced the main event, other complementary information is added, like the fact that it was 9.30 p.m. and that her mother was in the neighborhood when the accident happened.

A further characteristics of news articles is the fact that they tend to follow the "inverted pyramid style", which means that all major points are presented in the first paragraph, or even in the headline, and then the article proceeds through decreasingly important information. In our excerpt, the third and final paragraph presents this pattern, providing information about the family of the victim.

The main reasons for employing this method is due to the fact that this type of text/discourse is extremely oriented on the reader/receiver and it aims at providing him/her with the most important points of a news story, so that s/he could be able to abandon the reading at any point but still knowing what happened. As it should appear from what we have stated so far the analysis of temporal relations of news article is not a trivial task. In Figure 3.2 we represent graphically, and adapting from Bell (1999)'s original picture, the structure that normally holds in a news text.

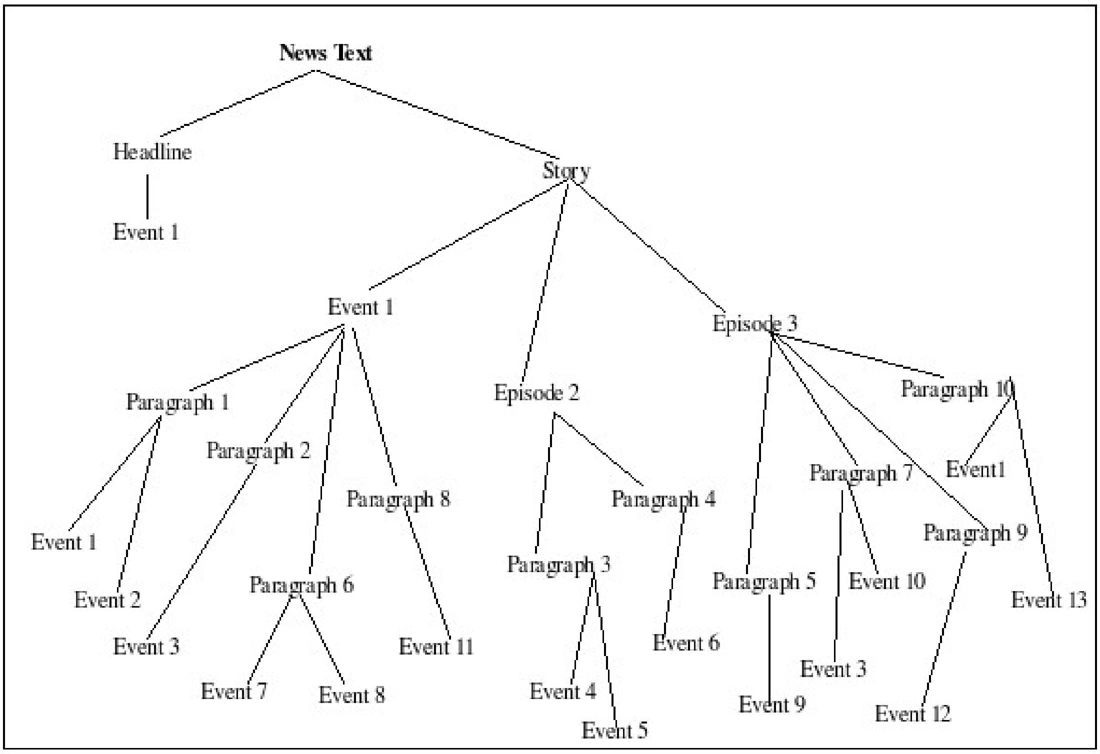

Figure 3.2: *Structure of a news article (adapted from Bell (1999).*

As it appears from Figure 3.2, a news article is clearly a well formed text, but what makes it peculiar with respect to other text types is the fact that inside a unique story, the different paragraph may "narrate" different episodes, which can be temporally disconnected with the previous ones. As a consequence of this type of textual organization we claim that the linguistic devices we have described in the previous sections have a sort of "scalar" or modular application. This means that inside a single episode they all have a major role, while in connecting one episode to the others what counts is the internal rhetorical structure of the text more than the tense, viewpoint and other devices. A further puzzling element in this picture is represented by the "leaking" of the various events composing a single episode along the entire article, thus scattering the information. This means that the bunch of events forming an homogeneous episode may be located in different paragraph and also in different points of the text itself in a discontinuous way. For instance, in a text made up by 10 paragraphs, we can identify 3 episodes structured as follows: Episode 1 = paragraphs 1;2;6;8 - Episode 2: paragraphs 3;4 - Episode 3: paragraphs 5;7;9;10. This internal structure of information has consequences also for its representation. As recent studies, namely Wolf & Gibson (2005), have demonstrated a descriptively adequate data structure for representing discourse structure as well as temporal relations is that of a graph (as in Figure 3.3 on the next page). Such a representation will be adopted as the output representation for temporal relations.

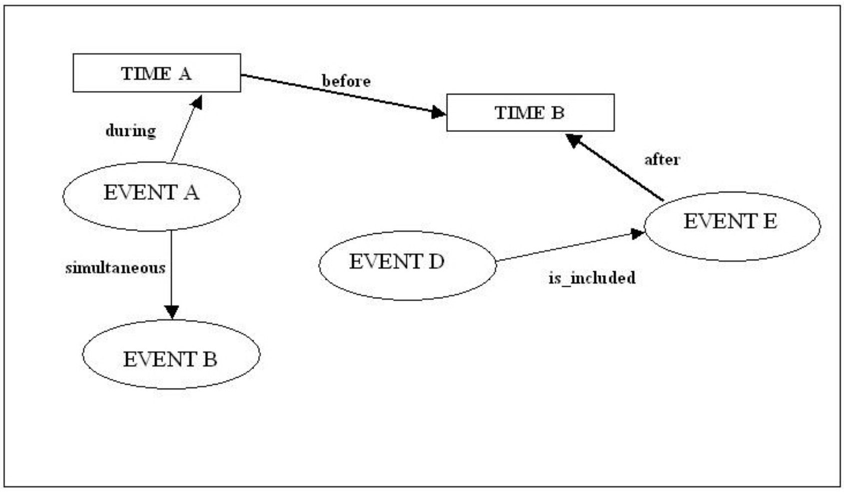

Figure 3.3: *Graph representation of temporal relations in discourse.*

3.5 Concluding remarks

In this chapter we have described how natural language conveys events, states, times and by means of which devices temporal relations are signalled and can be reconstructed. The descriptions we have provided are not totally exhaustive of the various phenomena. For instance, we have not treated the issue of atemporal sentences, that is sentences in which the temporal location of the eventuality cannot be stated, like for instance in 3.61:

(3.61) 2 + 2 fa 4.
2 + 2 equals 4.

Another issue linked to tense is the presence of non-finite verb forms like participles and gerunds. These tenses have locating properties but differentiate from absolute and absolute-relative tenses in that their deictic center is an R which is located inside the text and it not S. The phenomenon of aspectual information is also a bit more complicated than illustrated. In particular, as far as aspectual viewpoint is concerned in Italian the identification of the perfect aspect is quite puzzling. In fact, since the prototypical tense form with which this viewpoint value should be associated, i.e. the *passato composto*, has acquired also other aspectual value, like the aorist, its identification cannot be performed by taking into account only the verb morphemes but it requires also an analysis of the co-textual elements sourrounding it, like the presence of temporal signals and temporal expressions. A further element is represented by the so called lexical aspect hybridism, that is the fact that quite often the temporal properties of an eventualities are extremely fused together that it is very hard to state with a relative degree of certainty the actual aspectual value.

As it should have emerged from the various sections, the issue of re-constructing the temporal relations between eventualities is quite complex. This complexity derives from the cognitive nature itself of temporal relations which are based on inferencing mechanisms, which are constructed by exploiting and combining together linguistic and non linguistic, i.e. “pragmatic”, information. In Figure 3.4 on the facing page, we illustrate the different sources of information which contributes to the decoding of a temporal relation. The elements inside the boxes represent pure linguistic information, while those in the diamonds are the "pragmatic" information which includes commonsense knowledge of the event semantics, discourse structure and knowledge of the world:

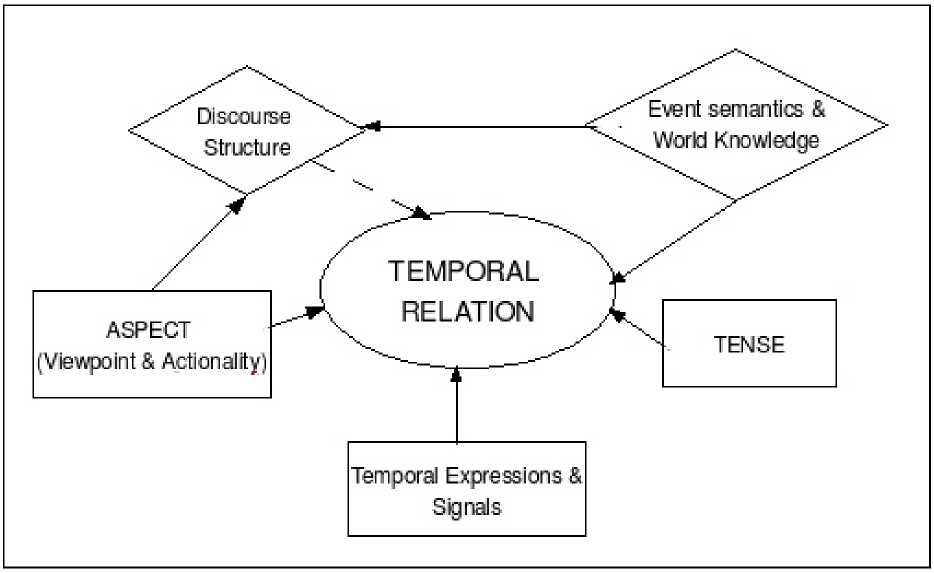

Figure 3.4: *The sources of information in action for decoding a temporal relation.*

A key issue which must be pointed out is the fact that temporal relations are a by-product of the text/discourse structure, as other phenomena, like bridgng anaphora. However, we do not agree with Lascarides & Asher (1993)'s proposal when they claim that temporal relations are the primary result of the computation of discourse structure. Of course, discourse structure can contribute to their identification but other purely linguistic device have a role which sometimes seems more relevant. As it appears in Figure 3.4, the dotted line from discourse structure to the temporal relation expresses this indirect influence of discourse structure.

We have also presented some characteristics of the newswire text genre, and tried to point out how the organization of the information in this genre has an influence on the application of the linguistic devices Italian has at disposal for coding temporal relations. Thus, in the development of the model it will be necessary to understand and formalize an order of application of the mechanisms and sources of information we have illustrated in Figure 3.4 to improve its robustness.

Table 3.5: *Viewpoint aspect values and semantics.*

Aspectual Value & Semantics	Quantifier	Default Tense Form
Progressive: it focuses on a single moment of the eventuality (*point of focus*), while it is happening. Beginning and end points of the eventuality are not visible, though the beginning point can be inferred. It is informationally open about its continuation. It shifts eventuality type to activities	$\forall$	Presente; Imperfetto
Habitual: it signals the (more or less) regular occurrence of an eventuality (under certain conditions). Every instance of the eventuality(-ies) involved presents visibility of both beginning and end point. It gives rise to a complex state, s, which corresponds to the regularity of the pattern of eventuality(ies).	$\forall$; *Gen*	Presente; Imperfetto; Trapassato I
Continuous: it does not identify a unique point of focus and it is undetermined both with respect to the number of times the eventuality is repeated and with respect to its possible continuation. beginning and end point are not visible, though the beginning point can be inferred. It shifts eventuality type to activities.	$\forall$	Presente; Imperfetto
Perfect: the eventuality is described as closed; beginning and end point are visible. In addition, it gives rise to a contingent state, s, independently from the eventuality type, which expresses the present state of affairs resulting from the prior eventuality, i.e. the eventuality is closed but its effects are still valid with respect to an established temporal anchor. Eventualities with this viewpoint introduces a further relation between Rpt and A, namely ($Rpt \equiv A$), to account for the "location" of the contingent state s.	$\exists$	Passato Composto; Trapassato I; Futuro Composto; Futuro nel Passato
Aorist: it presents the unique and single occurrence of the eventuality. The eventuality is perceived as closed, precisely determined from a temporal point of view. Its beginning and end points are visible to the receiver.	$\exists$	Passato Semplice; Futuro Semplice; Passato Composto; Futuro nel Passato

Chapter 4

Former Approaches on Temporal Structure of Text/Discourse

The aim of this chapter is that of providing a critical overview of influential previous approaches to the modelling of the temporal structure of a text/discourse. In order to provide also a systematization of these works, we propose to divide them into two main groups: on the one hand, we can identify formal approaches [1], and, on the other hand, those approaches which use extensive annotated data (i.e. corpora) and machine learning algorithms [2]. From a certain point of view we could see these two approaches as one being the evolution of the other, since it is possible to draw a red line which connects them all together. Formal approaches have provided the theoretical basis for the development of computational models, which have evolved into the creation of annotation schemes and machine learning algorithms.

The need of a critical examination of these approaches and influential works is essential to keep their goodnesses and overcome their limitations, in order to develop new and robust computational models.

4.1 Formal approaches

Formal approaches are not homogeneous. They can be divided into two main groups: referential approaches and non-referential, or discourse-based, ones.

Referential approaches are based on the notion of *temporal anaphora* (Partee, 1973, 1984) and propose an anaphoric analysis of tenses to account for the course of events in text/discourse. A first shortcoming of temporal anaphora theories is represented by the fact that they concentrate, and have been elaborated, not to account for the temporal structure of texts/discourses, but on a fragment, that is on narrative discourse segments.

Non referential-approaches extend the analysis to the entire text/discourse, and not only to specific fragments. Their theories try to amend some shortcomings of the temporal anaphora approach but this does not mean that they are perfect: they present shortcomings as well.

[1] Partee (1973, 1984); Lo Cascio (1985); Hinrichs (1986); Passonneau (1988); Webber (1988); Blackburn & Lascarides (1992); Hwang & Schubert (1992); Kameyama et al. (1993); Kamp & Reyle (1993); Lascarides & Asher (1993); Hitzeman et al. (1995); Wiebe et al. (1997); Kehler (2000)

[2] Bras et al. (2001); Filatova & Hovy (2001); Setzer (2001); Wilson et al. (2001); Mani & Pustejovsky (2001); Boguraev & Ando (2005); Bethard & Martin (2006); Mani et al. (2006a)

4.1.1 Temporal anaphora: the influence of Reichenbach's *moment of reference*

The notion of temporal anaphora has been first formulated by Partee (1973) to describe the semantic dependencies of tense morphemes on temporal adverbs or temporal conjunction as in the following examples[3]:

(4.1) Sheila had a party *last Friday* and Sam got drunk.

(4.2) *When* Susan walked in, Peter left.

In her original proposal, Partee considers tense to be as anaphoric as personal pronouns by showing a parallelism between pronominal anaphora and tense, in particular she pointed out that:

- a tense may be used to refer to an understood salient particular time, not introduced in the context, as pronouns are used to refer to salient individuals in the context:

  (4.3) **Ho dimenticato** di chiudere il gas.

  I forgot to turn the gas off.

  (4.4) **Lei** mi ha sgridato.

  She shouted at me.

- sequence of tenses have a similar behaviour to pronouns when used to refer to an individual previously introduced:

  (4.5) Marco$_1$ è sposato. $_{t1}$ Ha tre bambini.

  Marco$_1$ is married. He$_1$ has three children.

  (4.6) Marco ha fatto$_1$ una festa sabato e Giovanni si è ubriacato$_1$.

  Marco had a party on Saturday and Giovanni got drunk.

As the example 4.6 shows, the tense of the verb in the second sentence is understood to refer not to some time in the past, but it is interpreted to be referring to a particular time in the past introduced by the the first sentence;

- uses of pronouns as bound variables present comparable cases with temporal bound variables:

  (4.7) Nessun uomo apprezza la sua fidanzata.

  No man appreciates her fiance.

  (4.8) Ogni volta che Marco chiama, Giovanni dorme.

  Whenever Marco calls, Giovanni sleeps.

  (4.9) Quando Marco chiama, Giovanni dorme sempre.

  When Marco calls, Giovanni is always asleep.

Temporal anaphora frameworks assumes a reichenbachian analysis of tense semantics, according to which all tenses have a moment of reference, as we have illustrated in Figure 3.1 in chapter 3. The anaphoric status of tense is strictly dependant on the presence of the moment of reference *R*, which is taken to cospecify with some previously evoked events. To illustrate how this basic mechanism works, consider the following discourse:

(4.10) Marco è andato$_{E_1=R_1\prec S}$ all'ospedale. Si era rotto$_{E_2\prec R_2\prec S}$ un braccio.

Marco went to the hospital. He had broken his arm.

[3]The examples are taken from Partee (1973), italics are mine.

In example 4.10 the reference time of the event of breaking one's arm, R_2 is interpreted as anaphorically linked to the event time of going to the hospital E_1. Provided the temporal semantics of past perfect (or *trapassato I*) as illustrated 4.10, the second event, E_2 is interpreted to occur before the first. The inferred temporal order is then the following:

(4.11) $E_1 = R_2, E_2 \prec R_2 \Rightarrow E_2 \prec E_1$.

As it stands, however, the formalism is not able to account for the temporal order of the eventualities in sequences of sentences with the same tense. If we modify the previous example as in 4.12:

(4.12) Marco è andato$_{E_1=R_1 \prec S}$ all'ospedale. Si è rotto$_{E_2=R_2 \prec S}$ un braccio.
Marco went to the hospital. He broke his arm.

then the mechanism of temporal anaphora fails. The temporal order which we would obtain is the one illustrate in 4.13, where the event time of the second sentence occurs at the same time of the first, which is not what our intuitions suggest:

(4.13) $^*R_2 = E_1, E_2 = R_2 \Rightarrow E_2 = E_1$.

To amend these shortcomings, Hinrichs (1986) developed an account which takes in account not only tense, i.e. the relations between the three reichenbachian moments, but also the lexical aspect of the eventualities in the discourse sequence. He also introduces a mechanism for updating the reference time. In Hinrichs' account, according to the (ontological) types of the eventualities, the relations between these entities and the previous moment of reference could vary, namely:

- if the eventuality is a telic event, the moment of event, E, is temporally included into the preceding moment of reference, R and a new moment of reference is introduced which is subsequent to the previous one;
- if the eventuality is an atelic event or a state, the moment of event, E, temporally overlaps with the preceding moment of reference and the current moment of reference of the processed event is coindexical with the preceding one.

With these accommodations, the shortcomings showed in 4.12 are avoided and the correct temporal order can be reconstructed. In addition to this, Hinrichs assumes that the first event at the beginning of the discourse has a special status and must be interpreted with respect to an assumed R_0; so for the example 4.12 we will obtain the order represented in 4.14:

(4.14) $E_1 \subseteq R_0, R_0 \prec R_1, E_2 \subseteq R_1, R_1 \prec R_2 \Rightarrow E_1 \prec E_2$.

Through this principle, Hinrichs (1986) acknowledges the importance and role of the lexical aspect for reconstructing the temporal order of events in a text/discourse. It is interesting to notice that the mechanisms for updating and interpreting the anaphoric relations between the various moments of reference are different according to the lexical aspect of the eventualities. Citing Partee:

> [r]eference times [..] play a crucial role in temporal anaphora. [...] if it is a state or a process sentence, the corresponding state or process [activity] must hold or go on at the current reference time, while if it is an event sentence, the event [achievement or accomplishment] must occur within that reference time, and a new reference time following the event is introduced [Partee (1984): 256].

In this way temporal anaphora provides principled explanations and predictions for reconstructing the temporal order of events in a text/discourse.

The updating of the moment of reference is not only performed by means of events which are introduced into the discourse. A major role in this task is performed by temporal expressions or by subordinated temporal phrases: "[t]he adverb itself, whether phrasal or clausal, provides a descriptive characterization of the new reference time: it may identify it completely [...] or simply put bounds on it" [Partee (1984): 257].

The temporal anaphora framework is highly attractive, but, as already stated at the beginning of this section, it has some open issues and limitations. To avoid confusion and to preserve clarity we will examine each issue separately.

What does it means that tense is anaphoric? Temporal anaphora is based on the assumption that a tense in a clause gives rise to an anaphoric relation with a previously mentioned (or assumed) moment of reference. However, although the parallelisms Partee drew are intuitively appealing, the notion of tense as anaphoric is far from being obvious. In addition to this, the mechanisms which govern temporal anaphora are not similar to those governing the anaphoric resolution of pronouns.

In order to preserve the good points of temporal anaphora it is compelling to redefine the notion of anaphora, since by applying its definition in *strictu sensu* it is quite hard to consider tense as an expression being coreferential with its antecedent where the antecedent provides the information necessary for the expression's interpretation.

Following Bonomi (1995), we claim that the anaphoric status of temporal morphemes has been constructed on a bias in the interpretation of the referential nature of tense which falls out of the reichenbachian analysis. The term *reference* can be employed with two senses: in a narrow interpretation, reference it is used as a synonym of denotation. For instance, when we say that a personal pronoun is referring to an individual, this means that it is denoting a particular individual in the universe of discourse. On the other hand, a more relaxed interpretation of this notion is that of reference to a particular *context*. Tense is to be interpreted as referential in this weaker sense. For instance, in the example 4.3, "there is no particular time at which the hearer is invited to locate the event at issue" [Bonomi (1995): 487]. Thus the referential nature of tense is based on the notion of reference in a restricted portion of the temporal domain: "the context is simply a temporal framework [...], and it is this background that tense refers to" [Bonomi (1995): *ibid.*].

However, we claim that tense qualifies as a special case of anaphora due to its context dependence. As Webber (1988) pointed out, tense is to be considered as a discourse anaphora. The definition of a discourse anaphora is quite different from classical linguistic definition of anaphora, but it is widespread in computational linguistics and artificial intelligence, where the term anaphora is employed to describe a variety of linguistic expressions which are context-dependent and which share two fundamental properties, namely:

> 1. they specify entities in an evolving model of the discourse that the listener is constructing;
> 2. the particular entity specified depends on another entity in that part of the evolving "discourse model" that the listener is currently attending to. [Webber (1988): 61]

Under this definition of anaphora, tense is clearly anaphoric since it has both properties: in fact, a tensed clause may either specify a new entity, i.e. an eventuality, in the interpreter's discourse model or may both evoke and specify a new entity which is dependent on a previously introduced discourse entity for its interpretation. One of the main issues in temporal anaphora frameworks is that they are all grounded on an incorrect interpretation of tense semantics. In fact, they all assume as correct the analysis proposed by Reicheinbach (1947), according to which every tense has its own moment of reference, *R*. But this is not correct, since it does not distinguish between the real semantic of the various tenses and their interpretation in a discourse. In addition, temporal anaphora frameworks consider the previous discourse entity to be either the *R* or the *E* of the preceding sentence. Again, we argue that this analysis is not correct and does not consider temporal anaphora as a discourse phenomenon. Recalling the analysis of tense we have presented in chapter 3, tense has an associated reference point, *Rpt*, which is conceptually different from the reichenbachian *R*. In a homogeneous discourse segment, for instance a narrative discourse, formed by simple past tenses, the only real anaphoric relation which the various tenses give rise to is that between the *Rpt* and a general, common discourse segment reference time, or, using an insightful proposal by Webber (1988), the **Temporal Focus**, *TF*, of the discourse segment. It is this the particular entity on which tensed clauses in a text/discourse are dependent for their interpretation. The notion of Temporal Focus is akin to the more common notion of Discourse Focus (Sidner, 1983; Grosz & Sidner, 1986). If the Discourse Focus captures the intuition that at any point in the text/discourse there is one discourse entity which is the primary focus of attention and represents the most probable anchor for an anaphoric NP, similarly, in its original formulation, the Temporal Focus captures the intuition that at any point in the discourse there is an entity which is mostly attended and most likely to enter in an anaphoric relation with the *Rpt* of the next tensed clause/sentence. However, we do not accept Webber's original formulation. Our notion of Temporal Focus captures the intuition that all tenses in a coherent discourse segment refer to a common temporal framework.

Furthermore, the Temporal Focus is not be confused with the textual temporal anaphor *A*. They are two different elements: the first is presupposed to exist as an entity with which the various *Rpt*s of the events enter in an anaphoric relation (in the sense which we have introduced above), while the second is just a technical device to compute temporal relations in the text/discourse. It is also important to point out that the anaphoric relations which the various *Rpt*s of tensed clause give rise to do not benefit of the transitivity property, that is if Rpt_1 is anaphorically linked to TF_1, and so it is for Rpt_2, it does not derive that Rpt_1 is in anaphorically linked to Rpt_2.

Tense has limits As we have illustrated in chapter 3, tense has limits in order to reconstruct the temporal ordering of eventualities in a text/discourse. Although temporal anaphora frameworks have tried to amend these limitations with some special devices which keep track of the lexical aspect of the eventualities in analysis, they fail in the vast majority of cases.

First, even adopting the classical temporal anaphora framework, with the presence of a moment of reference for every tense, there are cases in which the updating of the reference time fails, in particular with states which are the result of previous events:

(4.15) Marco spense la luce. La stanza era al buio.

Marco swicthed off the lights. The room was dark.

Another interesting case of failure of temporal anaphora is represented by a sequence of past perfect tenses (e.g. the *trapassato I*), which according to their temporal semantics and the mechanisms at the basis of temporal anaphora would be interpreted as one preceding the other, contrary to the intuitions that a competent speaker would have:

(4.16) Marco è arrivato in ufficio alle 10.00. Si era svegliato presto$_{e1}$, aveva fatto colazione$_{e2}$ e aveva preso la macchina$_{e3}$.

Marco arrived at the office at 10.00. He had waken up early, had taken his breakfast and had taken his car.

In the example 4.16, the sequence of events at the *trapassato I* in Italian (and at the past perfect in English), would be (wrongly) ordered as follows:

(4.17) $e_3 \prec e_2 \prec e_1$

Finally, a major limit of temporal anaphora is represented by the complete lack of awareness of the influence of pragmatics and commonsense knowledge and of the ways in which this can be structured in the different discourse segments. For instance, the following two examples are totally out of reach for temporal anaphora frameworks:

(4.18) Il consiglio ha costruito il ponte. L'architetto ha disegnato i progetti.

The council built the bridge. The architect drew the plans.

(4.19) Marco è cascato. Giovanni lo ha spinto.

Marco fell. Giovanni pushed him

In the example 4.18, the second sentence cannot be interpreted as following, i.e. after, the first since that sentence marks a different discourse segment which describes an elaboration of the first event. Similarly, in example 4.19, the second sentence represents the cause of the first event, and, consequently, it must temporally preceed it, since causes preceed their effects. Temporal anaphora would predict that the second sentences are successive to the first ones.

4.1.2 Non-referential frameworks: Dowty (1986)'s TDIP and ter Meulen (1995)'s DAT

These two frameworks depart from the reichenbachian analysis of tense and try to provide a different principled account of how temporal relations are established in a text/discourse.

TDIP: Temporal Discourse Interpretation Principle (Dowty, 1986) The Temporal Discourse Interpretation Principle implements a non referential proposal. The interpretation of successive sentences in a discourse is based on an interaction between tense, aspect (both viewpoint and lexical aspects), temporal adverbials and some principles of conversation. As Dowty claims:

> the temporal relationships between sentences of a discourse are determined by three things: (I) the semantics analysis of aspectual class using the interval semantics [...]; (2) a single principle for the interpretation of successive sentences in a discourse, a principle which in itself does not make reference to the aspectual classes of the sentences involved, and (3) a large dose of Griecean conversational implicature and "common-sense" reasoning based on the hearer's knowledge of real world information. [Dowty (1986) in Mani et al. (2005): 336].

The TDIP is formulated as follows:

Definition 28 (Dowty (1986)'s TDIP) : Given a sequence of sentences $S_1, S_2...S_n$ to be interpreted as a narrative discourse, the reference time of each sentence S_i (for $1 \leq i \leq n$) is interpreted to be:

1. a time consistent with the definite time adverbials in S_i, if there are any;
2. otherwise, a time which immediately follows the reference time of the previous sentence S_{i-1}

Though Dowty acknowledges a reichenbachian-like representation of tense semantics, he avoids the complicated updating mechanisms of reference time proposed by the temporal anaphora frameworks. In his account, the notion of reference time is only allusively related to Reicheinbach (1947), since he defines it as the time at which the mentioned eventuality in the sentence occurs or holds, a definition which is more similar to the reichenbachian event time E. The ordering of the eventualities is based on the axioms proposed by the principle.

The TDIP makes no mention of a difference in the aspectual classes for locating the reference times, which are assumed to exist for every eventuality type. The temporal relations between eventualities are not only a consequence of the times eventualities are asserted to be true, but also of the times we assume that the eventualities occur or hold. Sentence semantics and further pragmatic inferences have to be linked to the information provided by lexical aspect to obtain a correct discourse interpretation. To better illustrate how the TPDI works, consider this example:

(4.20) Marco è entrato$_{e1}$ nello studio. I documenti erano$_{e2}$ sulla scrivania.

Marco entered the office. The documents were on the desk.

The TDIP assumes that there are two distinct and successive moments of reference, one for e_1 and one for e_2, i.e. $R_{e1} \prec R_{e2}$. The correct interpretation is obtained by taking into account both the semantics of the second eventuality, which is a state, and principles based on common-sense reasoning, according to which the normal interpretation of an interpreter is that states not only obtain at a certain point in a discourse but began to hold in advance of this point as well, leading to e_2 overlaps with e_1.

Though fascinating, Dowty (1986)'s account is not completely convincing since in some cases the TDIP does not give the most natural interpretation. For instance, in example 4.20 the two reference times of the eventualities are most naturally interpreted as overlapping, instead of being one after the other. Another issue concerns his account of reference time which seems to be completely separated from tense for its temporal location in a text/discourse sequence. In addition to this, it is not clear what is the role of tense, which appears to be marginal; in the TDIP everything seems dependant on the lexical aspect and on pragmatic inferencing principles. Finally, his account is not able to treat discourse segments other than narration similarly to temporal anaphora accounts.

DAT: Dynamic Aspect Trees (ter Meulen, 1995) A Dynamic Aspect Tree is a representational device for temporal relations between events in a past narrative discourse. The motivation for this tree-like representation is strictly linked to the framework of dynamic semantics, and, according to the author, it should better support temporal inferencing. DATs are step-wise constructed during the process of interpretation of a text/discourse. From a certain point of view, DAT representations are limited, since the entire system "is designed only to determine the consequences of an interpretative choice" [ter Meulen (1999): 3]. However, no heuristic guidelines are provided for making the interpretative choice. People can construct different DATs from the same premises and hence draw different conclusions. In this representation, the author claims that the need for reference times are eliminated, since inferencing is insensitive to them. Tense is represented like a semantic operator having scope on the entire sentence, more likely the priorean account. Temporal dependencies between eventualities are inferred from the DAT structure.

According to the author, a text/discourse provides three kinds of information:

- the descriptive content: it determines the truth-conditions of a sentence or clause. In DATs it is represented by labels on the nodes of the tree;
- the aspectual content: it describes how the the descriptive content of a sentence or clause is integrated with the given context; it barely corresponds to lexical aspect. Different actionality classes are represented by two different types of nodes in the tree: *holes* and *plugs*. Normally, holes correspond to activities, while plugs correspond to telic events, i.e. achievements and accomplishments. States are represented by labels, called *stickers*, on the tree nodes and they do not introduce a node type of themselves. A theoretical shortcoming of the sticker machinery is represented by the fact that stickers are used to represent progressive eventualities as well. The idea that progressive eventualities have a temporal behavior like that of states is very common in literature, but as it has been pointed out by Bertinetto (1997), wrongly stated, since the semantics of the progressive has a de-telicizing effect, and do not introduce stative eventualities. Holes and plugs influence the way the tree grows, for instance, when a hole is used a sister node is introduced, while when a plug is employed a child node is introduced.
- the perspectival content: it determines the point-of-view of the evaluation, it is the location of the interpreter from which s/he draws inferences from the given information. In DATs the perspectival content is represented by the unique right-most terminal node.

Though no heuristic is provided, DAT construction is based on a minimal set of rules which partially guides the interpreter. For instance, by applying the three basic rules, we will obtain the following DAT tree for the sentence in the example 4.21:

(4.21) Marco notò$_{plug}$ una macchina parcheggiata$_{sticker}$. Pattugliava$_{PROG_sticker}$ la zona. Stava guidando$_{PROG_sticker}$ lungo Diagon Alley.

Marco noticed a parked car. He pattrolled the area. He was driving down Diagon Alley.

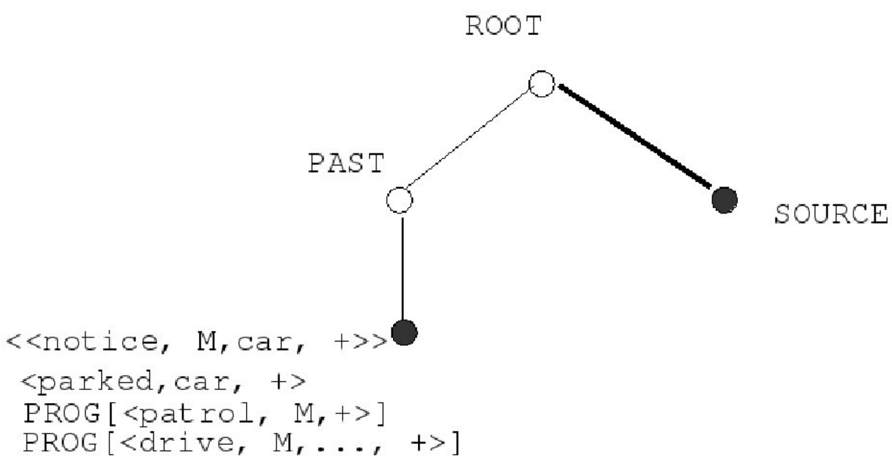

Figure 4.1: *DAT representation of 4.21.*

The temporal relations between the three events are to be inferred from the tree representation, according to which the noticing event took place within the time of Marco's patrolling and driving down Diagon Alley (or the other way round).

The machinery proposed by DAT is not simpler than that for temporal anaphora, although different. There are some aspects of the model which are not completely clear and some theoretical shortcomings. A first aspect, is represented by the complete lack of a role in DAT construction and inferencing of the viewpoint aspect which is only interpreted as a sort of semantic operator over eventualities. In particular, in her account, ter Meulen seems not to be aware of the differences between progressive and perfect aspect on event representation, since they are both treated as operator which gives rise to stickers. This seems to lead to an inability of DATs to represent extended flashback, which are normally realized in English by a series of past perfect clauses, which being treated as stickers, lose a big part of the intuitions an interpreter have when reading such discourse sequences. Another issue is represented by the complete lack of a role for tense. Tense is considered as a priorean operator. Sequences of sentences with the same tense forms are all grouped under the same heading, as illustrated in 4.1. We argue that this kind of representation is somehow contradictory with the claim of refusal of a reichenbachian representation. In fact, it suggests that the tense label assumes a value which is comparable to the reference time, since all tree branches, i.e. eventualities, with the same tense are grouped under the same node.

Nevertheless, a good point of DAT is represented by the statement that temporal reasoning is a paradigmatic example of situated reasoning with partial information provided by the natural language in analysis. Thus, a DAT is a representation of the accumulated information and it facilitates inferencing processes and simple search algorithms for verifying the validity of one's inferences, but this is not enough to safeguard the framework.

4.1.3 Discourse structure and non-monotonic reasoning

In this section we will present a brief overview of non-monotonic reasoning as a mean to process discourse structure. The theories developed under this framework show how coherence relations, anaphoric phenomena and temporal relations are all a primary by-product of computing the general discourse structure. The most known non-monotonic framework of this kind is DICE developed by Lascarides & Asher (1993).

Non-monotonic logics have been developed to represent world knowledge and pragmatics principles which are impossible to be expressed in standard predicate logic, like FOL[4]. Non-monotonic logics can be regarded as a way of formalizing our commonsense knowledge. A defeasible logic is "one where Γ defeasibly implies ϕ just in case from knowing only Γ, one would infer ϕ" [Lascarides & Asher (1993) in Mani et al. (2005): 345]. To show the difference of a non-monotonic logic representation, with respect to classical predicate logic consider this example, where we have the following set of premises Γ:

(4.22) Tweety is a bird (α).
All birds fly (β).
Penguins do not fly (γ).
Tweety is a penguin (δ).

By applying standard FOL derivation, we would obtain the following inconsistent derivation, i.e. $\Gamma \models$ Tweety flies $\wedge$ Tweety does not fly. On the other hand, non-monotonic

[4]First Order Logic.

reasoning is able to provide the desired derivation, that is, the fact that, according to our common sense knowledge, Tweety is a special case of birds that do not fly. The non-monotonic representation of our derivation will be the following: $\Gamma \mid\approx$ Tweety does not fly, where $\mid\approx$ represents the non-monotonic symbol of logical derivation.

The first aim of Lascarides & Asher (1993) is that of solving problems of previous accounts of temporal structure of text/discourse, in particular of temporal anaphora frameworks. A core issue of their proposal is represented by the claim that "temporal relations must be calculated on the basis of semantic content, knowledge of causation and knowledge of language use, as well as sentential syntax and compositional semantics" [Lascarides & Asher (1993): *ibid.*]. This means that, according to their perspective, temporal relations *are not* determined by relations between the reference times.

An important element that the two authors introduce is represented by the assumption, in line with Hobbs (1985); Grosz & Sidner (1986); Mann & Thompson (1988), that there are constraints between sentences in a text/discourse to form discourse segments, and that these constraints are characterized in terms of hierarchical discourse structure. With respect to the other approaches presented so far, their perspective is larger, since they do not only calculate the temporal structure of the events in discourse, but also how world knowledge and linguistic knowledge affects the interaction between discourse structure and temporal structure.

In order to reconstruct these two structures of a text/discourse, their theory assumes a set of patterns of inference in non-monotonic logic. It is interesting to point out that these patterns of inference are used both to infer discourse relations and temporal relations. However, since we are interested in the temporal ones, we will only illustrates how these latter can be inferred. Before discussing their theory, a final remark is compulsory: Lascarides & Asher (1993) are the first who explicitly treat temporal relations as *inferences* made by the interpreter, and not as elements derived only form syntax and compositional semantics. This is one of the most innovative element of their theory: temporal relations assumes the status of textual inferences made by the interpreter in order to maintain the discourse coherence and they become the primary by-product of computing the overall discourse structure.

The patterns of inference the two authors formalize in their theory are illustrated below. Each of these patterns is able to express a commonsense (i.e. non-monotonic) entailment:

Definition 29 (Defeasible Modus Ponens) : $\alpha \geq \beta, \alpha \mid\approx \beta$.

e.g.: *Birds fly, Tweety is a bird,* $\mid\approx$ *Tweety normally flies.*

This inference states that, if no further information is available either form the interpreter's world knowledge or from explicit linguistic knowledge, then normally (i.e. defeasibly) the default interpretation is valid.

Definition 30 (Penguin Principle) : $\alpha \rightarrow \beta, \alpha \geq \neg\gamma, \alpha \mid\approx \neg\gamma$.

e.g.: *Penguins are birds, penguins normally don't fly, birds normally fly, Tweety is a penguin* $\mid\approx$ *Tweety doesn't fly.*

This inference states that when the antecedent of two defeasible laws are verified, only the most specific conclusion can be derived, since both cannot hold in a consistent knowledge base. This entailment pattern is the key to resolve conflicts among the interpreter's knowledge sources. In fact, in non-monotonic logic, conflicts between defeasible rules are resolvable, only if one is more specific than the other, i.e. when it entails the antecedent of the other;

Definition 31 (Nixon Diamond) : $\alpha \geq \gamma, \beta \geq \neg\gamma, \alpha \mid\not\approx \gamma \vee \neg\gamma$

e.g.: *Quakers are normally pacifists, Republicans normally are non-pacifists, Nixon is a Quacker and a Republican* $|\not\approx$ *Nixon is a pacifist or Nixon is a non-pacifist.*
The so called Nixon Diamond is an inference pattern which provides a principled account for textual incoherence. The conflict between the defeasible rules in the example (*Nixon is a Quaker and a Republican*), cannot be resolved if the rules are not related.

A further interesting pattern is Doodley Dorite which, on the contrary, is a monotonic pattern of inference:

Definition 32 (Dudley Dorite) : $\alpha \geq \gamma, \beta \geq \gamma, \models (\alpha \vee) \geq \gamma$
e.g.: *A Quaker is normally a pacifist, A republican is normally a pacifist* $\models$ *A Quaker or Republican is normally a pacifist.*
Dudley Dorite is used to explain textual ambiguity, and, thus, temporal ambiguity.

Finally, the logic proposed by Lascarides & Asher (1993) is propositional, modal, and decidable.

4.1.3.1 Putting things to work: DICE's framework

The basic model of discourse the authors assume is one where discourse segments are linked by rhetorical relations which determine "the hierarchical structure of the discourse, and hence the structural constraints on which sentences can attach together to form text segments" [Lascarides & Asher (1993) in Mani et al. (2005): 355]. The rhetorical relations of *narration*, *background*, *explanation*, *elaboration* and *result*, which are central to temporal interpretation, are assumed as discourse default rules based on world knowledge and lexical knowledge.

Discourse interpretation is considered an incremental process, whereby each sentence is attached to the following according to a specific rhetorical relation which is computed by the interpreter. To account for this phenomenon, the authors have developed an updating function, represented as $\langle \tau, \alpha, \beta \rangle$, which relates the newly processed sentence, β, to the already existing discourse, τ and α. The updating function presupposes that the sentence under analysis is recognized as part of the preceding discourse, i.e. the interpreter has to believe that the discourse is coherent to give rise to a rhetorical relation, otherwise no attachment is possible. *Narration* is assumed to be the most basic default. It is interesting to notice that *narration* is derived by the application of Defeasible Modus Ponens (**Definition 29**). If this rhetorical relation is derived, the following maxim will apply, according to which a temporal relation of precedence is derived:

Definition 33 (Maxim of Narration) : If *Narration*(α, β) holds, then *it is necessary* that $\alpha \prec \beta$.

Narration is based on a defeasible law since, if more specific information is available in the discourse at the moment of updating, different rhetorical relations may hold and, consequently, different temporal relations are inferred. As it appears from **Definition 33** the so called maxim of narration is a different, somehow less specific, formulation of Dowty's TDIP.

Lascarides & Asher (1993)'s approach is able to treat the problematic cases presented in referential frameworks in a principled and more systematic way. For instance, cases like 4.19 and 4.18, are computed in DICE by applying the patterns of inference when updating the discourse. Consider, example 4.18, represented here as 4.23:

(4.23) Il consiglio ha costruito il ponte. L'architetto ha disegnato i progetti.
The council built the bridge. The architect drew the plans.

the logical form of the two sentences is represented as follows:

- α: [e_1, t_1][$t_1 \prec$ now, hold(e_1, t_1), build(council, bridge, e_1)]
- β: [e_2, t_2][$t_2 \prec$ now, hold(e_2, t_2), draw(architect, plans, e_2)]

if the reader knowledge base assumes that (i.) α and β are coherent, i.e. form a text/discourse, and (ii.) β is to be attached to α by means of a rhetorical relation, and (iii.) all defeasible world knowledge on building bridges, and all defeasible linguistic knowledge on the two eventualities e_1 and e_2, then, the reader verifies that Defeasible Modus Pones, and thus *narration*, does not hold, while the derivable inference pattern is that of the Penguin Principle, from which the more specific rhetorical relation of *elaboration* can be inferred. In fact, β can be interpreted as being part of the preparatory phase of the complex event of building bridges[5]. The associated axiom states that if *elaboration* holds then *narration* cannot hold and, consequently, the eventuality expressed in β cannot temporally follows the eventuality expressed in α. The specific temporal relation which hold between these two sentences is one of overlap and is derived by inferences based on world knowledge and lexical knowledge:

- $\langle \tau, \alpha, \beta \rangle \wedge prep(e_{1\beta}, e_{2\alpha}) \geq Elaboration(\alpha, \beta)$
- $\Box(Elaboration(\alpha, \beta)\Box \rightarrow \neg Narration(\alpha, \beta) \wedge \neg(\alpha \prec \beta))$
- $\langle \tau, \alpha, \beta \rangle \wedge prep(e_{1\beta}, e_{2\alpha}) \wedge Elaboration(\alpha, \beta) \geq overlap(e_{2\alpha}, e_{1\beta})$

The discourse structure for 4.19 can be computed with minor modifications. One of them, is represented by the law which in DICE encodes the logical relation of cause and effect, according to which causes cannot precede effects.

A further advantage of the DICE framework is represented by the uniform treatment of the past perfect (*trapassato I*) and of sequences of sentences at the past perfect. The claim that this tense "acts as a syntactic discourse marker to indicate that only a restricted set of discourse relations is possible, thus yielding different inferences on discourse structure" [Lascarides & Asher (1993) in Mani et al. (2005): 379]. Instead of using formal devices like reference times, the two authors exploit defeasible and indefeasible linguistic knowledge to explain this function. In particular, they claim that sentences at the past perfect can be connected to the preceding discourse only if they are either an explanation or an elaboration, or if the two discourse segments form a parallel or contrast rhetorical relation. If such connections between the two discourse segments holds, then the sentence at the past perfect expresses an eventuality which stands in a precedence relations with the previous discourse[6]. However, the most interesting part of their account of the past perfect is represented by their principled explanation of extended flashbacks, or sequences of past perfect sentences, which is based on the exploitation of discourse relations. Once a rhetorical relation is computed, the related temporal inferences are stated. The difficulties of referential frameworks are thus easily overcome, with no need of complex machinery with reference times.

[5]recall Moens & Steedman (1988)'s tripartite ontology. See also chapter 2, section 2.3.1.1.

[6]The authors propose the following formal principle to capture this property of the past perfect:

- Connections When Changing Tense (CCT): $\Box(\langle \tau, \alpha, \beta \rangle \wedge sp(\alpha) \wedge pp(\beta) \rightarrow C_{pp}(\alpha, beta)$

where *sp* stands for simple past, pp for past perfect and $C_{pp}(\alpha, beta)$ mean that α and β are connected by one of the discourse relations allowed between simple past and past perfect.

Although more robust than all the framework illustrated so far, the DICE framework is not perfect. Some issues and shortcomings can be identified. One of the main issue is represented by discourse segments. The authors do not propose a principled way of segmenting discourse. It is true that they may rely on previous discourse segmentation theory, like for instance Grosz & Sidner (1986). But these proposals present shortcomings right on this issue, that is on how to segment discourse. It is a matter of fact that discourse or rhetorical relations cannot be computed if a principled way of identifying homogeneous discourse segments is not formulated.

Another issue is represented by the temporal logic which underlies their framework. As Schilder (1997) points out, the only temporal relations they assume are precedence and overlap, while, as we have illustrated in chapter 2, section 2.3.2, the range of temporal relations is much wider. As for the overlap relation, it is not clear how big is the overlap, in particular whether it is a strict overlap or whether the two situations share only a common subpart. As we have illustrated in example 4.23, the subpart overlap is computed by means of an additional predicate, *prep*, based on a debatable interpretation of the event ontology of Moens & Steedman (1988). The authors extend the notion of preparatory phase of events to include also merological relations, which should be treated as relations of their own and cannot be included as preparatory phases.

Two other shortcomings should be mentioned: first, the role of other sources of information like tense, viewpoint and lexical aspect is not considered in the theory. It can be inferred that they are part of the linguistic knowledge of the interpreter, but what was a good point of referential framework, for instance, the acknowledgment of a pivotal role of lexical aspect, is here completely lacking. According to their proposal, the primary, and unique, source of knowledge to compute temporal relation is discourse structure. Finally, the *narration* default is very similar to Dowty's TDIP, and in addition to this, their decision to assume *narration* as the most default discourse relation is debatable. On the contrary, we claim that all relations should be put all on the same level of "defaultness": it is the linguistic knowledge and the interpreter's assumptions on the text/discourse s/he is processing that will activate one of the possible defaults.

4.2 Corpus-based analyses: the role of corpora and annotation schemes

The works presented in the previous section have followed the methods of analytical linguistics, philosophy, and, namely, symbolic Artificial Intelligence. Aspects of how temporal information is realized in natural language and how it can be represented and (automatically) extracted have been analyzed in terms of formal models and connected computational systems (for instance Passonneau (1988); Hwang & Schubert (1992)). The emphasis is on the model being developed or the theoretical approach, and not on the real linguistic data, or on a systematic evaluation of the related algorithms.

In the last decade, the need for real linguistic data, i.e. the language used by everyday speakers of a linguistic community, has emerged both in Theoretical and in Computational Linguistics (C.L.). We claim that in the early 90s there had been a sort of epistemological shift which can be summed up as: "*no more armchair intuitions and fake examples of language use, but real data and judgments on these data*". In Chomsky's terms, performance is as important as competence.

Corpus annotation is a research field which has now become largely influential. A *corpus* is traditionally referred as a principled collection of naturally occurring language

data, either written or spoken, or both, used for linguistic research. This original concept of corpus is now a little changed, especially in the C.L. community, to refer to a collection of texts, available in electronic format and which can be processed by a machine, used as part of natural language processing. With respect to early corpora collections and studies, the added value represented by modern corpora is their *annotation*. Annotation is the practice of adding explicit information to the linguistic content of a corpus according to a *scheme*. A very common form of annotation is grammatical or Part-of-Speech (POS) tagging, whereby the label, or *tag*, associated to a word explicits its grammatical class, whether it is a noun, a verb, an adjective and so on and so forth. Annotation is metalinguistic and interpretative. Metalinguistic because it provides us with information about the language. Interpretative because it depends on human understanding of the text.
Some of the benefits which corpus annotation brings are:

- annotation schemes and annotated corpora are data resources which can be shared, argued over, re-used and refined by the linguistic community. Evaluation of the accuracy and reliability of the annotation scheme can be performed by comparing the results produced by human annotators on the same set of data;
- annotated corpora can be exploited by machine learning algorithms to quickly acquire annotation capabilities;
- annotated corpora provide an objective basis to evaluate the performance of competing algorithms on the same tasks.

Works on annotation of temporal phenomena in natural language is quite recent, the first works dating back to 1995 and are mainly devoted to English. It is possible to identify an evolution in this field in terms of increasing representative power of the various annotation schemes (and related annotated corpora), from simple annotation of temporal referring expressions (MUC-6, 1995) to the annotation of the temporal relations between temporal expressions and events (Task 15: TempEval, SemEval Workshop, 2007).

4.2.1 Annotating Time, Eventualities and Temporal Relations

The most obvious temporal features to annotate in texts are temporal expressions. We have already illustrated in chapter 3, section 3.2, the variety of realizations and the complexity of the phenomena to be addressed which must be dealt with when devising an annotation scheme.

MUC `TIMEX` recognition task Works to devise annotation schemes for temporal expressions began as part of the Named Entity (N.E.) recognition task in the DARPA Message Understandig Conference 6 (MUC-6) in 1995. The participants to this task were asked to insert SGML tags into the text to mark each string representing:

- an `ENAMEX`, i.e. a person, organization, or location name;
- a `TIMEX`, i.e. a date or a time stamp;
- a `NUMEX`, i.e. a currency or percentage figure.

Only absolute temporal expressions were to be marked, that is temporal expressions that refer to complete calendrical dates, or a specific year, month, minute . . . ; context-dependent (relative) temporal expressions (like *now*, *last July*) were not marked. A key element of this task was a set of texts manually annotated to provide a **gold standard** measure of correctness over which to evaluate the competing algorithms. Metrics, like *recall*[7] and *precision*[8] were used to evaluate the systems' responses against the human supplied annotations. The top system performance on the `TIMEX` tagging task was 0.97 recall and 0.96 precision.

In MUC-7 (1998) relative temporal expressions were added to the `TIMEX` tagging task. This introduced into the task indexical expressions, like *yesterday*, and event-related temporal expressions, like *the morning after the attack*. Blind evaluation was performed as well and the highest scoring system was 0.89 recall and 0.99 precision for absolute and relative temporal expressions and 0.81 recall and 0.97 precision for event-related temporal expressions.

One of the main limitations of the MUC tasks was that the temporal expressions were only identified. This means that systems were able to know if a certain string in a text was a temporal expression, but it was impossible for them to interpret, evaluate or dereference that string and associate it with the time it denotes. According to the MUC-7 guidelines, an expression like *today* in an article datelined *December 30, 1998* was just tagged as a `TIMEX`. What complex systems, like Question-Answering or Information Retrieval systems, really need is to know that *today* refers to the same date of publication, i.e. *December 30, 1998*. In addition to this, the whole set of linguistic expressions which may realize a temporal expression was restricted just to calendrical dates and times of day, and classified via the attribute `type` as `DATE` or `TIME`, respectively. Finally, it is important to point out that as far as temporal relations were concerned their identification was very limited and focused only on temporal relations between a temporal expression and an event. The MUCs' tasks were based on a scenario filling task of template elements. Event identification, for instance, was restricted to predetermined events, like joint venture announcements or rocket launchings. The scenario template contains a set of specific fields which have to be filled in with information extracted from the texts in analysis. The temporal relations were expressed by a link to the appropriate time entity in one of this field. For instance, in MUC-7 the scenario template concerned rocket launching events. The temporal relation between the rocket launch and the associated temporal expression, if present, was expressed by a field called *LAUNCH_DATE*. No further analysis of the temporal relations was performed.

`TIMEX2`: improving expressiveness of temporal expressions In 2000 the development of the Translingual Information Detection, Extraction, and Summarization (TIDES) research program proposes an innovative annotation scheme for temporal expressions by introducing a new tag: `TIMEX2` (Ferro et al., 2001). The two main novel features are:

- the fact that the range of expressions flagged is wider than in the MUC tasks; three different time values are represented: time points, durations (or intervals) and frequencies;
- the fact that all temporal expressions, including context-dependent ones, such as *yesterday* or *now*, are evaluated and *normalized*, i.e. assigned a standard value based on a ISO format[9] which captures their semantics including some extensions to allow the treatment of "fuzzy" expressions, i.e. those expressions having a general temporal denotation, but without confidently possessing a precise temporal value corresponding to a calendrical date.

[7]The number of relevant documents retrieved by a search divided by the total number of existing relevant documents (which should have been retrieved).

[8]The number of relevant documents retrieved by a search divided by the total number of documents retrieved by that search.

[9]ftp://ftp.qsl.net/pub/g1smd/8601v03.pdf

With TIMEX2 a set of precise and reproducible criteria for annotating temporal expressions was identified ensuring relative high values in terms of agreements among annotators. In principle, in TIDES if a phrase or word refers to some area on the timeline, its meaning must be captured. However, to avoid an overextension in the annotation, the syntactic head of the markable expression must be an appropriate lexical trigger.

The expressiveness of the annotation is improved by the presence of six attributes in the TIMEX2 tag. The most innovative one is the VAL attribute which expresses the semantics of temporal referring expressions, i.e. its normalized value. In Table 4.1 we illustrate the remaining attributes.

Table 4.1: *TIMEX2 tag attributes.*

Attribute	**Function**
MOD	Captures temporal modifiers e.g.: *more than...*
ANCHOR_VAL	Contains the normalized form of an anchoring temporal expression used to retrieve the value of a context-dependent temporal expression.
ANCHOR_DIR	Captures the temporal relations between a context-dependent temporal expression and its anchor, i.e. whether the context dependent expression *precedes*, *follows*, or *overlaps* the anchor.
SET	Identifies expressions denoting sets of times.
COMMENT	Contains any comment the annotator wants to add.

The application of the TIMEX2 tag has introduced a *de facto* standard practice for annotation of temporal expressions by splitting the annotation process in two steps: first, the temporal expressions are identified and flagged, and later the process of normalization is performed. However, the evaluation process is performed all at once even for context-dependent expressions. There is no separation between the semantic interpretation of a temporal expression and its full evaluation. So, for instance, a context-dependent expression like *last month* is not interpreted as a functional expression of the type `month (predecessor (monthDCT))`, where DCT stands for the Document Creation Time, from which the full evaluation is computed once the DCT is assigned.

It is interesting to point out that the increase both of the set of lexical items denoting temporal expression and of the complexity of the annotation, with the introduction of the attributes and the normalization process, do not result in a diminishing processing power of algorithms. Wilson et al. (2001) report the performance of a temporal tagger trained on an human annotated corpus of English[10] achieving 96.2 f-measure (a balanced measure of recall and precision) for the identification of temporal expressions and 83.2 f-measure for the normalization task.

Finally, the TIMEX2 tag concerns only temporal expressions, no suggestion for annotating eventualities is proposed, nor the developers of the TIMEX2 scheme seem to be particularly interested in this task. For instance, the authors claim that a TIMEX2 tag must be created whenever a lexical trigger, i.e. a temporal referring expressions is encountered and that the full extent of the TIMEX2 tag must correspond to entire phrases, namely NPs, AdjPs and AdvPs. This approach, though correct in principle, does not consider the complexity of event-related temporal expressions, like *the morning after the attack*. Phrases like the former are marked with a TIMEX2 tag corresponding to the maximal NP, loosing

[10]The corpus consists of 32,000 words of a telephone dialogue corpus (English translation of the "Enthousiast" Spanish corpus), 35,000 words of the New York Times newspaper text and 120,000 words of broadcast news.

the (ontological) complexity of the elements composing the phrase, where an instance of a temporal expression, *the morning*, and an instance of an eventuality, *the attack*, occur. Moreover, temporal relations are annotated only between temporal expressions and by means of an attributes of the TIMEX2 tag (the ANCHOR_DIR attribute). Consequently, only context-dependent temporal expressions are available for further reasoning by computational algorithms. Temporal relations between absolute temporal expressions are not resolved producing a partial annotation.

The 2001 ACL Workshop: the issues of eventualities and temporal relation annotation During the ACL-2001 *Workshop on Temporal and Spatial Information Processing* some other approaches were reported. The three main influential works of this workshop, (Filatova & Hovy, 2001; Katz & Arosio, 2001; Schilder & Habel, 2001), try to move forward the task of temporal annotation. If the TIMEX2 guidelines have provided a complete framework for annotating temporal expressions and to express their semantics, though with some shortcomings, so far no annotation scheme has proposed a method for identifying and annotating eventualities and all possible types of temporal relations, i.e. relations between temporal expressions, relations between eventualities and temporal expressions and, finally, relations between eventualities.

The task of annotating eventualities is not a trivial one. We have illustrated in the previous chapters (chapter 2, section 2.3.1 and chapter 3, section 3.1) how eventualities can be analyzed at an ontological level and how they can be realized in language. None of the cited works attempt to make a distinction between events and states and all of them assume that the eventualities which need to be annotated can be identified via a set of syntactic or lexical criteria. It is interesting to notice how these early annotations schemes for event annotations deliberately restricted the linguistic realizations of events to verbs and, at most, to nominalizations. Such restrictive notions of eventualities were already employed by early computational systems based on temporal anaphora models (e.g. Passonneau (1988)'s PUNDIT system). The breaking innovation of these approaches is represented, on the one hand, by the algorithms employed to automatically perform the tasks of event identification and temporal ordering: no more rule-based systems, but machine-learning ones, and, on the other hand, by the evaluation of the systems' performance.

Although a set of linguistic criteria have been identified for annotating events, the textual span to be annotated is still an open issue. For instance, in Filatova & Hovy (2001) only simple clauses containing a subject (i.e. a noun phrase) and a predicate are assumed to be the text containing events. On the other hand, Katz & Arosio (2001) consider as the textual span of events the verbs of a sentence. Schilder & Habel (2001) have a broader target, and consider two types of event-denoting expressions: sentences and event-denoting nouns, but restricted to nominalizations.

As a matter of fact, these annotation schemes for tagging eventualities are quite poor in terms of event-related temporal information. For instance, information about tense and aspect are not annotated by human but recovered automatically from parsers. In addition, events are marked not by using a specific tag, as it has been elaborated for temporal expressions, but they are distinguished, as in Schilder & Habel (2001), by means of internal attributes.

Even the task of automatically annotating temporal relations between the temporal entities identified is limited. Although these works implement different methodologies for recovering temporal relations, they all share the following elements:

- the temporal relations are computed only between temporal expressions and events;

event-event relations are annotated only when explicitly signalled by a temporal preposition or adverb, like *before*, or if they are syntactically marked;

- the idea that all events could be placeble on a time-line and associated to a time (either a calendrical date or an interval), i.e. the time-stamping of events.

As it appears from this description, although innovative in the methodology, these annotation schemes capture only partial temporal information. The lack of analysis of event-event temporal relations in intersentential contexts misses the largest and most common way by which natural languages code temporal relations. The range of metalinguistic information associated to events is almost absent and limits itself to information about tense, while as we have showed in chapter 3 and other cues from the grammar and the lexicon are pivotal in order to compute the existing temporal relation. The idea of using a time-line representation is appealing but not the best solution for a graphical representation of temporal relations though it fits with the restricted and limited aims of these works. It is also interesting to notice the fact that all these works do no present a validation in terms of human inter-annotator agreement of the annotation schemes employed to train/implement the algorithms, an element which is nowadays compulsory because the performance of an algorithm is related to the average goodness of the annotation performed by the humans.

A further aspect which emerges is the impossibility of comparing the results obtained by the systems, since the notions of what types of eventualities to annotate, their linguistic realizations and textual span, and the kinds of temporal relations annotated do not share a common practice. So the various figures reported by the authors for their systems though impressive (for instance Katz & Arosio (2001) reports a 82% of correctly assigned time-stamps to clauses correctly identified, while Schilder & Habel (2001) reports a 84.49% recall and precision for their system in extracting temporal relations from sentences containing a temporal expressions) cannot be compared and evaluated one with respect to the other.

STAG: Setzer (2001)'s annotation scheme The idea of a complete annotation scheme which takes into account all the elements contributing to the temporal information in a text/discourse appears for the first time. The striking innovations introduced by Setzer in her seminal work are:

- the fact that for the first time eventualities are annotated with a tag of their own, namely `EVENT`. The set of grammatical elements which can codify an event is extended to include verbs, both finite and non-finite forms, and nominalizations. Since the primary aim of the annotation scheme are temporal relations of all kinds, including those between two events, the textual span of the eventualities is restricted to the head of the phrase group which expresses the eventuality. This means that only the main verb head is annotated for events expressed by verbs and only the nominal head for nominalizations. Event arguments, such as logical subject or object are disregarded unless they are events. States are not annotated;
- the set of metalinguistic information related to the event taken in account is wider and try to provide as much information as possible to the algorithm in order to improve its performance. So, for instance, tense and viewpoint aspect are expressed by two attributes. In addition, events are grouped together in classes. The idea is not *per sé* innovative but it is the first time that it appears in an annotation scheme. The classes proposed are related to the semantics of the event to be annotated, and do not attempt to represent the lexical aspect;

- all types of temporal relations are annotated, both implicit and explicit, and between all entities involved, thus aiming to provide a complete temporal analysis of texts. In case the temporal relation is signalled by temporal prepositions or adverbs, this information is annotated and thus made available;
- the extension of the set of entities which may enter into a temporal relation has also an important consequence in terms of graphical representation. The time-line approach is rejected since it is impossible for all events to be assigned a precise point or interval and substituted with a graph-based one;
- the annotation of temporal expressions is improved with respect to the `TIMEX2` guidelines. In particular, temporal expressions are classified in terms of the time object conveyed, that is whether they express a *date*, a *time* or a *complex* temporal expressions. Event-related temporal expressions are not tagged into a unique tag but each element is annotated with a tag of its own. So an expression like *the morning after the attack*, will present three different tags: one for the temporal expression (*the morning*), one for the event (*attack*) and, finally, one for the temporal preposition (*after*) signalling the temporal relation between the temporal expression and the event;

The STAG scheme marks a change in the field of temporal annotation. It is the first time that each element which may contribute the identification of temporal relations is explicitly annotated. Although the notion of what is an event is not elaborated (event are still considered as things which happen or occur in time), the methodology used to annotate eventualities introduce clarity in terms of representational power and of what is the textual extent for annotating these entities. From a certain point of view, this can be considered the first annotation scheme completely conceived for extracting temporal information from texts.

Finally, an important element introduced by Setzer (2001) is represented by the methodology proposed to evaluate the annotated texts with temporal relations. The annotation of temporal relations allows alternative equivalent taggings because what is annotated are *relations* between multiple strings (i.e. events and temporal expressions). For instance, consider this situation, where two events A and B are said to occur at the same time and a third event C is said to occur later. Then, if one annotator marks A and B as simultaneous and C after B, and a second annotator marks A and B as simultaneous as well, but C after A, these two annotations would not differ in terms of the annotated temporal relations. Nor they differ if a third annotator marks A and B simultaneous and C after A and C after B. To provide an account of this phenomenon, Setzer proposes a semantic principle for comparing temporal annotations. This principle is represented by the temporal closure of an annotated text as being the deductive closure, i.e. the set of all temporal consequences which may be drawn from the annotation using a set of inference rules which capture essential properties of the temporal relations, like the ones we have illustrated in chapter 2. Thus, two annotations are said to be equivalent if their temporal closure is equivalent. Using this measure of agreement between the annotators, the three annotations of the temporal relations between A, B and C presented above are exactly the same.

4.2.1.1 TimeML and TimeBank: an annotation standard and a reference corpus

TimeML[11] (Pustejovsky et al., 2003c) is so far the most complete annotation scheme for extracting temporal information from texts. It is the result of a DARPA founded workshop which has now evolved into a proposed ISO international standard: ISO-TimeML.

The innovations presented in TimeML all aim at creating a robust specification language for extracting events, temporal expressions and temporal relations in texts/discourses. As for eventualities, TimeML keeps the definition presented in STAG and its annotation methodology (i.e. the head of the phrase coding the event) but it extends the set of elements expressing an eventuality to include nouns, adjectives, predicative clauses and even prepositional phrases. Moreover, for the first time states are annotated, though only *temporally related* ones (this means that a permanent state like *being tall* is not annotated). All eventualities are annotated using the `EVENT` tag. The distinction among the different types of eventualities is performed by the `class` attribute, which extends the number of classes proposed by Setzer (2001).

The annotation of temporal expressions is further improved to obtain the most specific representation of their semantics and extends and overcomes some aspects of the `TIMEX2` tag, in particular for the normalization process and in terms of the textual extent of the tag.

As in STAG, TimeML has a reserved tag for the class of signals, the `SIGNAL` tag which comprises all those linguistic elements, like prepositions, adverbs, conjunctions and similar, which, either explicitly or implicitly signal the existence of a relation, not necessarily temporal, between two entities, being two eventualities, two temporal expressions or a temporal expression and an eventuality.

The most important feature of TimeML is represented by three link tags, called `TLINK`, `SLINK` and `ALINK`. These tags are non text consuming tags, but are XML pointers which link the annotated temporal entities and associate a relation type accordingly. The links are particularly useful since:

- they keep a separate representation between the temporal entities, i.e. the temporal expressions and eventualities, and their relations, thus allowing the use of the same annotated corpus for different tasks. For instance, a system implementing the TimeML specifications, can be separately evaluated on its performance with respect to event detection, temporal expression recognition and normalization, and on the different types of relations which may holds between these entities;
- the use of a link to annotate temporal relations, namely the `TLINK`, allows to annotate both intersentential and intrasentential temporal relations between any event-denoting expression (or temporal expression);
- the presence of the `SLINK`, for subordinating relation between eventualities, and the `ALINK`, which expresses a phasal relation between aspectual verbs and their arguments, allows to annotate those contexts where a temporal relation cannot be determined, but there exists a relation between the entities involved. The ability to distinguish these contexts is extremely important for automatic systems to improve their performance and robustness.

TimeML, as most annotation schemes, is theory neutral but one of its main insights is represented by its powerful descriptive framework where all the theoretical elements which have been identified as responsible for coding temporal relations are taken into

[11] http://www.cs.brandeis.edu/ jamesp/arda/time/timeMLdocs/TimeML12.htm

account and made explicit during the annotation process. Algorithms using a TimeML annotated corpus for training are presented with all the necessary and sufficient information to obtain (theoretically speaking) good results for retrieving temporal relations, no matter the way they are implemented. For reasons of clarity, we have put in appendix C a comprehensive description of the specifications of TimeML and its adaptation to Italian, including some annotated examples.

One of the main results of the TimeML project is the creation of a reference corpus of English language for events, temporal expressions and temporal relations: the TimeBank[12]. The actual release of the TimeBank (TimeBank 1.2), though not big in size (it contains almost 61,000 non-punctuated items from 183 articles), has offered to the C.L. community a reliable and re-usable language resource for training algorithms and comparing over an objective basis their performance. Some of the most interesting results deriving from the creation of the TimeBank are represented by the validation of the related annotation scheme. As we have illustrated above, one of the main insights of TimeML is its descriptive power and the annotation methodology proposed, according to which the *markables*, i.e. the elements which are the focus of the annotation process, are kept separated and then linked by means of pointers. This procedure allows to evaluate the validity of the annotation scheme both on a global level but also on the annotation of each different tags.

The evaluation of the reliability of annotation schemes has now become a standard practice. Nowadays, no annotation scheme is made publicy available without its own evaluation. This practice is necessary because in order to be used, first to create corpora and then to train/implement algorithms, annotation schemes must be coherent and, most importantly, their representational power must be rightly finely grained to allow a reasonable agreement among human annotators. The information which one can obtain from the evaluation process of annotation schemes is twofolded: on the one hand, evaluation informs on the reliability of the annotation schemes: the higher the inter-annotator agreement[13], the more reliable the annotation scheme, and, on the other hand, on the difficulty of a specific annotation task, where the lower the inter-annotator agreement, the harder the task.

The TimeBank has been evaluated on a subset of 10 articles by two experienced annotators. To measure the agreement on tag extents, the average of precision and recall were computed with one annotator's data as the key and the other's as the response. The tag extent for link tags was defined as the combined tag extents of the two linked events and times. The figures are reported in Table 4.2 on the next page.

As the figures illustrate, TimeML qualifies as a reliable scheme. The granularity of its descriptive power does not diminish the quality of the annotation. Moreover, all tasks, except the annotation of temporal relations (`TLINK`) can be performed with no major difficulties by human annotators. The low figures for the `TLINK` are due to the large number of event-pairs that can be selected for specifying temporal links. This issue can be resolved by providing strict annotation guidelines for temporal relations, for instance, annotators can be instructed to annotate some temporal relations, and leave others to be computed by inferencing mechanisms. This may result in a non 100% correct annotation of all temporal relations, but would increase the agreement and, thus the coherence, of

[12]http://www.timeml.org/site/timebank/documentation-1.2.htmlval

[13]It is a standard to measure the inter-annotator agreement by using the K-value. This measure derived from statistics has been proposed to be valid for annotation schemes by Carletta (1996). The K-coefficient measures the agreement of the raters who each classify N items into C mutually exclusive categories. Its values range from 0, no agreement, to 1, complete agreement. Reliable annotation schemes are those with K-value ranging from 0.68 to 1.

Table 4.2: *Evaluation figures of the TimeBank 1.2.*

TimeML tags	Agreement (exact match)
TIMEX3	0.83
SIGNAL	0.77
EVENT	0.78
ALINK	0.81
SLINK	0.85
TLINK	0.55

an annotated corpus.

Algorithms implementing TimeML: the 2007 TempEval competition One of the main advantages of the creation of the TimeBank is represented, as already stated, by the availability to the C.L. community of a reusable language resource against which the performance of competing algorithms can be evaluated. This was the aim of the SemEval 2007 Task 15 (TempEval Task). TimeML and the TimeBank have already been used as training and test data for automatic temporal annotation tasks in previous works (Mani et al., 2006b; Boguraev & Ando, 2005; Pan et al., 2006; Bethard & Martin, 2006) but this is the first open evaluation challenge in the area of temporal annotation. One of the main interesting points of the TempEval task is that it avoids the complexities of full temporal annotation, as it was attempted in previous works, and proposes a stage-based approach in the accomplishment of the various tasks.

The evaluation exercise was performed on three limited tasks:

- Task A: it addresses the identification of temporal relations holding between temporal expressions and events in the same sentence;
- Task B: it addresses the identification of temporal relations holding between the Document Creation Time (DCT) and the events;
- Task C: it addresses the identification of temporal relations holding between the main events[14] between adjacent sentences.

For tasks A and B a restricted set of event terms were identified – those whose stems occurred twenty times or more in TimeBank. The ultimate goal of the systems was the identification of the temporal relations, but each system, in fact, had to be able to correctly identify events and temporal expressions according to the TimeML specifications. As for temporal expressions the additional task of normalization is to be performed as well. Temporal relations were reduced to six relations with respect to the fine grained distinctions of TimeML: *before*, *after*, *overlap*, *before_or_overlap*, *overlap_or_after* and *vague*.

Six systems took part in the competition, three of them used statistical techniques only, one a rule-based approach and the remaining two a hybrid approach (machine learning plus rule-based heuristics). The systems' performance was measured in terms of precision, recall and f-measure. The f-measure for Task A ranges from 0.34 to 0.62. For Task B, from 0.66 to 0.80 and for Task C from 0.42 to 0.55. The winning systems was the hybrid system WVALI (Puşcaşu, 2007) which relies on sentence-level syntactic tree generation,

[14] A main event is identified with the syntactically dominant verb in the sentence

bottom-up propagation of the temporal relations between the constituents, a temporal reasoning mechanism, and on conflict resolution heuristics.

4.3 Concluding Remarks

In the previous sections we have presented a sample of influential approaches whose aim is that of resolving the issue of temporal processing of text/discourse. Unfortunately, due to reason of space and time, it is impossible to present a detailed revision of all the works and related proposals which have been developed in this field of research.

A striking observation which emerges from the analysis of all these works is the complete lack of a unitarian framework, in particular from a theoretical point of view, for explaining and predicting the interactions of the various elements which are involved. Different authors and theories have tried to explain this process by focussing only on one of these elements, either tense, or aspect (in particular lexical aspect), or discourse structure. Some elements are always missing or disregarded and used as critical remarks by other authors.

It is our opinion that the elaboration of a robust computational model is a necessary condition in order to give rise to systems which are able to automatically extract temporal relations from texts/discourses. A sort of indirect proof to this statement is represented by the winning algorithm of the 2007 TempEval competition. The WVALI system, in fact, is a hybrid system which implements machine learning techniques and rule-based heuristics. Though not explicitly stated, the presence of rule-based heuristics suggests the existence of a general model for processing temporal relations behind the system. A model is also necessary to interpret the mistakes of the algorithm itself. One of the main shortcomings of pure machine learning systems is the lack of a theoretical model behind their implementation. Their development is purely statistical and mechanical, usually based on the combination of a series of features which may prevent a correct interpretation of their mistakes. This critics, however, must not be interpreted as a refusal of machine learning techniques. These techniques are useful and computationally valid, because grounded on real linguistic data (do not forget that machine learning algorithms have developed as an effect of the creation of annotated corpora), but natural languages, though regular, have exceptions or particular structures. It is the task of a model to explain these behaviours and identify strategies to deal with.

The revision of the theoretical models in the first part of this chapter has provided us with useful points for the elaboration of the computational model, in particular, the following statements seem to be valid:

- tense has a referential value, though with respect to a relevant context. The idea of tense as a discourse anaphor can be preserved, since it contributes to the cohesion of a text/discourse;
- tense is the primary source of information for the identification of temporal relations, though not the only one;
- it exists a role of the general discourse structure, which in some occasions seems to overcome the linguistic information coded by the tenses, and whose processing may guide the ordering of events. Nevertheless, discourse structure cannot be considered as the primary source of information for the identification of temporal relations;
- temporal relations are inferences made by the interpreter during his/her incremental process of understanding of the text/discourse. They are not coded by purely prag-

matic factors, but seem to qualify as complex inferences built by the combination of linguistic (co-textual) and extralinguistic (con-textual) information which contribute to determine the informative content of a sentence;

- a complete semantic representation of the elements contributing to the processing of temporal relations in a text/discourse can be successful only under a unitarian framework;
- real language data cannot be ignored. As the development of annotation schemes has demonstrated, it is now compelling to "keep an eye on the data". Theories and models must be data grounded in order to be real models of natural language;
- the need of models is a necessary element for the implementation of robust systems. A good practice in this field of research, as in many others, should be the following: modelization, system's implementation and evaluation, error analysis,, and if necessary, re-modelization.

Recently, Kehler (2000) has proposed an attempt to a unifying framework for English by merging together the proposals made by temporal anaphora theories and Lascarides & Asher (1993). Though interesting and innovative, his proposal is somehow too simplistic, since he did not take into account the contribution of other elements from the grammar, like viewpoint aspect, and from lexicon, as the event actionality. In addition to this, no analysis of the contribution of other elements such as connectives and temporal expressions is undertaken.

The next chapter will be devoted to the presentation of our computational model, which represents an attempt to propose a unitarian framework for computing temporal relations in Italian texts/discourses.

Chapter 5

An Empirical Model for Temporal Relations in Italian Texts/Discourses

5.1 Introduction

This is the final chapter of the first part of this work. Its aim is that of providing a computational model for temporal relations processing and understanding in texts/discourses of Italian news articles. The main interesting proposals of our model are the following:

- the development of an empirical unitarian framework which takes into account the contribution of all the sources of information participating in the inferencing process of computing temporal relations;
- the possibility of varying the granularity level of the temporal representations, i.e. the set of events and their temporal relations, from precise temporal value to more abstract ones.

The chapter is organized as follows: in section 5.2 we will present a cognitive experiment inspired by Mani et al. (2006b) which has provided us with the empirical data for the development of the unitarian framework implemented into the model. Section 5.3 will be devoted to the description of the model itself and of the mechanisms governing its functioning. The creation of a prototype implementing the whole system is not achieved to due reason of time and lack of data for evaluation. However this does not diminish the scope of this work since, as already stated, the creation and validation of a computational model is the first step to be accomplished in order to create robust algorithms for automatic processing of natural language.

5.2 Linguistic information *vs.* Pragmatic mechanisms: an experimental study

Representing and reasoning about time and events are central elements in the construal of our personal and historical lives. Experiences in the world are at the basis of various inferences about events and their temporal organization. Psychological studies had shed some lights on these inferential processes (see also chapter 2, section 2.2) but only recently some studies (Moeschler, 2000) have analyzed how temporal relation inferences are performed. As we have illustrated in chapter 3, natural languages have a variety of devices to communicate information about events and their temporal organization, such as tense, viewpoint aspect markers, temporal expressions, signals, and each of them plays a different role in different languages.

One of the main issues which has not been answered so far is how the various linguistic devices which languages have at disposal to codify temporal relations interact both with each other and, most importantly, under which conditions they are autonomous, i.e. able to codify a temporal relations between eventualities without the support of non-purely linguistic elements, like for instance discourse structure or pragmatic, world-knowledge based inferences. In chapter 3, we have illustrated a compositional account of how tense, aspect and actionality contribute to inferencing of temporal relations. Though that description is theoretically correct, it does not necessarily reflect how this grammatical and lexical information interacts together. It simply illustrates what is its contribution to the creation of this kind of inferences but it does not tell us anything about the probable existence of an order of application of this information. We point out on the idea of an order of application because we think that a robust computational model for processing temporal relations should be organized in modules, each of them specialized in retrieving a certain kind of information. This kind of organization does not aim at reflecting the human organization of the brain/mind but it aims at creating a principled way of processing different types of information in a correct way and making them available to the system only when needed, so that to improve its computational efficiency. A modular organization also avoids complicated solutions which aim at a complete representation of all information which are difficult to be achieved and sometimes unnecessary.

Recent psychological studies (Zwaan, 1996; van der Meer et al., 2002; Kelter et al., 2004) have established correspondences between the formal aspect of the temporal structure of discourse and the mental representations interpreters built. The order in which

> events are narrated, their chronology, [...], the narrator's explicit shifts in reference times, marked by temporal adverbials, are all important features used in constructing mental models of narratives. [..] [T]hese features are of the sort that can be constructed automatically by information extraction systems [Mani (2007): 129].

Knowing how these features interact with respect to their different nature, i.e. linguistic *vs.* world-knowledge based, is a necessary step to have robust automatic extraction systems.

In order to develop the model we have decided to investigate through an experimental study if it is possible to determine a hierarchical order of application of the various linguistic and non-linguistic information and under which conditions purely linguistic information is necessary and sufficient to determine the temporal relations between the various entities in analysis. The aim of this study is that of identifying how deep must the computation of information go, that is how many modules must be activated in order to obtain a reliable temporal representation of the text/discourse.

Recalling Figure 3.4 on page 71 in chapter 3, the data should offer us a set of cues to provide a processing order of the various sources of information involved in the inferencing of temporal relations. In order to discover the borderline of the independence of the linguistic information we have concentrated on tenses. It is trivial to claim that two consecutive events with the same tense are ordered by making use of other sources of information, either linguistic - like the presence of temporal expressions, or the relationships between actionality values - or non-linguistic - like the common sense knowledge. Theoretically, deep shifts in tense, such as a shift from a *passato composto* to a *trapassato I*, seem to favour an informational salience of the tense as a necessary and sufficient condition for the identification of the temporal relation holding between the two events. An informational salience which should be preserved also in presence of other kinds of linguistic information, like the presence of explicit signals of temporal relations (i.e. a temporal adverb like *dopo* [after]) or temporal expressions. If such hypothesis were confirmed by the empirical data, we could be able to elaborate a more reliable framework on the various referring properties of tenses and on the interaction, in term of processing salience, between purely grammatical information (tense) and lexical linguistic information (temporal expressions, signals and lexical aspect). Finally, the analysis of the agreement on the temporal relations between the subjects involved in the experiment would offer us a threshold measure of the best system performance to be expected. In fact, provided the inferential nature of temporal relations, we expect to obtain a varying level of agreement on the relations: relative quite high values in presence of clear linguistic information, like temporal expressions, shifts in the verb tenses and shifts in the lexical aspect of the eventualities, and relative low values when these kinds of information are lacking, since the reconstruction of temporal relations is based on world knowledge and common sense reasoning, elements which may vary, in a certain measure, from speaker to speaker.

5.2.1 Methodology

In order to verify our hypotheses and to obtain cues on the way the model should be implemented we have elaborated a test which has been submitted to two groups of subjects: a first group of 29 subjects, none of them having knowledge in linguistics (Group 1), and a second group of 6 subjects, all MA students in Linguistics at the University of Pavia (Group 2). The two different groups will offer us different levels of information in terms of the granularity and organization of the sources of information at play for reconstructing the temporal relations.

The two groups were submitted with comparable, though not identical, test data, provided their different backgrounds and the level of metalinguistic analysis required. In both experiments eventualities at moods different than the indicative have been excluded. In the remaining of this section, we will present the characteristics of the test data in details.

Experiment 1 - Group 1 Group 1 was submitted with a test made up of 52 couples of sentences, 33 of which have been automatically extracted from our corpus and 19 which are human-modified variations of the corpus-based ones. Every couple of sentences corresponds to a coherent discourse segment or unit. Each couple was presented to the subjects with the main eventuality in each sentence (which was a verb) highlighted. Each couple of sentences has been modified so that the two sentences could look as if they were two unrelated main sentences. To clarify, a couple of sentences like the one in example 5.1:

(5.1) La compagnia olandese Klm ha definito l' accordo con Aeroporti di Roma per la subconcessione del servizio passeggeri, seguendo cosi' l'esempio dell' americana United che dall'inizio del mese è autorizzata al selfhandling delle operazioni a terra di assistenza ai passeggeri.

The Dutch airline company Klm has reached an agreement with Aeroporti di Roma for the subconcession of the passangers' service, thus following the example of the American company United which from the beginning of this month has been authorized to the selfhandling of all land operations of passangers' assistance.

was presented to the subjects as in 5.2:

(5.2) La compagnia olandese KLM **ha definito** l' accordo con Aeroporti di Roma per la subconcessione del servizio passeggeri.

L' americana United **è autorizzata** al selfhandling delle operazioni.

The Dutch airline company Klm ***has reached*** *an agreement with Aeroporti di Roma for the subconcession of the passangers' service.*
The American company United ***is authorized*** *to the selfhandling of all land operations.*

The subjects were asked to temporally order the two eventualities in each couple. To improve the reliability and avoid inconsistency, the subjects had to choose the temporal relations among a restricted set of 5 pre-determined temporal relations, namely BEFORE, AFTER, SIMULTANEOUS, OVERLAP, and NO TEMPORAL RELATION. Furthermore, we have not allowed binary interpretations of the temporal relations, thus if the relation between two eventualities is "e_1 BEFORE e_2", the subjects cannot choose the inverse relation, that is "e_2 AFTER e_1". The particular way in which the test sentences have been presented to the subjects aims also at verifying to what extent the computation of temporal relation is a by-product of the computation of the general discourse structure. It is our opinion that in case a couple of sentences is not recognized as a text/discourse, i.e. a coherent and cohesive whole, the subjects will choose the NO TEMPORAL RELATION value, though all the original segments are coherent text segments where there exists a temporal relation between the two eventualities.

In order to discover the existence of a hierarchical order of application of the various sources of information, in terms of informational salience, and also to determine in a reliable way under which conditions linguistic (grammatical and lexical) information is autonomous (i.e. necessary and sufficient) to determine the temporal relations of the eventualities with respect to non-purely linguistic (i.e. con-textual[1]) one, the subjects were asked to state what source of information had helped them mostly in the identification of the temporal relation. To avoid inconsistencies and keep the experiment under control, we provided the subjects with a predetermined set of possible answers, namely TENSE, TEMPORAL EXPRESSIONS and NOT SPECIFIED. This relative small group of sources of information allowed us to investigate:

- the role and independence of purely linguistic information: the choice of either TENSE or TEMPORAL EXPRESSIONS respect to NOT SPECIFIED as the primary sources for the identification of a temporal relation will offer important cues on the constraints under which linguistic information is more salient than co-textual information. In this experiment, the value NOT SPECIFIED functions as a sort of waste basket for all sorts of information whose granularity level would require the knowledge of experts or advanced student in Linguistics. In fact, this value could be used to signal both linguistic information, like a shift in the lexical aspect (i.e. actionality) of the two eventualities, and context-dependent or pragmatics one, like the activation of scenarios. To keep control on this value, the subjects were asked to leave a comment explaining why they have used it;
- an evaluation of the (hypothetical) hierarchical order of application of the linguistic information: tense and temporal expressions are both linguistic expressions, but they are different in terms of their status. In fact, tense codify grammatical information, by means of the tense-aspect morphemes, while temporal expressions codify lexical information. In those cases where both these sources are present, the preference for one respect to the other will offer cues on their order of application;

[1]By means of con-textual information we refer to all kind of information based on commonsense knowledge but activated by textual elements.

- tenses' temporal polysemy: as we have illustrated in chapter 3, section 3.3.2.1, tenses do not present the same properties and characteristics. This suggests that they may also differ in terms of the degree of grammaticalization of the temporal relation(s) when they occur in a text/discourse domain. Particular patterns of tense sequences could be associated with one or more temporal relations. For instance, a tense pattern like *trapassato I* - *passato composto* seems to express a temporal relation of precedence (i.e. *trapassato I* BEFORE *passato composto*) in a unique manner. On the contrary, tense patterns such as *imperfetto* - *passato composto* or *passato composto* - *passato composto* have a tendency to code more than one temporal relation. We propose that the grammaticalization level of temporal relation(s) of the Italian tenses may be inferred by the number of the possible temporal relations associated to the various tense patterns: the fewer the temporal relations associated with a tense pattern, the more grammaticalized the temporal relation. A further result of the analysis of the tense patterns will also provide us with information about the cohesive properties of the various tenses. Provided the structure of the test data, it will be interesting to observe which tense patterns the subjects have mainly associated the NO TEMPORAL RELATION value. Recalling the fact that tenses are referential, i.e. they all have a *Rpt*, the idea that only some tenses have all the necessary and sufficient (i.e. grammaticalized) information which could offer a principled way to set the *A* textual parameter (Table 3.4 on page 58, chapter 3) could be supported[2].

In the selection process of the tense sequences we concentrated on the Past due to the fact that, on the one hand, it is by far the most used temporal dimension, as a corpus exploration has shown and, on the other hand, it presents the largest number of tense forms with respect to the other two temporal dimensions, i.e. Present and Future. However, the variation in the surface form of the past tenses very often does not correspond to a difference in temporal meaning as well. Taken in isolation sentences at the *passato composto*, *imperfetto* or *passato semplice* have all the same configuration of E and S, namely $E \prec S$. The only shift in tense form and in meaning is represented by both *trapassato*s (*trapassato I* and *II*), which introduce a further deictic point, R, which mediates the relationship between E and S, i.e. $((E \prec R) \bullet (R \prec S))$.

The 33 original tense sequence patterns are the followings: *passato composto* - *passato composto*, *passato composto* - *trapassato I*, *passato composto* - *imperfetto* and *passato composto* - *presente*. Provided our analysis of tense, we consider as same tense sequences, patterns of the kind *passato composto* - *passato composto* and *passato composto* - *imperfetto* (and viceversa), while a tense shift is represented by a sequence *passato composto/imperfetto* - *trapassato I* (and viceversa). A shift in tense, in fact, is a different configuartion of the relationships between E, S and, when present, R. Tense shifts are important cues about the existence of a particular temporal relation. The working hypothesis is that in presence of a shift in tense the agreement of the subjects should improve on the identification of the temporal relation and provide a principled way to set the A parameter. However, provided the fact that we are analyzing tense in a particular textual domain, i.e. disocurse sequence, in this domain the *imperfetto* can represent a smooth tense shift. Due to the the relationship between the A and *Rpt*, ($Rpt \equiv A$), particular attention we will be paid to tense patterns involving the *imperfetto*. In order to verify

[2]The proposal of tenses' temporal polysemy is constructed by taking into account only the relations among tenses and their semantics and assuming that the associated viewpoint values are the default ones, as illustrated in Table 3.5 on page 72, chapter 3.

if these tense patterns tend to grammaticalize a temporal relation[3] we have manually modified two couples of sentences from *passato composto - passato composto* to *passato composto - imperfetto*. As for this kind of tense sequences, the main interesting results will be obtained by the analysis of the sources of information and by comparing them with the data of the subjects of the Experiment 2, provided the influence of the viewpoint aspect on the tense form of the *imperfetto*. All tense are at the active diatesis with the exception of the *presente*, which is at the passive.

The modification introduced with respect to the original sentences are of two kinds:

(i.) same sequences of tenses but presence of a temporal expression in each sentence of the couple; e.g.:

(5.3) La Galbani **ha registrato**$_{passato\_composto}$ un fatturato di circa 2mila miliardi (+7% secondo un primo consuntivo).
L'Ifil ne **aveva ceduto**$_{trapassato\_I}$ un altro 10% alla Bsn.
Galbani ***reported*** *a net income of about 2 billion (+7% according to a preliminary balance.* Ifil **had sold** another 10% of it to the Bsn.

(5.4) La Galbani **ha registrato**$_{passato\_composto}$ un fatturato di circa 2mila miliardi nel 1991$_{temporal_expression}$ (+7% secondo un primo consuntivo).
L'Ifil ne **aveva ceduto**$_{trapassato\_I}$ un altro 10% alla Bsn
all'inizio dello scorso anno$_{temporal_expression}$.
Galbani ***reported*** *a net income of about 2 billion* in 1991 *(+7% according to a preliminary balance.* Ifil **had sold** another 10% of it to the Bsn
at the beginning of last year.

The temporal relation of the couple in the example 5.3 is, normally, interpreted as a precedence relation (*ha registrato* [reported] BEFORE *aveva ceduto* [has sold]). The source of information which allows us to infer such a relation is grammatical, i.e. a tense shift from the first to the second event. This should be reflected by the judgements of the subjects who should prefer the TENSE value as the source of information for the identification of the temporal relation. In the example 5.4 the temporal relation between the eventualities is exactly the same, although in this case the subjects face a further source of information due to the presence of a temporal expression (plus a signal) in each of the sentences of the couple. Although the two sources of information, grammatical (represented by the tenses) and lexical (represented by the temporal expressions), are not conflicting with respect to the temporal relation, they represent conflicting information as far as the choice of the sources is concerned. A working hypothesis based on the revision conducted in chapter 4 suggests that in these cases the subjects should still prefer the value TENSE, considering the temporal expressions as an additional and redundant information. If the data will confirm our expectations, we will obtain important cues on the constraints on tense salience and on the order of application of the sources of information taking part in the determination of temporal relations.

(ii.) maintenance of the same tense sequence in both sentences but change of the order of presentation of the eventualities in the couple; e.g.:

(5.5) L'assemblea degli azionisti della Siat **ha rinnovato**$_{e1}$ il consiglio di amministrazione, confermando presidente Enrico Piantà.
L' assemblea **ha approvato**$_{e2}$ il bilancio '85 chiuso con un utile di 585 milioni.

[3]The entire set of 52 sentences present a total of 12 sequences *passato composto - imperfetto* balanced on the order of presentation of the two tense forms.

The Siat stock holders assembly has renewed the board of directors, confirming Enrico Piantà as president. The assembly has approved the balance, closed with a gain of 585 millions.

(5.6) L' assemblea **ha approvato**$_{e2}$ il bilancio '85 chiuso con un utile di 585 milioni.
L'assemblea degli azionisti della Siat **ha rinnovato**$_{e1}$ il consiglio di amministrazione, confermando presidente Enrico Piantà.

The assembly has approved the balance, closed with a gain of 585 millions. The Siat stock holders assembly has renewed the board of directors, confirming Enrico Piantà as president.

The evaluation of the subjects' judgements on the same couple which differs from its counterpart only for the order of presentation of the eventualities will provide us with a series of information on the existence of preferred temporal relations related to the order of presentation of the eventualities, and on the influence and role of the contextual information. For instance, we expect that couples like those in 5.5 and 5.6 should be judged by the subjects as having the same temporal relation since the change in order of $e1$ and $e2$ should not suggest a change in the temporal relation. The two eventualities are not related by any special relationships but describe two independent events which occurred during a bigger event, i.e. a meeting. On the other hand, if the change of the order of the eventualities correlates with a change of the temporal relation, we will face cases where the two eventualities stand in particular relation, like for instance a causal or an elaboration relation. These relationships are based on commonsense knowledge or encoded into the discourse structure by means of rhetorical relations. In both cases special heuristics are requireed to automatically retrieved them.

As for tense, we have preferred not to introduce manual changes but present to the subjects similar sentences in terms of discourse relations between the eventualities (but with different tenses, of course!). This is due to the fact, that when introducing a shift in tense[4] it is often necessary, in order to maintain the discourse coherence, to introduce some temporal connectives, like *già* [already], which could influence the subjects in their judgements.

During the subministration phase, in order to facilitate the analysis of the data and avoid biases among the subjects, the 52 couples of sentences have been divided into two subtests, Test 1 and Test 2. The two subtests differentiates each namely with respect to the distribution of the three types of modifications we have described above. In Table 5.1 we report the main characteristics of the two subtests.

Table 5.1: *Experiment 1 - Characteristics of Test1 and Test2*

Test 1	**Test 2**
high number of temporal expressions	low presence of shifts in tense
presence of shifts in tense	shifts in tense and temporal expressions
low number of same tense pattern sequences	high number of same tense pattern sequences

The original group of 29 subjects has been divided into two subgroups, Group 1A and Group 1B, to whom we have separately submitted the two subtests. In order to improve

[4]The *imperfetto* does not represent a shift in tense but a smooth shift. Shifts in tense are marked by a different configuration of the E, S, and, when present, R moments.

the accuracy of the data and avoid that the modifications introduced could influence the answers, the the subtests have been submitted at different times. First, Test 1 was submitted to Group 1A and Test 2 to Group 1B. After a week, Test 2 was submitted to Group 1A and Test 1 to Group 1B. The subjects did not receive a training phase, but were provided with a manual with detailed instructions and examples on how to accomplish the task. The test were submitted in remote mode by means of e-mails.

Experiment 2 - Group 2 Group 2 was submitted with a set of 33 couple of sentences automatically extracted from the corpus. The main differences with respect to Experiment 1 are:

- all the couples are presented to the subjects on a "as they are" basis. This means that we have limited to control if they are coherent text segments, to highlight the two main eventualities, and balance the type of tense patterns. No further modification was performed;
- the type of tense patterns was extended, including past tenses (*passato composto*, *trapassato I*, *passato semplice* and *imperfetto*), the *presente* and the *futuro semplice*. Instances of passive diatesis occur, namely with the *presente*;
- extensions of the possible values for the sources of information, by including finely grained distinctions. In this experiment, the whole set of possible sources of information is TEMPORAL EXPRESSIONS, TENSE, SIGNALS, ASPECT, SEMANTICS and NOT SPECIFIED. The value ASPECT refers to viewpoint aspect, while with SEMANTICS we refer to the lexical meanings of the eventualities which can give rise to the activation of scenarios, causal relations and others relations based on commonsense knowledge. We did not asked the subjects to distinguish the role of the lexical aspect as a distinct feature *per sé*.

The use of unmodified text segments is necessary to allow the subjects to perform the required fine-grained distinctions among the sources of information and to verify the role of discourse structure.

No subtests or subgroups have been created and the subministration took place all at once. As in the Experiment 1, the subjects did not received a training phase, but were provided with a manual with detailed instructions and examples on how to accomplish the task. The test was submitted in remote mode by means of e-mails.

The data collected will provide us with empirical results for the elaboration of the computational model. It is important to point out that the model will result from a combination of the two experiments. In this way, we could obtain a clearer picture of the ways in which temporal relations are computed and of the conditions under which the various sources of information we have identified are at play and, in particular, when they are necessary and sufficient or only necessary. The role of Experiment 2, in fact, is that of widening and balancing the perspective which could result from the highly controlled situation of Experiment 1.

5.2.2 Data Analysis

Both experiments have been evaluated by using the percentages of agreements among the subjects and the K-statistic[5]. For clarity's sake we will present the results of the two

[5]As already stated, the K-statistic measures the agreement between N raters who each classify N items into C mutually exclusive categories. It is thought to be a more robust measure than simple

experiments separately, and then we compare them.

5.2.2.1 Experiment 1 - Data

The agreement on the first task, i.e. the identification of the temporal relation between the highlighted eventualities, has been measured by means of the K-statistic. Both Test 1 and Test 2 obtain a global K value of 0.49. This value is in line with previous experiments (namely Mani et al. (2006b)) and confirms that the task of identifying temporal relations is not a trivial one due to the fact that crucial information is often left implicit. This low value can also be due to the relative fine-grained set of temporal relations available to the subjects. As Mani et al. (2006b) have shown reducing the set of temporal relations correlates with an increase of agreement (in their experiment the initial K changed from a 0.50 to 0.61, when reducing the distinction between *Entirely Before* - *Equal* and between *Entirely Before* and *Upto* which barely may correspond to the OVERLAP relation in our experiment). However, if we compute the performance of the two groups on each of the subtest, it is interesting to notice that this value can be improved. The K value, in fact, rise to 0.50 when Group 1 took Test 2 and to 0.51 when Group 2 took Test 1. This improvement suggests that a sort of training effect could have influenced the subjects by helping them to familiarize with the task. The relative higher value of Test 1 reached from Group B can also be due to the internal structure of that subtest, which as we reported in 5.1, has more temporal expressions and shifts in tense which offer important cues for the identification of particular temporal relations. Nevertheless, we can quite reliably state that the experimental data support the idea that everyday speakers, though competent in assigning a temporal relation between two eventualities (all subjects have always provided an answer), normally disagree on *what* is the actual temporal relation. This observation questions the level of fine-granularity that an algorithm whose aim is that of temporal processing of text/discourse should reach - and of annotation schemes as well.

The data are more interesting when we consider the various modifications we have introduced and when the K is computed for subsets of couples presenting the particular characteristics we have described. For clarity's sake we report them separately in the remaining of this section.

Temporal Expressions The role of temporal expressions is that of signaling a fixed point in time or an interval which anchors an eventuality and thus facilitates its ordering. In our data, we have 20 couples, representing the 40% of the total, which have at least a temporal expression. 10 of them have two temporal expressions and represent the manually modified couples, as illustrated in point (i) in the above section. All of them have the role of temporal localizers of the E moment of the eventualities with which they appear. In Table 5.2 on the following page we report the K values for those sentences with temporal expressions for both Test 1 and Test 2. The row "Presence of TimExes" refers to the 20 couples of sentences presenting at least a temporal expression; the row "TimExes in both sentences" refers to the 10 manually modified couples which is to be compared with the "Couples without TimEx" row which include the original corpus-extracted sentences:

As the figures show, and as expected by our hypotheses, the presence of temporal expressions, in general, improves the agreement of the subjects on the identification of a temporal relation (K = 0.66). The manually modified ones outperform both their corresponding couples without temporal expressions (K = 0.69 *vs.* K = 0.49) and those

percent agreement calculation since it takes into account the agreement occurring by chance.

Table 5.2: *Experiment 1 - Temporal Expressions: K coefficients on temporal relation.*

Sentences' Structure	**K value**
Presence of TimExes	0.66
TimEx in one sentence	0.60
TimExes in both sentences	0.69
Couples without TimEx	0.49

with just one temporal expression in it (K = 0.60). However, and quite surprisingly, the presence of two temporal expressions has an agreement still relative low compared with the idea that if both eventualities are anchored in time in an explicit way, then the computation of their temporal relation should be relatively easy. To explain this result, it is necessary to go into the details of the various temporal expressions which we have inserted. None of them is an absolute temporal expression, of the kind DD - MM - YYYY, they are all relative ones, e.g. *ieri* [yesterday], *lo scorso semestre* [last semester]. These expressions require the interpreter to compute the absolute value and then to put them in relation. The decision to insert only relative expressions is strictly related to the corpus study which has preceded the creation of the test data. As it emerged, the presence of absolute expressions is almost null inside a text/discourse. The ones we have identified usually correspond to the Document Creation Time (henceforth DCT). The values we have obtained are a consequence of this computation effort that the subjects were required to perform, according to the type of temporal expression and their relation may have created biases in taking a decision on which temporal relation to choose when two of them are present. A verification of this claim emerges if we consider the percentages of the judgements expressed by the subjects. In both cases, either when one or two temporal expressions are present, the agreement of the subjects on the existence of a temporal relation between the eventualities is of 96.40%. The discrepancies between these two data is represented by the fact that a relevant minority of the subjects was unable to correctly compute the information of the temporal expressions and in some cases was even unable to correctly identify the relation between the two temporal expressions. These elements reflect on the computation of the K, which is a measure of the agreement per class (where in this case each class is a temporal relation).

Further information on the role of temporal expressions emerges from the second task of the experiment, i.e. signaling the source of information which mostly helped to identify the temporal relation. Analyzing the percentages of judgements, it emerges that in presence of temporal expressions, the value TEMPORAL EXPRESSION has been chosen 72.50% of times as the main source. On the other hand, the 10 corresponding couples without temporal expressions concentrates on the other two sources, with a preference for TENSE (58.78%) over NOT SPECIFIED (41.22%).

The values are again different when considering those sentences with only one temporal expression and those containing two. In the former case, the temporal expression is not perceived as a salient element for the identification of the temporal relation. In fact, the subjects has marked them as the main source only 23.42% of the cases, preferring by far the value NOT SPECIFIED (44.61%), followed by TENSE (31.97%). These percentages provide us with important elements on the role of temporal expressions. In particular, we can conclude, that when just one temporal expression is present it does not represent the main source of information to compute the temporal relation since most of the computation relies both on con-textual information, i.e. on some form of reasoning based on commonsense knowledge, and tense. In these cases, the temporal expression limits itself to anchoring "its" eventuality in time. On the contrary, when the eventualities are explicitly anchored in time by means of temporal expressions, they qualify the most salient source for the computation of temporal relations. It seems that, first, every eventuality is anchored to its temporal expression, and then the temporal relation is inferred by means of the relation which exists between the two time expressions. So far, then we can conclude that temporal expressions are useful since they improve both the agreement on the existing temporal relation, thus making the computation and the inferencing process easier.

Tense We have already discussed the role of tense in recovering temporal relations. The test have 11 couples of sentences with a tense shift, 7 sequences of *passato composto* - *trapassato I*, 1 *trapassato I* - *passato composto*, 3 *passato composto* - *presente*, and 41 couples with same tense. Of these latter, 29 couples are absolute same tense sequences (28 *passato composto* - *passato composto*, and one *imperfetto* - *imperfetto*) and 12 with a smooth tense shift (5 of the kind *imperfetto* - *passato composto* and 7 *passato composto* - *imperfetto*).

In accordance with our hypothesis, tense shifts improve the identification of a particular temporal relation. Measuring this value by means of the K- statistic, it is interesting to notice how in presence of tense shifts the value is relatively close to that obtained when in presence of temporal expressions (K = 0.63 *vs.* K = 0.66). On the other hand, same tense sequences (both absolute and smooth shifts) obtains a K equals to 0.45, even lower than the global value of all 52 couples (K = 0.49).

A further proof of this positive effect of tense shifts as a trigger of the existence of a temporal relation between two eventualities can be obtained by analyzing the percentages of the judgements, illustrated in Table 5.3.

Table 5.3: *Experiment 1 - Tense: percentages of judgements identifying a temporal relation.*

Tense Pattern		**Value**
Tense Shift	Presence of a Temporal Relation	98.50%
	No Temporal Relation	1.50%
Absolute Same Tense	Presence of a Temporal Relation	92.96%
	No Temporal Relation	7.04%
Smooth Tense Shift	Presence of a Temporal Relation	93.97%
	No Temporal Relation	6.03%

The figures in 5.3 show that tense has a primary role in signaling the presence of a temporal relation. It is interesting to notice that when we are in presence of tense shifts almost every subject has judged that there is a temporal relation between the two sentences. On the other hand, we can observe how there is a relevant increase of the judgements claiming that no temporal relation is present with couples of sentences with absolute same tense while those with smooth tense shift perform slightly better.

These results offer information on the conditions under which a temporal relation can be computed. Provided the structure of the test, i.e. the presentation of the discourse segments as two main sentences with the set of possible cohesive devices reduced to the minimum, it is not surprising that the higher number of couples which have been judged as not expressing a temporal relation is to be found among those with absolute same tense and smooth tense shifts. In fact, in absence of pervasive cohesive devices, as we have tried to reproduce in this experiment, the texture of the discourse segments relies mainly on tense interpretation. Tense creates texture by means of the A parameter which, when set, either relate directly the eventualities or identify the current Temporal Focus of the *Rpt*s. We suggest that the lack of a temporal relation for the couples presenting these tense patterns is due to a failure in the setting of the A textual anchors. This failure may prevent the activation of the mechanisms related to the identification of the existence of a discourse structure between the two sentences of the couple. The interpreter feels the two sentences as violating the Co-operative Principle (Grice, 1975) and the sentences are not perceived as forming a text/discourse. It is in this sense that temporal relations can be considered as a by-product of the computation of the discourse structure. Furthermore, the fact the lowest values are those obtained for absolute same tense sequences, e.g. *passato composto - passato composto*, can be a cue on the limitation of these tense sequences to create texture, i.e. improve the cohesiveness of a text/discourse. These data, together with the K values, also provide us with evidence to the hypothesis that tense sequences involving a shift in the meaning of the tense forms, as it is for sequences of *trapassato I - passato composto*, may present a principled, i.e. grammaticalized, way for setting the A parameter and facilitate the identification of a discourse structure and of temporal relations. It is important, however, to point out that these remarks are not absolute: we are not claiming that the *passato composto* or that the *imperfetto* are tenses which give rise to incoherent texts/discourses or that prevent the identification of temporal relations, on the contrary, we are observing that these tense forms provide the interpreter with a reduced set of information which may be not sufficient to activate the correct interpretation mechanisms. A proposal which we advance from this experiment, is that of a hierarchy of cohesiveness of Past tenses, whereby the *trapassato I* is the highest cohesive tense form, followed by the *imperfetto* and finally by the *passato composto*. However, a comparison with the data of the Experiment 2 is compelling in order to reliably assert this.

The analysis of the sources of information offers other interesting data both in support to the observations and statements made above and also on the mechanisms which govern the activation and identification of temporal relations. We have already seen how the presence of temporal expressions may influence the judgements of the subjects on the choice of the source of information. In order to correctly analyze the role of tense we have first excluded those couples which present temporal expressions. In these cases, all the judgements of the subjects are divided between the values TENSE and NOT SPECIFIED, as reported in Table 5.4.

Table 5.4: *Experiment 1 - Tense: choice of the source of information (excluding the presence of temporal expressions).*

Tense Pattern		**Value**
Tense Shift	TENSE	97.43%
	NOT SPECIFIED	2.56%
Absolute Same Tense	TENSE	46.74%
	NOT SPECIFIED	53.26%
Smooth Tense Shift	TENSE	75.77%
	NOT SPECIFIED	24.23%

Not surprisingly, in case of tense shifts TENSE is the preferred value, while the choice for NOT SPECIFIED is very low. Analyzing sequences with absolute same tense with respect to those with smooth shift we can observed a different situation. According to our hypotheses, we can notice a crossed inversion of the percentages with a majority of preferences for NOT SPECIFIED (53.26%) with sequences of absolute same tense and for TENSE (75.77%) for smooth tense shift. Provided these figures, we can quite reliably state that when the temporal information provided by tense is the same, the interpreters rely on different types of knowledge as cues for inferencing temporal relations. This preliminary data seem to confirm the **Hypothesis 1**, formulated in chapter 3, according to which tense may be a necessary and sufficient element for reconstructing the order of eventualities when there is a deep shift in the temporal meaning of the different tense forms, i.e. when it is possible to set a value for A in a principled way and which does not correspond to the default. However, in presence of smooth tense shifts, tense is still considered as the main and mostly preferred source of information. Although the difference in the surface structure of the *passato composto* and *imperfetto* may have influenced our subjects, this could also be interpreted as a further cue of the fact that *in the textual domain* the temporal information expressed by *imperfetto*, though identical to that of the *passato composto* as for the relationships between the E and S moments/points, differs for the relationship between the Rpt and the A parameter[6]. This suggests that sequences with the *imperfetto* may offer a principled way to set the A. Nevertheless, the main difference between the two tense forms is with respect to the viewpoint aspect according to which, normally, eventualities at the *imperfetto* have an imperfective reading. Moreover, the fact that a consistent minority of subjects has considered tense as the main source of information even for sequences with absolute same tense suggests that the average competent speaker has a relative low consciousness of the tense semantics and has difficulties in explaining what purely linguistic elements have guided him in the identification of the temporal relation. Temporal relations, thus, qualify as highly complicated inferencing processes which are obtained from pertinent linguistic input which, when not sufficient enough - recall the differences in the subjects' choice between tense shifts and same tense couples -, is enriched with con-textual knowledge. Using a definition from the Relevance Theory (Wilson & Sperber, 2004), temporal relations are *explicatures* and not simple pragmatic implicatures directly derived from the discourse structure.

The crossed analysis of tense patterns and associated temporal relations allows us to verify the existence of what we have called tense temporal polysemy. The measure of grammaticalization is obtained by computing the percentages of judgements per temporal relation according to the various tense patterns available. As already stated, the interpretation of the values is based on the idea that the fewer the number of temporal relations associated with a certain tense pattern, the less temporally polysemic it is. Of course, to improve the consistency of the analysis we have to keep present the data obtained from the K statistic and similarities and differences among the various tense patterns. In Table 5.5 on the following page we report the percentages obtained for each tense patterns based only on those judgements expressing the presence of a temporal relation excluding all judgements which have signalled as valid the value NO TEMPORAL RELATION; in Table 5.6 on the next page the percentages of those tense patterns which mostly elicited the absence of a temporal relation.

Observing the figures in Table 5.5 and comparing these data with the K statistic, it is possible to identify a sort of grammaticalization of the temporal relations with respect

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- passato composto $= (E \prec S) \wedge (Rpt \equiv E) \wedge ($

Table 5.5: *Experiment 1 - Tense: Relationships between tense patterns and type of temporal relations.*

Tense Pattern	Temporal Relation			
	$e_1 BEFORE e_2$	$e_2 BEFORE e_1$	$e_1 OVERLAP e_2$	$e_1 SIMULT. e_2$
Passato composto - Passato Composto	45.01%	21.70%	7.52%	25.66%
Passato composto - Trapassato I	6.55%	89.67%	1.79%	1.79%
Trapassato I - Passato composto	100.0%	0%	0%	0%
Passato composto - Imperfetto	3.94%	47.13%	32.82%	15.35%
Imperfetto - Passato composto	7.32%	1.47%	83.34%	7.9%
Imperfetto - Imperfetto	7.14%	10.71%	28.58%	53.57%
Passato composto - Presente$_{passivo}$	41.36%	34.54%	3.63%	20.00%

Table 5.6: *Experiment 1 - Tense: Relationships between tense patterns and absence of a temporal relation.*

Tense Pattern	No Temporal Relation
Passato composto - Passato Composto	54.44%
Passato composto - Trapassato I	3.33.%
Trapassato I - Passato composto	0%
Passato composto - Imperfetto	24.44%
Imperfetto - Passato composto	6.67%
Imperfetto - Imperfetto	1,11%
Passato composto - Presente$_{passivo}$	10.00%

to the different tense patterns we have analyzed. As a disclaimer, we want to point out that these are general tendencies and need further study. Considering as a threshold for polysemy percentages above the 10% for each temporal relation, we can claim that patterns containing absolute same tenses are the most temporally polysemic. On the contrary, patterns with tense shifts or smooth tense shifts seem to qualify as the ones which mostly grammaticalize temporal relations The *imperfetto* in smooth tense shift sequences can be considered only as relatively polysemic. Observing the data we can notice that it clusters on three temporal relations, namely:

- precedence;
- simultaneity; and
- overlap.

However, if we apply coarse grained knowledge on temporal relations according to the definition of conceptual neighborhood provided by Freska (1992), i.e. two relations between pairs of events can be considered as conceptual neighbors if they can be transformed into one another by continuously deforming the eventualities in a topological sense, we can assume that simultaneity and overlap are direct conceptual neighbors obtained by deforming in one direction (namely lengthening) the eventualities and consequently could be assumed as expressing a unique temporal relation which can be called, using Freska (1992)'s terminology, *contemporary*. It is under this perspective that we can define smooth tense shifts sequences as relatively polysemic since, according to the data, they may be associated mainly with two temporal relations[7]: precedence and contemporary. Such a reasoning cannot apply to the absolute same tense sequences with the *passato composto* provided the fact that the main temporal relations expressesed, i.e. precedence, succession and simultaneous, cannot be considered as immediate conceptual neighbors.

As for the values of the couples presenting the passive diatesis we can notice that they present a distribution among the various temporal relations which is comparable to that of *passato composto - passato composto*. A possible explanation for this phenomenon is a similarity in the surface forms which may have biased the subjects in the identification of a different tense. This suggests that a change in diatesis may influence the identification of temporal relations, but we do not think that this may correlate with the phenomenon of tense temporal polysemy.

The results of Table 5.6 on the facing page offer further support to our proposal of tense cohesiveness hierarchy since the tense pattern which is mostly associated with no temporal relations is *passato composto - passato composto* (54.44%), followed by *passato composto - imperfetto* (24.44%). The remaining tense patterns are below or equals the 10% threshold. It is interesting to notice that the presence of the *imperfetto* as the first tense of a sequence reduces the number of judgements claiming the absence of a temporal relation. This suggests that the *imperfetto*, due to its aspectual value, seems to create a sort of background where the following eventuality is placed.

In calculating the setting of the A the proposal we advance is the following (it refers to adjacent sentences with a shift in tense and provided that they form a discourse segment):

- *trapassato I* as the first tense in a discourse sequence $(((E \prec R) \bullet (R \prec S)) \wedge (Rpt \equiv E) \wedge [(Rpt \prec A) \wedge (R \equiv A)] \wedge (A \prec S)])$: $A = R$. The A of the following tense is always to be set as equals to S;

[7]This claim does not hold if we consider sequences containig perfective or habitual readings of the *imperfetto*.

- *trapassato I* as the second tense in a discourse sequence $(((E \prec R) \bullet (R \prec S)) \wedge (Rpt \equiv E) \wedge [(Rpt \prec A) \wedge (R \equiv A)] \wedge (A \prec S)])$: $A = Rpt_1$, where Rpt_1 stands for the reference moment of the preceding eventualities;
- *imperfetto* either as first or second tense in a discourse sequence and with no change in its default viewpoint aspect $((E \prec S) \wedge (Rpt \equiv E) \wedge (Rpt \equiv A) \wedge (A \prec S))$: A equals to the Rpt either of the second or the first eventuality. Note that this is a way of expressing the contemporary relation;
- *passato composto* either as first or second tense in a discourse sequence $((E \prec S) \wedge (Rpt \equiv E) \wedge (Rpt \prec A) \wedge (A \prec S))$: no principled setting of the A which always corresponds to the default value, i.e. $A = S$.

Order of presentation The analysis of the order of presentation of the eventualities is a strategy to control what is the role of discourse structure and if there is a sort of mostly preferred temporal relation, i.e. if it is true that as a general principle the order of narration of eventualities tend to be conducted by presenting in their chronological order temporally adjacent eventualities. As already stated, we have presented to the subjects the same sentences in the couples but inverting the order of presentation of the eventualities. 7 couples of sentences with tense pattern *passato composto - passato composto* have been involved in this modification.

As for the other subtests, we have calculated the K statistics for temporal relation for this case as well. The values we have obtained are K = 0.41 for the original sentences (i.e. $e_1 - e_2$) and K = 0.35 for their inverse ($e_2 - e_1$). This drop in agreement seems to suggest that the order of presentation of the eventualities is relevant for the identification of temporal relation and would assign to the discourse structure a more importanat role than the one we have proposed so far. However, a detailed analysis of the couples has shown that one of the couples involved in this modification present a very strong cohesive device, namely a bridging anaphor (Clark, 1977) on the eventuality of the first sentence. In 5.7 we have reported the involved couple; the anaphoric element is in italics, and its anchor is underlined:

(5.7) La società **ha elevato** nel '94 il capitale sociale$_j$ a 198,5 miliardi, grazie alla raccolta di 161,4 miliardi.
Questa ricapitalizzazione$_j$ **ha consentito di emettere** obbligazioni convertibili per 21,9 miliardi.
The firm raised in 1994 its shared capital to 198,5 billions, thanks to the raising of 161.4 billions. This recapitalization allowed the emissions of bonds for 21.9 billions.

In this case the inversion of the order of the two eventualities of the couple breaks the cohesiveness of the two sentences, since the anaphoric element is transformed in a cataphoric one, whose resolution is not easy to accomplish. As a proof, if we exclude this sentence from the subset of the inversed relation, and re-calculate the K, we obtain a value of 0.40, which is almost identical to that obtained for the original couples. Moreover, the number and types of temporal relations is the same for both types of order of presentation. The only exceptions are represented by sequences of eventualities connected by a logical relation of cause-consequence, according to which by inverting the order of the eventualities the temporal relation is inverted as well to be compliant to the logical relation. In Figure 5.1 we present a graphical representation of the judgements per temporal relation expressed by the subjects for these sentences. The first column of every couple represents the original sentences, while the second the manually modified ones with the

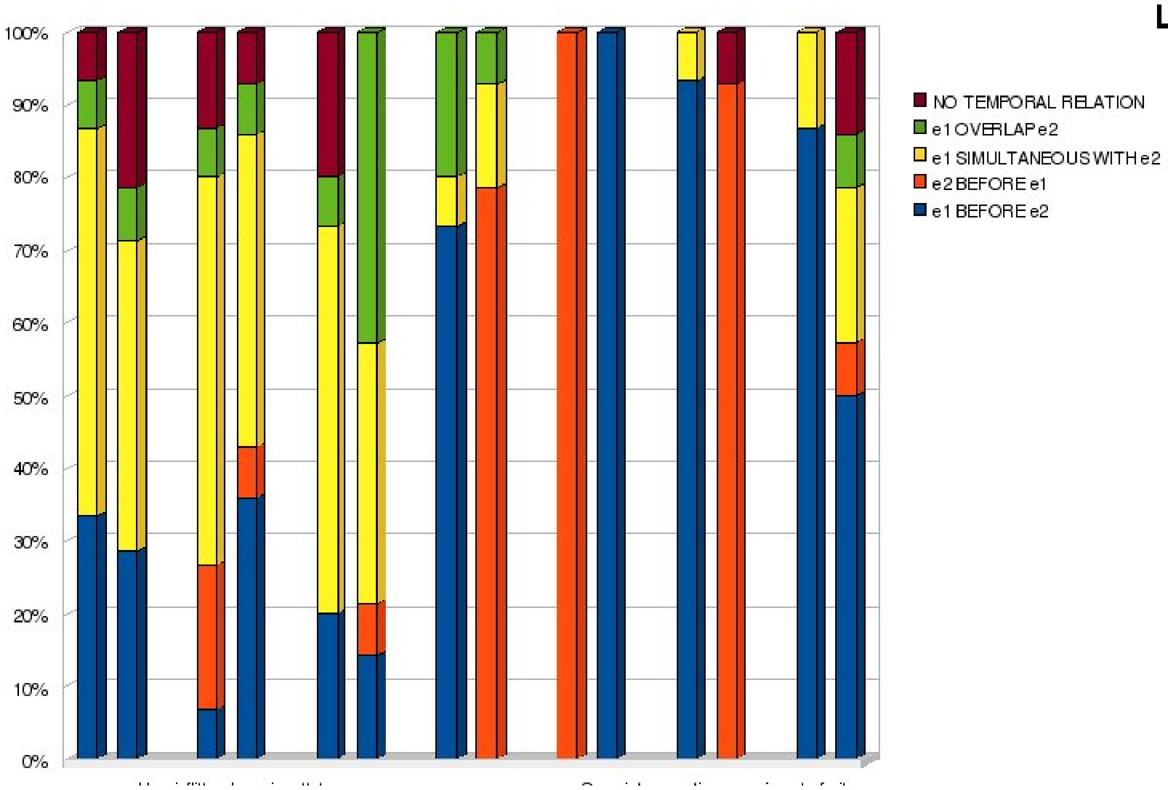


Figure 5.1: *Experiment 1 - Inversion of the order of presentation of the eventualities.*

inverted order of presentation. Notice how the couples from 4 to 6 present a change in the temporal relations due to the presence of a logical relation of cause-effect between the two eventualities. In the following examples we report the data for couple 5 in Figure 5.1:

(5.8) **Sono intervenuti** cinque mezzi dei vigili del fuoco e dieci ambiulanze del 118. Otto persone **sono rimaste ferite**. $[e_2 BEFORE e_1]$

Five fire-fighters squads and ten ambulances have intervened. Eight people were injured.

(5.9) Otto persone **sono rimaste ferite**.
Sono intervenuti cinque mezzi dei vigili del fuoco e dieci ambiulanze del 118 $[e_1 BEFORE e_2]$

Eight people were injured. Five fire-fighters squads and ten ambulances have intervened.

Couple 7 shows the effect of the bridging anaphor (example 5.7): in the second column of the number of temporal relations is higher than in the first one and the number of judgements claiming the absence of a temporal relation increase (14.29%).

On the basis of our data we cannot provide further support to the claim that the presentation of the order of the eventualities is perceived as if it corresponds to the chronological order in which they have occurred[8]. In fact, the first 3 couples in Figure 5.1 show that the subjects have mostly preferred the temporal relation of SIMULTANEOUS

[8]However, if we analyze the data from the relationship between tense patterns and temporal relationships they provide support to this claim. In fact if we consider the cases of *passato composto* - *passato*

even if there is no special connection or relationship between the eventualities. This suggests that such the general order of presentation may be easily bypassed for various reasons. For instance, there may be a logical relationship between the two eventualities; or the presence of a particular discourse relation, like for instance *Elaboration*, influences the temporal interpretation; or the interpreters abstract the specific relationships[9] between the two eventualities and set them into a lager situation, or scenario, where the eventualities lose their specific temporal relations and are perceived as happening at the same time and as part of this larger event/scenario set. As a matter of fact, these examples can all be perceived as expressing such larger scenarios, in particular a meeting, for couple 1 and couple 3, and a trial, for couple 2; e.g.:

(5.10) L'assemblea degli azionisti della Siat **ha approvato** il bilancio '85 chiuso con un utile di 585 milioni.
L'assemblea **ha proceduto** al rinnovo del consiglio di amministrazione, confermando presidente Enrico Piantà. [business meeting scenario; couple 1]
The assembly of the Siat shareholders has approved the 1985 budget closed with a profit of 585 million. The assembly has proceed to the the renewal of the Board, confirming Enrico Piantà as president.

(5.11) La pena inflitta **ha rispettato** le richieste del pubblico ministero "spedirli per sempre dietro le sbarre".
Ha inflitto 240 anni di carcere ciascuno ai tre imputati. [trial scenario; couple 2]
The inflicted punishment has respected the requests of the attorney to send them " forever behind the bars". It has inflicted 240 years in prison to each of the three defendants.

However, these are tentative explanations based on the subjects comments which require more data and further study. Nevertheless, the main result form this subset of data is represented by the fact that, in absence of particular relationships between the two eventualities and of tense shifts as well - that is in a situation of undifferentiated temporal information - the inversion of the order of the eventualities has no effect on the type (and number) of temporal relations perceived. What is questioned, by observing the values for the temporal relations, is the fact that temporal precedence between eventualities is the default temporal relation to order eventualities. This provides support to our criticism of the account of Lascarides & Asher (1993) which claimed that *narration*, and consequently temporal precedence, was the preferred default temporal relations. The data also suggest that when the purely linguistic information is not sufficient to determine the temporal relation, an interpreter makes affordance on its pragmatic, i.e. commonsense, knowledge which may offer an interpretation which could be unexpected and not predicted from linguistic theory or general principles of conversation.

Tense and Temporal Expressions In order to verify if there is a hierarchical order of application of the sources of information which are involved during the inferencing process of the identification of temporal relations we have concentrated on the following sentences' couples configurations of the test data; as for temporal expressions we have not distinguished when there is just one temporal expression or two of them:

composto the mostly preferred temporal relation is that of precedence where the fist eventuality occurs before the second (45.01%).

[9]Because they are difficult to compute? The experiment from Mani et al. (2006b) seems to suggest so.

- absolute same tense and no temporal expression;
- absolute same tense and temporal expressions;
- smooth tense shift and no temporal expression;
- smooth tense shift and temporal expressions;
- tense shifts and temporal expressions;
- tense shifts and no temporal expression.

Our interest is in discovering if it may be identified an order of application of the linguistic information, i.e. if the grammatical information (tense) is more salient than the lexical one (temporal expression) and what is their relationship with the con-textual information (commonsense knowledge). In Table 5.7 we report the percentages of the judgements of our subjects[10] while in Table 5.8 on the following page the K values for the temporal relations are illustrated.

Table 5.7: *Experiment 1 - Tense and Temporal Expressions: choice of the source of information.*

Tense Pattern	Value	
Absolute Same Tense - temporal expressions	TIMEX	79.89%
	TENSE	8.47%%
	NOT SPECIFIED	11.64%
Absolute Same Tense - no temporal expression	TIMEX	0%
	TENSE	46.74%
	NOT SPECIFIED	53.26%
Smooth Tense Shift - temporal expressions	TIMEX	51.81%
	TENSE	41.57%
	NOT SPECIFIED	6.63%
Smooth Tense Shift - no temporal expression	TIMEX	0%
	TENSE	75.77%
	NOT SPECIFIED	24.23%
Tense Shift - temporal expressions	TIMEX	64.18%
	TENSE	35.07%
	NOT SPECIFIED	0.75%
Tense Shift - no temporal expression	TIMEX	2.56%
	TENSE	94.87%
	NOT SPECIFIED	2.56%

The data in the two tables suggest that, though carefully, it is possible to identify a hierarchical order of application of the three sources of information in terms of their salience, according to which the linguistics information has constraints which influence its informational power. Temporal expressions qualifiy as the most salient and informative type of linguistic information, but with constraints. In fact, only when present, they are chosen as the most informative source of information for the identification of the temporal relation by the vast majority of subjects. Its counterpart is represented by the bunch of different types of information which we have identified as commonsense knowledge and

[10]Some of these values have already been presented in 5.4. Temporal expressions have been abbreviated in TIMEX.

Table 5.8: *Experiment 1 - Tense and Temporal Expressions: K coefficients on temporal relation.*

Sentences' Configuration	**K value**
Absolute Same Tense - no temporal expression	0.36
Absolute Same Tense - temporal expressions	0.59
Smooth Tense Shifts - no temporal expression	0.25
Smooth Tense Shifts - temporal expressions	0.25
Tense Shifts (+ passive) - no temporal expression	0.53
Tense Shifts (- passive) - no temporal expression	0.70
Tense Shifts (+ passive) - temporal expressions	0.70
Tense Shifts (- passive) - no temporal expression	0.80

expressed by the value NOT SPECIFIED. This claim finds support by combining the information from the judgements with those obtained from the K. The very poor values obtained for the temporal relations for sequences of absolute tense, in absence of temporal expressions, and smooth tense shift, both with and without temporal expressions, are a cue of the activation of inferencing mechanisms based on non-linguistic sources of information which rely on commonsense knowledge. A type of knowledge which may vary among the interpreters, according to their education and life's experiences. As for the case of smooth tense shifts the data obtained from the K values are in agreement with those obtained for the judgements on the sources of information, where even when temporal expressions are introduced in the sentences they have been perceived as salient only for the 51.81%. Furthermore, recalling the data for the source of information for those sentences' couples presenting just one temporal expression, where barely the 25% of the judgements signalled temporal expressions as the main source of information, we are in a position to claim that the salience of temporal expressions is strictly linked to their role (either as temporal localizers or temporal measurements of the eventualities) and number in the discourse sequence.

Tense qualifies as the least salient source of information. The claim that it has a primary role in signaling the existence of a temporal relations is confirmed by the data from the subjects, but it offers mainly only sufficient information for the identification of the temporal relation, with the exception of real changes in tense semantics as shown by the data for tense shifts. A further proof of this low salience of tense is also represented by the values for the K statistic of tense shift sequences including the *presente* at the passive diatesis. The similarity of surface structure of this tense forms may have biased the subjects in the identification of the difference in the meaning of the tenses' sequences. Linguistic information is thus only relatively salient and with constraints. The (preliminary) hierarchical order of salience of information that we propose is illustrated by means of the following formula (**Formula 1**), where the symbol $\lessapprox$ stands for "in absence of more specific linguistic information, X is the most salient source of information" and $\lesssim$ for "in absence of more specific information, X is the most salient source of information":

Formula 1 (Hierarchical order of information) : COMMONSENSE KNOWLEDGE $\lessapprox$ (TENSE $\lesssim$ TEMPORAL EXPRESSION)

thus, reading the **Formula 1** we will obtain the following statements: *in absence of more specific linguistic information, commonsense knowledge is the most salient source of* *information; in absence of more specific information, tense is the most salient source of information; temporal expression is the most salient source of information.*

5.2.2.2 Experiment 2 - Data

Similarly to the previous experiment, we have measured the agreement of the subjects on the temporal relations. We have obtained a global K value of 0.58, much bigger that the one from the Experiment 1. A better knowledge of language and of its mechanisms seem to be useful and required to perform such complex tasks and obtain good results. The fact that these subjects were submitted with larger textual segments i.e. more cohesive and coherent, could also be considered a factor of influence for this relative good K value. This suggests that temporal relations are a complex type of inferences which result from the combination of linguistic and non-linguistic, i.e.pragmatic, information whereby the identification that subsequent sentences give rise to a text/discourse sequence is a pre-condition for their identification. It is in this sense that we consider temporal relations as a by-product of the computation of discourse structure.

An increase in the agreement for discourse sequences with temporal expressions can be observed, by registering a K of 0.67, with an increase of almost 10 points. Temporal expressions in this experiment have not been kept under control. This means that their role does not always correspond to that of temporal localizers of the *E* moments of the highlighted eventualities. Their distributions is varied: they can signal either (a.) the DCT, or (b.) the temporal localizer(s) of the E moment of the highlighted eventuality/ies - but very rarely we have a temporal expression for both eventualities (only the 11.76% of all test data), or (c.) the temporal localizers of other eventualities in the discourse segment. They have the same roles and distributions which can be found in real texts/discourses. As for the distinction between presence or absence of temporal expressions we refer to the presence inside the text segments of a temporal expression. This means that text segments which present only the DCT are considered, in principle, as not having temporal expressions. We report in Table 5.9 the various K values obtained for the different sentences' configuration.

Table 5.9: *Experiment 2 - Tense and Temporal Expressions: K values on temporal relation.*

Sentences' Configuration	**K value**
Absolute Same Tense - no temporal expression	0.43
Absolute Same Tense - temporal expressions	0.36
Smooth Tense Shifts - no temporal expression	0.26
Smooth Tense Shifts - temporal expressions	0.35
Tense Shifts - no temporal expression	0.52
Tense Shifts - temporal expressions	0.70

The results for the K values provide a further proof to the analysis we have proposed on the basis of the Experiment 1. However, some data, if not correctly interpreted, could suggest at a first sight counterevidences, though it is not so. It is important to remember that in this case we are facing real language data, and if things appear different from those described in the previous experiment it is necessary to go into the details of the various sentences, observe their internal structure (presence and type of temporal expressions, presence of signals, lexical aspect of the eventuality etc.) and then interpret them in the lights of the results of the Experiment 1. Some of the most interesting data are those provided by the judgements on the sources of information which could offer more details on the constraints which govern the proposed saliency-based hierarchy of sources of information and even extend it. Thus, in order to avoid repetitions and, sometimes, bizarre explanations we report in Table 5.10 the percentages of preference for the sources of information. It is important to remember that in this case we have asked the subjects to provide more fine-grained distinctions, extending the set of possible sources of information to 6 values.

Table 5.10: *Experiment 2: choice of the source of information.*

Tense Pattern	**Value**	
Absolute Same Tense - temporal expressions	TIMEX	8.33%
	SIGNAL	30.56%
	TENSE	5.56%
	ASPECT	0%
	SEMANTICS	52.78%
	NOT SPECIFIED	2.78%
Absolute Same Tense - no temporal expression	TIMEX	13.33%
	SIGNAL	13.33%
	TENSE	0%
	ASPECT	0%
	SEMANTICS	70.00%
	NOT SPECIFIED	3.33%
Smooth Tense Shift - temporal expressions	TIMEX	10.64%
	SIGNAL	50.00%
	TENSE	0%
	ASPECT	22.22%
	SEMANTICS	11.11%
	NOT SPECIFIED	1.61%
Smooth Tense Shift - no temporal expression	TIMEX	4.35%
	SIGNAL	8.70%
	TENSE	13.04%
	ASPECT	60.87%
	SEMANTICS	8.70%
	NOT SPECIFIED	4.35%
Tense Shift - temporal expressions	TIMEX	16.94%
	SIGNAL	16.94%
	TENSE	33.06%
	ASPECT	21.77%
	SEMANTICS	9.68%
	NOT SPECIFIED	1.61%
Tense Shift - no temporal expression	TIMEX	0%
	SIGNAL	5.56%
	TENSE	55.56%
	ASPECT	22.22%
	SEMANTICS	11.11%
	NOT SPECIFIED	5.56%

Temporal expressions and signals One of the most striking results is represented by the K values obtained for text/discourse segments which have temporal expressions. We can observe that text/discourse segments both with absolute same tense and those with smooth tense shift in absence of temporal expressions perform better than when they are present. In fact, in absence of temporal expressions we obtain a K = 0.43 for absolute same tenses and K = 0.26 for smooth tense shift, while when present this value drops to K = 0.36 for absolute same tense sequence and rise to K = 0.35 for smooth tense shifts. On the contrary, things are much better when we consider tense shifts text/discourse segments. We register a K value slightly lower than the global one in absence of temporal expressions, K = 0.52, and an improvement in their presence, K = 0.70. Moreover, taking into account the judgements on the sources of information it is striking to observe that temporal expressions when present are well below the values we observed in the Experiment 1 (8.33% for absolute same tense, 10,64% for smooth tense shifts and 16.94% for tense shifts), while other sources of information are mostly preferred, namely SIGNAL for absolute same tense and smooth tense shift (30.56% and 50%, respectively) and TENSE for tense shift (33.06%). Combining these results without taking into account the internal structure of the various text/discourse segments it could be inferred that the preliminary conclusions based on the Experiment 1 are contradicted and no more valid. We claim that it is not true. Analyzing in details the internal structure of the various text/discourse segments, and keeping present both the results and the particular structure of the Experiment 1, it is possible to identify a reliable explanation for these results. As we have already stated, barely the 12% of all the test segments present two temporal expressions whose role is that of temporal localizers of the *E* moment of the eventuality. The remaining segments have the following characteristics:

- absence of temporal expressions (20.58%);
- presence of only the DCT (11.76%) and have not been considered as having a temporal expression;
- presence of the DCT and a temporal expression in the text which is not related to neither of the highlighted eventualities (8.82%);
- presence of the DCT and two temporal expressions, each of them expressing the *E* moment of the highlighted eventualities (8.82%);
- presence of the DCT and a temporal expression corresponding to the *E* moment of a highlighted eventuality (11.76%);
- presence of only one temporal expression corresponding to the *E* moment of a highlighted eventuality (20.58%);
- presence of a temporal expression not related to neither of the highlighted eventualities (8.82%);

These conditions, as it emerged also from Experiment 1, are not favourable to temporal expressions, which, as we have stated are more salient than tense *provided their role and number in the discourse sequence*. Moreover, if we analyze separately the sources of information for the segments with two temporal expressions and the DCT, we can observe that the choice of temporal expressions is preferred only 29.17% of the times, in competition with tense (33.33%). A similar result holds for those segments with DCT and a temporal expression fixing the *E* moment, where temporal expressions are chosen only 16.36%. These data introduce a further constraint on temporal expressions as it emerged from the analysis of the text segments involved: granularity and anchoring relationship with each other.

As a matter of fact, temporal expressions may stand in relation with each other only if the granularity level of their semantics allows them. The values that they may denote can be grouped according to the granularity level of the temporal unit which is expressed (**Y**ear, **M**onth, **S**eason, **D**ay, **D**ay-**O**f-**W**eek, **T**ime-**O**f-**D**ay...). The different granularity levels then stand in a hierarchical order with each other, creating anchoring relationships between temporal expressions. Anchoring relationships and hierarchical order can be further specified by means of semantic relations, like *part_of*, *has_hyperonym*, *is_a* and others. This means that if a temporal expression is not correctly interpreted both in term of the granularity level it expresses and the semantic relationship which governs the supposed anchoring relationship with another temporal expression, namely inside the text segment, their salience is not perceived. Moreover, if the granularity level of the two temporal expressions is the same, its role is *de facto* null as useful cues for the identification of the temporal relations. Similarly, when there is just one temporal expression and the DCT, the temporal expressions are not felt as relevant input for inferencing the temporal relations with the other eventuality which do not have any point in time to be related with. In this case, we could have obtained results even better than those from the Experiment 1, if we would have asked the subjects to order the eventuality with respect to the DCT. It is for this reason that absolute same tense sequences with temporal expressions have obtained this low value.

As for the class of signals its interpretation is not so trivial. In fact, this class has a scattered distribution in the various discourse segments, with percentages which ranges from 5.56% up to 50.00%. Thus in order to verify their role in the process of inferencing temporal relations we have computed separately both the K value and the preferences, or the sources of information, for those sentences which present a signal (14.70%). We have excluded all those cases of temporal expressions introduced by a prepositions, like *dal mese scorso* [since last month], because we are concentrating on temporal relations between eventualities and not between temporal expressions and eventualities. The value we have obtain are K = 0.73 but a very low preference for the value SIGNAL (37.04%), followed by temporal expressions (24.07%) and tense and aspect (18.52% for both). These elements suggest that signals are less informative and salient than temporal expressions. It is interesting to notice that the distinction between implicit and explicit signals, which we have proposed in chapter 3, offers a different interpretation. In our test data we have identified 4 different types of signals in 8 sentences: 2 explicit, namely *mentre* [while], *subito dopo* [immediately after], and 2 implicit, *già* [yet/already] and *quando* [when]. If we compute the agreement on temporal relations separately for these signals we can observe that all explicit signals obtain the stunning value of K = 1, i.e total agreement. On the contrary, *quando* obtains an agreement which is as low as 0.43. If we combine these data with those for the sources of information, we can observe that only explicit signals obtains percentages above the 50% (66.66% for *subito dopo*, and 75% for *mentre*), while implicit signals have percentages which ranges well below: the value SIGNAL is preferred only 29.17% of the times with *quando*, in competition with temporal expressions and aspect, while *già* 0%[11]. On these bases, we claim that the contribution of signals to the identification of temporal relations is not unique as for temporal expressions, but it differentiates according to the semantic transparency of their meanings: explicit signals are

[11]The 0% value for *già* can be interpreted as a consequence of its highly "polysemic" nature. In fact, *già* can be used to signal different temporal relations, like precedence, succession or beginning. Its role is that of reinforcing the information which is provided by tense, in fact in our data in presence of *già* the most preferred source of information was tense with 66.66%.

perceived as very salient lexical linguistic information even more than temporal expressions, while the contribution of implicit signals sometimes seems to be negative since they allow the activation of interpretation mechanisms which are based on other sources of information, like tense, aspect and even commonsense knowledge. Thus, the collocation of signals in our hierarchy of the sources of information is double: **implicit** signals are the least salient source of linguistic information and **explicit** signals are more salient than tense and temporal expressions.

Tense and Aspect In the Experiment 1 we have identified the conditions under which tense is a necessary and sufficient information for the identification of temporal relations. We have seen how only in presence of tense shifts which corresponds to a difference in tense semantics, like for sequences of *passato composto - trapassato I*, it is possible to associate to a particular tense a temporal relation. The data of Experiment 2 extend and improve the analysis for tense and offer important information on the role of other two types of linguistic information, namely viewpoint and lexical aspect.

The first interesting set of data is represented by the different distributions of the sources of information for tense, aspect and semantics. It is possible to identify a correlation between these sources of information and the various tense patterns. With absolute same tenses the main source of information is represented by semantics (61.39% on average, with an expected increase in absence of temporal expressions - 70.00%). Notice how, with respect to the judgements of the Experiment 1, the subjects with a relative good knowledge in Linguistics has not signalled as salient tense nor aspect. This data confirms our claim on the limits of tense as a cue for the identification of temporal relations[12]. Smooth tense shifts tend to correlate mostly with aspect (41.54% on average, 60.87% in absence of temporal expressions) and, finally, tense shifts correlate with tense (44.31% on average, 55.56% in absence of temporal expressions). It is interesting to notice how these results correlate also with the K values for temporal relations. In fact, the less salient is the linguistic information (in this case, tense), the worst is the agreement due to the influence of less specific sources of information.

Nevertheless, this claim cannot be accepted unless we provide an explanation for the data for the smooth tense shift patterns. In the previous section we have stated that the main differences between the *passato composto* and the *imperfetto* are represented by the relationship between the Rpt of the eventuality and the textual anchor A, precedence for the former and simultaneous for the latter, and by the "default" viewpoint aspect associated with them (see also Table 3.5 on page 72 in chapter 3). As already stated, the role of viewpoint aspect is that of providing the interpreter with information about the openness or closeness of the interval representation of the eventuality and this further reduces the number of temporal relations available between the eventualities. The *imperfetto*, in its default viewpoint interpretation, presents the eventuality as open[13] while the

[12]Identification of temporal relation is different from signaling or marking. The first refers to the process of stating what is the particular temporal relations between two entities, i.e. *before*, *after*, *overlap*.... The latter refers to the fact that the presence of a tense is a cue of the existence of a temporal relation.

[13]A well known phenomenon in linguistics is represented by changes in these default values: an example of this phenomenon is the perfective reading of the *imperfetto* (for instance, the well known *imperfetto narrativo*, or its use in hypothetical sentences) or of the *presente* (*presente storico*). In this cases, the proper temporal meaning is *de facto* cancelled. This does not mean that the tenses are interpreted as atemporal, but that their temporal meaning is by-passed by the viewpoint aspect which by changing the way in which the event is presented influence the tense interpretation. In our data we have only one perfective reading of the *imperfetto* which occurs with a stative verb denoting a temporary state in a negative clause: "*non erano in possesso*" [(they) were not belonging to]. The negative particle forces the

passato composto as closed. The fact that the majority of judgements signals as the main source of information the value ASPECT for sequences with smooth tense shifts confirms what we have previously stated, but does not explain the low agreement for temporal relations. Similarly to the Experiment 1 we can observe that the subjects cluster on two main temporal relations, namely overlap and simultaneous. If, again, we apply the definition of concept neighbors to these two temporal relations and thus collapse them into the contemporary value, we can observe that the agreement jumps to K = 0.65. This change in value due to a more coarse grained temporal relations is a proof of the fact that humans can hardly discriminate very precise temporal relations unless all the crucial information is explicitly stated. In line with this observation, we can notice that if the viewpoint aspect is the same for the two types of eventualities, its role is limited. In fact, we can notice that in segments which have the same absolute tense pattern, and thus do not signal by means of the tense-aspect morphemes a difference in the interval representation of the eventuality, the aspectual viewpoint and the tense are not considered as salient information for the identification of the temporal relation.

It is interesting, under this perspective, to compare the data for viewpoint with those obtained for signals, in particular for the explicit ones. Similarly, to the analysis that we have illustrated in the previous section, by observing the values in Table 5.10 on page 118 explicit signals qualifies as a more salient source of information even in presence of a difference in viewpoint aspect.

Finally, the data offer us other important elements for inferencing what is the role of the last linguistic source of information, namely lexical aspect. To discover its influence we have performed an analysis of the lexical aspects expressed by the eventualities in our discourse segments. We did not perform a very fine-grained distinction, as we have proposed in our ontology (chapter 2), since we have considered only the primitive types, i.e. events and states. Anyway, this allows us:

- to interpret the role of the value SEMANTICS and its relationships with the other sources;
- to discover when the lexical aspect is a necessary information for the identification of temporal relations;
- to infer what is the salience of the lexical aspect with respect to the aspectual viewpoint and under which conditions lexical aspect can be considered either an accessory information, i.e. not significant, or when it is necessary to avoid failure.

We have reported the data in Table 5.11 on the facing page. To keep the various factors under control and provided the relative sparseness of the two types of lexical aspect, we did not consider the overall value based on the bare distinction between the subtypes of lexical aspect. In fact, among the test data we have only one instance of tense shift and change of the lexical aspect[14].

It is interesting to notice how by means of this rough distinction in actionality we can obtain empirical evidences to the theoretical-not-data-grounded statements on the role of this source of information. First, notice how with absolute same tense patterns the value SEMANTICS is the mostly preferred on (55.56% and 52.27%). But this fact, reinterpreted in the lights of the distinction of the lexical aspectual values, assumes a complete different interpretation. In fact, when the two lexical aspects are different they correlate with an

perfective reading of the stative in the sense that it is no more valid and presented as a closed interval.

[14]Provided the fact that drawing reliable inferences and generalizations on *hapax* cases is a nonsense, we excluded this case from the analysis.

Table 5.11: *Experiment 2 - Lexical Aspect: distribution of the sources of information .*

Tense Pattern	Value	
Absolute Same Tense - Event -State	TIMEX	5.56%
	SIGNAL	11.11%
	TENSE	11.11%
	ASPECT	11.11%
	SEMANTICS	55.56%
	NOT SPECIFIED	5.56%
Absolute Same Tense - Event - Event	TIMEX	13.64%
	SIGNAL	29.55%
	TENSE	0%
	ASPECT	2.27%
	SEMANTICS	52.27%
	NOT SPECIFIED	2.27%
Smooth Tense Shift - Event - State	TIMEX	13.79%
	SIGNAL	24.11%
	TENSE	13.79%
	ASPECT	44.83%
	SEMANTICS	0%
	NOT SPECIFIED	3.45%
Smooth Tense Shift - Event - Event	TIMEX	5.56%
	SIGNAL	44.44%
	TENSE	13.04%
	ASPECT	27.78%
	SEMANTICS	22.22%
	NOT SPECIFIED	0%
Tense Shift - Event - Event	TIMEX	25.54%
	SIGNAL	8.45%
	TENSE	49.30%
	ASPECT	9.68%
	SEMANTICS	8.45%
	NOT SPECIFIED	1.41%

increase in the agreement on temporal relations (K = 0.65), while, on the other hand, when the lexical aspects are the same, the agreement is even lower than the one we have identified for absolute same tense sequences (K = 0.31). These results offer a different way to interpret the value SEMANTICS. In the former case, it refers to a difference in the lexical aspect of the eventualities, while in the latter one, it represents its real value, that is the role of commonsense knowledge. Nevertheless, this is a partial analysis on the basis of our data. It would be interesting to observe the agreement which could be obtained for events with same lexical aspect and when it differs[15]. In principle, we could infer what

[15]We refer to cases like activity - accomplishment, activity - achievement and accomplishment - achievement

would be the behaviour on the basis of the theoretical analysis of the lexical aspects and their contribution to temporal relations. In particular, we predict a low agreement in case of same lexical aspect, similar to the one we have obtained for the segments event-event, and a higher one when the lexical aspect is different. However, the picture is much more complicated. Lexical aspect refers to the temporal structure of the eventualities but next to this type of information there is the pure lexical meaning of the eventualities, which can give rise to relationships between eventualities based on commonsense knowledge. For instance, if in principle we may state that an activity overlaps an accomplishment or an achievement, but the semantics of the eventualities in analysis may give rise to a different temporal relation, even unexpected. From the data we can observe, once again, how the contribution of linguistic information is constrained by a series of parameters. Lexical aspect, though it refers to a part of the lexical semantics of the eventuality, is less informative and salient than commonsense knowledge.

These data also offer important elements to state when the lexical aspect is a necessary information and when it is simply ancillary. If we observe the preferences for the sources of information for the others three types of patterns in Table 5.11 it emerges that knowledge of the lexical aspect is necessary only when all other linguistic information, like tense, temporal expressions, signals and viewpoint aspect, either are absent or have an equivalent meaning. For instance, in presence of a shift in the aspectual viewpoint, from perfective to imperfective or viceversa, its knowledge is a necessary and sufficient condition to identify the temporal relation between two eventualities (44.83% and 27.78%). Of course, there may be disagreement on the final decision of what is the precise temporal relation due to their granularity level (as it is for overlap and simultaneous). The same observation is valid for tense. In case of tense shifts, lexical aspect is ancillary, as the choice of the value TENSE (49.30%) shows.

Tense polysemy and role of discourse Finally, the analysis of the various tense form patterns, which in this experiment is wider than those of the Experiment 1, provides further information on the correctness of the proposal of the tense temporal polysemy, on the level of grammaticalization of a certain temporal relation and also important data on the relationships between discourse structure and temporal relations. We illustrate in Table 5.12 on the next page the percentages obtained for each tense patterns excluding all judgements which have signalled as valid the value NO TEMPORAL RELATION and *hapax* temporal patterns.

Observing the data we found further evidences to the proposal of temporal polysemy we have presented in the Experiment 1 and extend its analysis. Again, by applying the 10% threshold we can notice how some tense patterns (namely, absolute same tense sequences) can be used to express more than one temporal relations while others seem to be specialized in, i.e. grammaticalize, either one (tense shifts sequences) or two temporal relations (smooth tense shifts) which, usually, can be considered as conceptual neighbors. It is also important to notice that unexpected temporal relations in presence of not polysemic or relatively polysemic tense patterns may be due to a change in the default aspectual value, a phenomenon which limits the contribution of tense semantics.

The data from Experiment 2 have shown that the possibility of setting in a principled way the *A* does not correspond to a role of tense as a necessary and sufficient source of information. In fact, the data in Table 5.10 on page 118 for smooth tense shift sequences clearly show that, in absence of more specific sources of information like signal or temporal expressions, the value ASPECT is preferred by far over tense. This does not diminish the idea of tense temporal polysemy but points out a crucial issue on the relationship be-

Table 5.12: *Experiment 2 - Tense: Relationships between tense patterns and type of temporal relations.*

Tense Pattern	**Temporal Relation**			
	$e_1 BEFORE e_2$	$e_2 BEFORE e_1$	$e_1 OVERLAP e_2$	$e_1 SIMULT. e_2$
Passato composto - Passato Composto	56.67%	8.33%	21.67%	13.33%
Passato composto - Trapassato I	24.14%	72.41%	0%	3.45%
Trapassato I - Passato composto	100.00%	0%	0%	0%
Passato composto - Imperfetto	3.33%	26.67%	33.33%	36.67%
Imperfetto - Imperfetto	0%	0%	33.33%	66.67%
Passato composto - Presente$_{passivo}$	50.00%	33.33%	16.67%	0%
Passato composto - Futuro semplice	100.00%	0%	0%	0%
Futuro semplice - Passato composto	0%	100.00%	0%	0%

tween the setting of the A and the identification of temporal relations. As for the setting of the A textual anchor[16], the data of these new tense patterns, on the one hand, confirm the settings we have illustrated on the basis of the Experiment 1 and extend them, in particular:

- *futuro semplice* $(((E \succ S) \wedge (Rpt \equiv E)) \wedge (Rpt \succ A) \wedge (A \succ S))$: as the first tense discourse sequence $A = S$. As the second tense, $A = Rpt_1$, where Rpt_1 is the reference point of the eventuality in the previous discourse segment. In case we have sequences of eventualities all the *futuro semplice*, we claim that no principled setting for the A can be proposed. This claim, though not based on empirical data, is inferred by observing the behaviour of what are the Past counterpart of the *futuro semplice*, namely *passato composto* and *passato semplice*;
- *imperfetto* either as first or as second tense in a discourse sequence with no change in its default viewpoint value $((E \prec S) \wedge (Rpt \equiv E) \wedge Rpt \equiv A) \wedge (A \prec S))$: $A = Rpt_1$ or $A = Rpt_2$. As already stated these configurations are acceptable only with reference to the coarse temporal relation of contemporary. It is interesting to notice that the data of Experiment 2 suggest that the *imperfetto*, even in sequences of the kind *imperfetto* - *imperfetto* (absolute same tense), seems to maintain this principled setting of the A, thus confirming the proposal of the *imperfetto* as a relatively polysemic tense[17].

As for the *presente*$_{passivo}$ the data of this experiment provide further information on its status. We claim that, in principle, the *presente*, in both kinds of diateses, has a behaviour for setting the A textual parameter as the *futuro semplice* when in presence of tense shifts but as the *imperfetto* when in same tense sequences, thus:

- in tense shift sequences: as the first tense of a sequence or discourse $A = S$; as the second tense $A = Rpt_1$;
- in same tense sequences (as first or second tense): $A = Rpt_1$ or $A = Rpt_2$. These configurations are valid only with reference to the coarse temporal relation of contemporary. As for the *imperfetto*, we claim that this principled setting of the A is maintained even in absolute same tense sequences. The *presente* should not be considered as a polysemic tense. Though we do not have enough empirical data to support this claim, we ground this analysis on theoretical studies and intuitions as competent speakers.

As for the 33.33% of judgements assigning to *passato composto* - *presente*$_{passivo}$ the relation of inverse precedence, according to which the event at the *presente* happened before the event at the *passato composto*, we claim that it is a mistake by a part of the subjects due to an incorrect interpretation of the aspectual viewpoint value. The passive diatesis may have the effect of presenting the eventuality as if it is closed, i.e. with a perfective viewpoint. Nevertheless, in one of the example, reported in 5.12, the correct interpretation of the viewpoint aspect is perfect. The perfect viewpoint has the effect of presenting the eventuality as closed, but it gives rise to a contingent state which is valid at the moment of utterance, as it is in our example.

[16]The A setting we have presented refers to adjacent sentences with a shift or a smooth shift in tense.

[17]On the nature of the *imperfetto*, typical of the so-called neo-Latin languages, there is a huge debate in literature. We will provide a brief revision of this debate and support to the validity of our analysis in section 5.2.3. Here, we want to point out again that we are referring to the "prototypical" interpretation of this tense, without taking into account its other uses like the hypocoristic, the narrative, the commercial or the politeness ones. We claim that these are special uses of the *imperfetto* which have important consequences on its pure temporal meanings.

(5.12) 25-05-94 IL SOLE 24 ORE - Autoproduzione dei servizi a Fiumicino anche per Klm. La compagnia olandese **ha definito**$_{passato\_composto}$ l'accordo con Aeroporti di Roma per la subconcessione del servizio passeggeri, seguendo cosi' l'esempio dell'americana United che dall'inizio del mese **è autorizzata**$_{presente\_passivo}$ al selfhandling delle operazioni a terra di assistenza ai passeggeri.

25-05-94 IL SOLE 24 ORE - Selfhandling of the passangers' services also for the KLM. The Dutch airline company Klm has reached an agreement with Aeroporti di Roma for the subconcession of the passangers' service, thus following the example of the American company United which from the beginning of this month has been authorized to the selfhandling of all land operations of passangers' assistance.

Thus the correct temporal relation between the two events in the discourse segments is not a relation of inverse precedence but one of overlap. The relation of inverse precedence can be accepted only by taking in account the relations between the two E moments of the events. In fact, the representation of the most specific level of temporal analysis of the discourse segments in 5.12, only for the two highlighted eventualities, comprises:

- a relation between the two temporal expressions, namely the DCT, *25-05-94*, and the other temporal expression, *l'inizio del mese* [the beginning of this month];
- a relation between the two temporal expressions and the two E moments of the two eventualities;
- a relation between the contingent state of the second eventuality and the E moment of the first;
- a relation between the temporal expression, *l'inizio del mese* [the beginning of this month], and the contingent state of the associated eventuality;
- a relation between the contingent state of the second eventuality and the E moment of the first one.

This example shows that the inferencing process of temporal relations is a difficult task and that crucial information is often left implicit, leaving room open for mistakes. In addition, these kinds of discourse segments introduce the issue of how deep, i.e. specific, should the representation of temporal information go. The interpretation of our subjects was limited[18]: only 2 of the subjects have selected the relation between the associated contingent state and the E moment of the first event, the rest of them selected the relation between the two E moments and without taking into account the contribution of viewpoint aspect, i.e. the further relation between the contingent state S_c of the second event and the E moment of the first. On the contrary, on the basis of the analysis of this discourse segments we have illustrated, there is not just one possible temporal relation betwen the eventualities but two.

Finally we want to report also the results for those judgements expressing absence of temporal relations. On 198 possible judgements, only 3 of them have been assigned to the value NO TEMPORAL RELATIONS, a striking difference with respect to the Experiment 1 where almost 6% of the judgments expressed the absence of a temporal relation. We claim that this very low value is due to the way the test data were submitted. In fact, in this second experiment we presented the subjects with longer discourse segments without any modification. This suggests that discourse structure in general is a necessary pre-condition for the identification of temporal relation but it is not to be considered as the

[18]A possible element which could have limited the analysis could be the fact that the subjects could choose only one relation.

primary source for their identification. Quite unsurprisingly, the tense pattern which has received most preferences for signaling the absence of temporal relation is *passato composto - passato composto* (66.00%).

5.2.3 Summary and Comments

In the previous sections of this chapter we have presented in details the empirical results for a set of two experiments conducted in order to discover under which conditions the various sources of information necessary to the identification of temporal relations between eventualities are autonomous, i.e. necessary and sufficient, what are the constraints which govern their use and when they need to be integrated. We claim that the results of this study, though further research is needed on particular issues, represent the first work which tries to offer a unified account of all these elements, which in previous studies, as we tried to show in chapter 4, had been singularly emphasized, i.e. one source of information was considered more relevant than the others without taking into account the relationships with each other.

One of the main results is the identification of constraints and preferences[19]. The constraints apply both to the role and to the relationships between the sources of information involved, while the preferences deal with tense patterns and temporal relations. In particular, the empirical data seem to support the following conclusions:

- the different types of linguistic information - grammatical, semantic and lexical - have different saliences. Lexical information is more salient than grammatical and semantic. All of them are less salient than commonsense knowledge under particular circumstances. Different types of constraints are activated for each type of information. The constraints can be conceived as representing the condition under which each source of information is a necessary and sufficient element for recovering the correct temporal relation. In particular:

  Constraint 1 (Tense) : tense represents the primary source of information for marking out the presence of a temporal relation. As for the identification of a specific temporal relation between eventualities, tense has the following constraint: sequences of adjacent tensed eventualities must have different temporal meanings, otherwise other sources of information are responsible for their ordering. The possibility of finding a principled setting for the A is only a necessary but not sufficient criterion, as the analysis for smooth tense shifts sequences has shown. This constraint is valid only for tense in adjacent main clauses in the text/discourse domain and not for eventualities in the complex sentence domain. As we have previously shown, the complex sentence domain (i.e. a sequence of main clause and subordinated one) does not need a shift in the temporal meaning of the tenses for ordering the eventualities, provided the principle according to which the main clause represents the temporal focus of the subordinated one and allows the setting of the A parameter as $A_{subordinateclause} = Rpt_{mainclause}$, since in complex sentences the relation between the A parameter of the subordinate clause and the Rpt of main one is "$A_{subordinate\_clause}$ *relative* Rpt_{main_clause}"[20].

  Constraint 2 (Temporal Expressions) : temporal expressions may represent explicit information for the ordering of eventualities provided that:

[19] On a similar, but different, approach see Hitzeman et al. (1995).

[20] On the contrary relations between adjacent sentences present always the inverse relation Rpt_{e1} *relative* A_{e2}. This shift in relation explains why in presence of same tense sequences is impossible to provide a setting to the A, except for the default value S.

(i.) they refer to the E moment of the eventuality or the R moment in case it is expressed by the tense meaning, i.e. if they are temporal localizers;

(ii.) if more than one temporal expression is present in the text/discourse, they must stand in an anchoring relations one with each other to signal a temporal relation, according to (i.) the granularity level of time they express (i.e. whether they signal a day, a day of week, a time of day ...) and (ii.) the semantic relation governing the anchoring;

(iii.) in case there is just one temporal expression related to an eventuality, its contribution is relevant for identifying the temporal relation between the temporal expression and the eventuality, but is irrelevant in for the relation between two eventualities.

Constraint 3 (Signals) : signals have only one single constraint based on their semantics. They represent salient information for temporal relations only when their semantics is explicit. When implicit they are accessory information which reinforces the contribution of other sources, like tense, viewpoint aspect, lexical aspect and commonsense knowledge. As we stated in chapter 3, implicit signals express their semantics by means of a lambda abstraction which takes into account information from the surrounding elements. Due to this reason we claim that implicit signals represents the least salient type of linguistic information.

Constraint 4 (Viewpoint and Lexical Aspect) : these two types of information have a constraint similar to that for tense: when eventualities have the same information, either for viewpoint or lexical aspects, their knowledge is ancillary. It is important to point that that these two types of information, though strictly connected with tense, have different salience. On the basis of the empirical data collected, we claim that viewpoint aspect is less salient than lexical aspect.

- commonsense knowledge is used when all other sources of information fail to provide clear-cut cues. With respect to this point, we claim that, in absence of cues from the linguistic information, commonsense knowledge is the most salient source of information for recovering temporal relations but also the less affordable, since it may introduce biases and disagreement;
- the role of discourse structure and rhetorical relations as cues for temporal relations seems to be different with respect to the proposal advanced by Lascarides & Asher (1993). We claim that the identification that a set of sentences forms a text/discourse, i.e. a coherent and cohesive whole, is a pre-condition for the existence and identification of any sort of relations between the various elements/entities in it. In this sense then, temporal relations are a by-product of the computation of discourse structure. Under this perspective, stating that discourse rhetorical relations *tout court* are responsible for the temporal order between eventualities does not take into account the role of the linguistic sources of information. In addition to this, general principles of conversation, based on (neo-)griecian approaches and psychological experiments (Zwaan, 1996; Kelter et al., 2004), offer explanations for particular constructions or order of preferences for describing or narrating events in texts/discourses, but we do not go as far as Lascarides & Asher (1993) in claiming that the *narration* relation is the most default discourse relation. Nevertheless, the identification of discourse structure, though not consciously performed by an interpreter, is a way to encode our pragmatic and commonsense knowledge. Thus, knowledge of discourse structure can improve the automatic recognition of tempo-

ral relations, as Forascu et al. (2006) have demonstrated, but this goes on a par as saying that knowledge of commonsense relation between eventualities improves the identification of temporal relations. Nevertheless, we are not claiming that identifying discourse rhetorical relations is not a worthwile task[21] which may reduce the scope of commonsense knowledge and facilitate ways for its ecoding.

As the analysis of the various tense patterns with respect to temporal relations (Table 5.5 on page 110 and Table 5.12 on page 125) have suggested, it is possible to associate a preference order for temporal relations according to the combination of the various tense forms. It is the proposal of temporal polysemy we have advanced in this work. Temporal polysemy is subject to constraints as well, namely (i.) the granularity, in terms of distinction, of temporal relations and (ii.) the tense temporal semantics. For instance, we have observed how adapting a coarse grained level of temporal relations, namely precedence, successions and contemporary, some tense patterns are able to preserve a principled way for setting the A textual temporal anchor, even in sequences of absolute same tense (this is the case of sequences involving the *presente* and the *imperfetto*). On the other hand, other tense patterns need as a necessary condition for setting the A a shift in meaning of the tense forms in the pattern even in presence of coarse grained temporal relations (it is the case of sequences with the *passato composto*, *trapassato I* and *futuro semplice*). In these latter cases, the A anchor assumes the role of a general temporal discourse focus for the *Rpt*s of the eventualities. In sequences of same tense (excluding the *presente* and the *imperfetto*) it seems that the *Rpt* makes reference to the same temporal textual anchor A but provided the fact that it is underspecified, it prevents the possibility of determining on the sole basis of tense meaning the temporal relations between the various *Rpt*s which are ordered by exploiting other sources of information. On the basis of these observations we claim that the **Hypothesis 1**[22] we formulated in chapter 3 is confirmed but needs some refinements in its formulation. In particular, we claim that in a text/discourse, tense is a necessary and sufficient source of information for reconstructing the order of eventualities when it is possible to set the A parameter in a principled way **and** the basic temporal meaning of the tensed eventualities, i.e. the relationships between the E moment and the deictic center S, and when present R, are different.

As for the analysis of the *imperfetto* we have presented, some remarks are compelling. In literature some scholars[23] have questioned the temporal nature of the *imperfetto* has a past tense, claiming that it signals that the designated situation must be located in an "actuality" other than the speaker's here-and-now. Following De Mulder (2004), and as suggested by evidences from the Experiment 1 where most subjects signalled the value TENSE as the main source for identifying the temporal relations in sequences of the kind *passato composto* - *imperfetto*, we claim that the prototypical meaning of the *imperfetto* is

[21]Provided the fact that discourse relations can be signalled in an explicit way by a set of linguistic cues, their identification and computation is an easier task than the creation of a huge database of commonsense knowledge, like Cyc. The point we want to express here is that theories which posit too much reliance on the role of discourse structure for the temporal processing of texts/discourse misinterpret somehow the role of discourse structure itself which is only a necessary pre-condition for the existence of temporal relations and not the core element which allows their identification.

[22]In a text/discourse, tense may be a necessary and sufficient element for reconstructing the order of eventualities in a restricted set of cases, in particular when there is a deep shift in the temporal meaning of the different tense forms, i.e. when it is possible to set a value for A in a principled way and which does not correspond to the default. On the other hand, sequences of tenses with the same forms, i.e. meaning, keep the value of A set on the default, and the temporal order of the eventualities involved is not based on tense information, but on the type of aspect (grammatical and lexical) and contextual, pragmatic information.

[23]Damourette & Pichon (1936); Coseriu (1980) among others

that of signaling past reference. However, one of the major issues relates to the analysis of the *imperfetto* is represented by its intrinsic connection with viewpoint aspect. As a consequence of this situation, very often it is stated that the difference between the *imperfetto* and the *passato composto* is not in their temporal meaning but with respect to viewpoint aspect. We have adopted this analysis only in part: in fact, we have considered the tense semantics of the *imperfetto* in most part as equals to that of the *passato composto*, the only difference is represented by the relationship between the *Rpt* and the temporal textual anchor *A*. Recalling the representations of Table 3.4 on page 58, the *imperfetto* can be represented as $((E \prec S) \wedge (Rpt \equiv E)) \wedge (Rpt \equiv A) \wedge (A \prec S)$, while the *passato composto* as $((E \prec S) \wedge (Rpt \equiv E) \wedge (Rpt \prec A) \wedge (A \prec S)$. But as we have clearly stated the *A* parameter is a necessary device to interpret tense in texts/discourses and is not to be confused with the interpretation of the viewpoint aspect. In De Mulder & Vetters (2002), the original analysis of Damourette and Pichon was reformulated using notions of mental-space theory (Fauconnier, 1984; Doiz-Bienzobas, 1995) according to which the *imperfetto*[24] informs that the situation is to be interpreted in a mental space constructed from a point of view different from the speaker's actual one. We claim that this different mental space is represented by the relation between the *Rpt* and the *A* textual anchor. As for the use of the *imperfetto* with a viewpoint aspect different that the default one, we claim that the temporal meaning of the tense is by-passed thus loosing the "virtual reality" instantiated by the prototypical uses[25].

Finally, we are in a position to reformulate the saliency-based hierarchical order of application of the various sources of information (**Formula 1**) with that in **Formula 2**. Again, the symbol $\lessapprox$ stands for "in absence of more specific linguistic information, X is the most salient source of information" and $\lesssim$ for "in absence of more specific information, X is the most salient source of information"; notice that when stating "in absence of more specific (linguistic) information", we are referring to the constraints we have identified on the saliency of the sources of information:

Formula 2 (Hierarchical order of information) : COMMONSENSE KNOWLEDGE $\lessapprox$ (IMPLICIT SIGNALS $\lesssim$ TENSE $\lesssim$ VIEWPOINT ASPECT $\lesssim$ LEXICAL ASPECT $\lesssim$ TEMPORAL EXPRESSIONS $\lesssim$ EXPLICIT SIGNALS)

[24] The original study was on the French *imparfait*. Due to highly linguistic similarity of uses and structures between French and Italian we have adopted their analysis as valid for the Italian *imperfetto* as well.

[25] On the role of viewpoint aspect as a device which may block the temporal interpretation associated with the various tenses it is worth analyzing in more details the habitual viewpoint aspect, which is a specialized reading of the general imperfective. In many cases the habitual aspect is expressed by means of the *imperfetto* morphology, for instance consider this sentence:

- Tutte le mattine il professore faceva colazione al bar e comprava un giornale.
  Every morning the professor had its breakfast at the bar and bought a newspaper.

In this case, the *imperfetto* is not to be interpreted with its default aspectual viewpoint value, i.e. general imperfective, but in a specialized reading of it, the habitual. As a consequence of this shift in viewpoint, we claim that the *imperfetto* maintains only partially its proper tense semantics, loosing the activation of the virtual reality mechanism, i.e. the relationship between *Rpt* and *A*. However, the prototypical temporal meaning, that is marking past reference, is still active. When computing the temporal relations between the eventualities, it is evident that the two eventualities stand in a precedence relation, first the breakfast and then the buying of the newspaper. The two eventualities give rise to a complex state, *S*, which accounts for the regularity of the course of the actions involved. In this case, the *imperfetto* code a temporal relation of precedence between the two eventualities, and not of contemporary as we have claimed because the viewpoint aspect prevents the activation of the relation between the *Rpt*s and the *A*s. On the habtual viewpoint, see also section 3.3.2.2, chapter 3.

It is important to point out that the saliency based hierarchy is an abstraction. A human interpreter always has at disposal all the various sources of information. On the basis of the experimental data, we have deducted that the most probable order of processing of the information is the one illustrated in the hierarchy since as soon as the subjects have found an reliable solution they have blocked their inferencing processes. The behavior of the pragmatic, i.e. commonsense, knowledge seems to offer further support to this observation. In fact, this source of knowledge was selected as the most salient only when all the others were "absent", i.e. when the constraints we have illustrated were not respected.

5.3 Putting things together: the Model

This section is entirely devoted to the illustration of the mechanisms and general architecture of a computational model for automatically resolve temporal relations in a text/discourse. The model is empirically based on the data and results illustrated in the previous section. Its modular organization is proposed as a strategy to improve the reliability of the output and avoid failure. Each module has some specialized functions and components which are conceived to deal with just one source of information at time. The modules are organized on a pipeline according to which the output of one module represents the input for the following, and so on and so forth. On the basis of the hierarchy we have illustrated by means of the **Formula 2** and as a general strategy, the specialized components of each module should be activated only when necessary. In Figure 5.2 on the facing page we have illustrated the overall workflow of the model, from raw input text to the final output.

As it is shown, the model is grounded in the empirical data and has four main modules. Each module can be thought as corresponding to a specialized level of analysis of three inter-linked domains: lexical and morpho-syntactic, temporal logic semantics, and pragmatics. The modules are structured as follows:

Module 1 : the first module is responsible for the identification, normalization and assignment of temporal relations between the temporal expressions in the text/discourse and also for the identification of the eventualities. Two different components are instantiated: one for temporal expressions and one for event detection and classification, i.e. assignment of the default lexical aspect;

Module 2 : it is responsible for the identification of the temporal relations between the temporal expressions and the eventualities. It has five internal components, organized in a pipeline;

Module 3 : this module is responsible for determining the temporal relations between eventualities, both in complex sentence context and in text/discourse context. On the basis of **Formula 2**, it has four internal components, each of them specialized in the treatment of one type of information, and an external one, which cointains the rhetorical structure of the discourse. The output of the module adds the temporal relation between the eventualities in analysis;

Module 4 : the last module is responsible for the complete temporal processing of the text/discourse. It implements a set of heuristics based on Allen's transitivity table in order to connect temporally, by means of inferencing processes, all eventualities and temporal expressions. It takes in input the outputs of Module 2 and of Module 3.

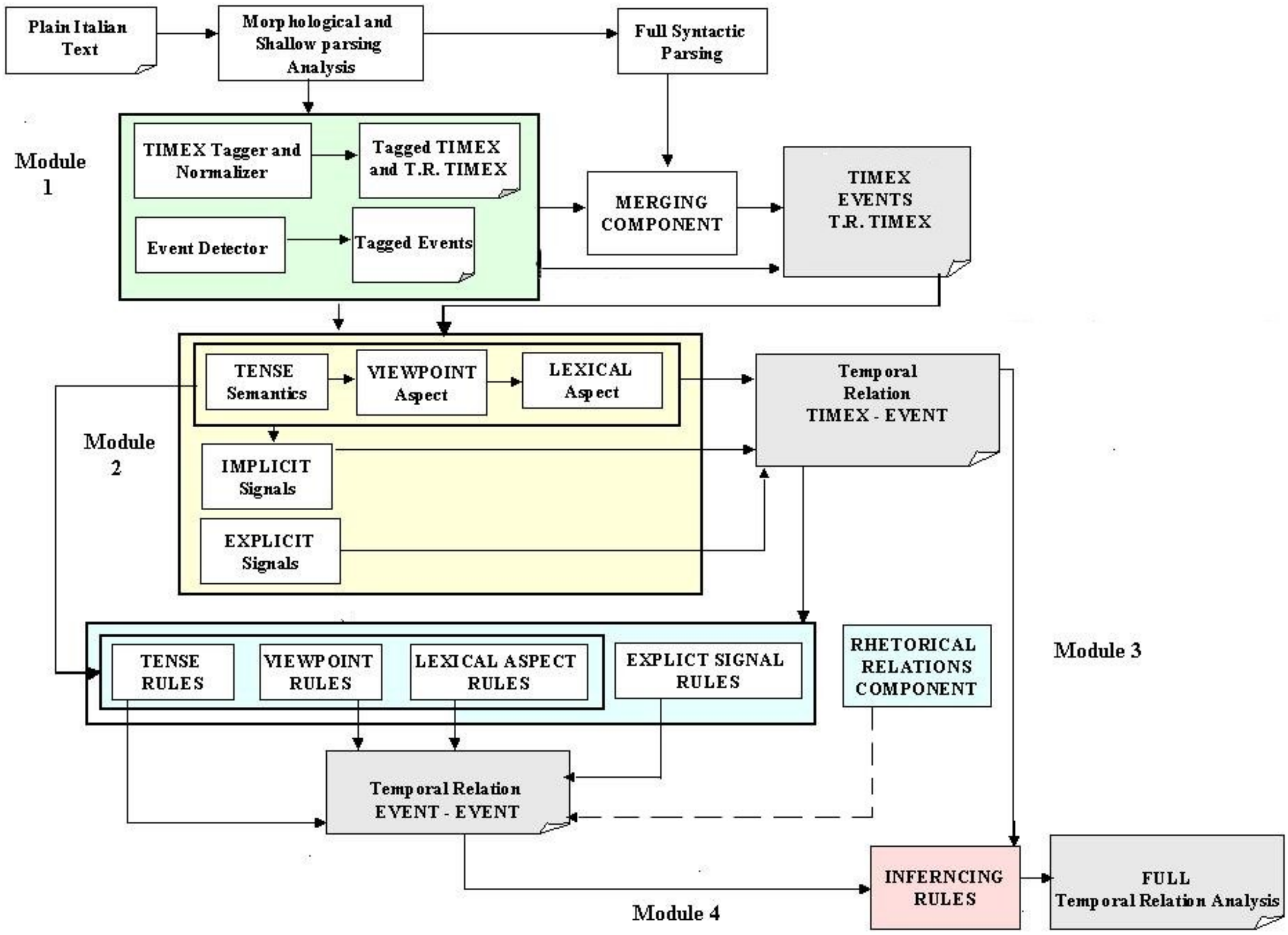


Figure 5.2: *Workflow of the Model.*

Some issues need clarifications and some components need to be illustrated in order to explain their functioning in the lights of the constraints and preferences presented in the previous section. In the remaining of this section we will illustrate how the most important component of the various modules work, and how their outputs represent crucial information for the correct functioning of the other modules and components.

5.3.1 Module 1: temporal expressions and events

The first module takes in input shallow parsed text (chunks) and activates its components:

- TimEx component: it is responsible for the identification, classification, normalization and computation of the temporal relations between temporal expressions; and
- Event Detetector and classification component.

The process of determining the temporal relations between temporal expressions is activated during the normalization phase. In fact, once the temporal expressions have been identified they are all normalized to a standard input which allows their ordering. Each temporal expression is classified according to their reference in one of the following classes, namely: DATE, when the input corresponds to a calendar date, TIME, when it denotes a part of the day, like "*mattina*" [morning], "*notte*" [night], "*pomeriggio*" [afternoon] and clock times ("*15:00*"), DURATION, if it refers to pure temporal intervals which cannot be associate to a calendar date, like "*due mesi*" [two months], "*il periodo passato*" [the last period], and SET, if it denotes a set of times which repeat themselves regularly like "*una volta a settimana*" [once a week]. The class of the temporal expressions also offers information on its ontological status, i.e. interval or instant. In particular, DATE, DURATION and SET always denote interval temporal expressions. As for the class TIME, which may be assigned to interval and instantaneous temporal expressions, the identification of the ontological status is not performed on the basis of the class itself but exploiting the normalized, i.e. standard, value assigned. For instance, two temporal expression like *le 3 del pomeriggio* [3 o'clock in the afternoon] and *la mattina* [(in the) morning] will be both classified as TIME. The difference in their ontological status, i.e. instant for the former and interval for the latter, could be recovered only by means of the normalized values, according to which the first, which is an instant, will have `YYYY-MM-DDT15:00`, while the latter, which is an interval, `YYYY-MM-DDTMO`.

The Event Detector component will signal if the head of a chunk is an event or not. In addition to spotting the eventualities in a text/discourse, its other main function is that of classifying the eventualities with respect to their default lexical aspectual value[26] and the identification of same, i.e. coreferential, eventualities.

From a raw text like the following:

(5.13) La Repubblica 03/10/1986
Un giovane di 19 anni è stato ucciso nella notte. Un killer, nascosto al buio, lo ha aspettato sotto casa e gli ha sparato contro. Il giovane aveva avuto dei diverbi con numerose persone.
La Repubblica 03/10/1986
..A young men aged 19 was killed last night. A killer, hidden in the dark, waited for him in the nearby of the young man's home and shoot him. The young man had quarreled with lots of people.

once at the shallow parsing level of analysis, Module 1 provides the following outputs:

- Temporal Expressions Identification and Normalization: T_1 = 1986-10-03_DCT type = `DATE`; T_2 = "notte" value =02-10-1986TNI type = `TIME`.
- Temporal Relations between Temporal Expressions: ($T_2 \prec T_1$).
- Event Detector = e_1 = "è stato ucciso" default actionality = `ACHIEVEMENT`; e_2 = "nascosto" default actionality = `STATE` e_3 = "ha aspettato" default actionality = `ACTIVITY`; e_4 "ha sparato" default actionality = `ACTIVITY`; e_5 = "aveva avuto dei diverbi"
default actionality = `ACTIVITY`.

In the second part of this work we will describe two applicative devices (a tagger for temporal expressions and a general strategy for event detection and classification) to illustrate in more details some mechanisms of Module 1.

[26] A possible strategy, and the one we have adopted in 7, is to connect the event detector to a lexical resource which encodes this information. A different strategy to identify the default lexical aspect of a certain eventuality is represented by the computation of the relative frequency in a reference corpus. Provided an eventuality with lemma X, its default lexical aspect value is obtained by calculating the frequency of the various lexical aspect values that all the occurrences of the lemma X **with same sense** have in the corpus with respect to the global frequency of the lemma with that sense. In this way, we are able to maintain under control the well known phenomenon of lexical aspect hybridism. This work, however, is out of the scope of this thesis.

5.3.2 Module 2: Tense, Aspect, and Signals

Module 2 takes in input the output of Module 1. Three main components, organized in a submodule, deal with and compute three different types of information strictly connected with each other, namely tense, viewpoint aspect and lexical aspect.

The tense component is responsible for the identification of the basic temporal meaning of tensed eventualities, according to the values reported in section 3.3, chapter 3. As for eventualities at the infinitive, we propose the following analysis: NULL, for simple infinitive, and (E $\prec$ R) for past infinitives. Otherwise, if the infinitive is governed by a phasal verb the tense value of the phasal verb is assumed as being that of the infinitive. For instance, if we have a sequence of the kind:

(5.14) Marco ha finito di studiare.
Marco has finished studying

The event of *studiare* [studying] is assigned the tense semantics of the phasal verb, which in this case is the *passato composto*. In addition to this, the tense component will signal also the mood and diatesis. The presence of this additional information is highly important for two main reasons: (i.) mood offers useful information on the reality, i.e. real happenings, of the eventualities: the subjunctive or the conditional[27] moods tend to signal the fact that an eventuality may not have occurred, thus requiring special heuristics to deal with these cases, and (ii.) diatesis is a cue which can be used to facilitate the identification of viewpoint aspect. In this phase of analysis no textual anchor A is present and the only reliable setting which can be performed is represented by the S, which is assumed to be for all eventualities the DCT. This temporal expression, which is always present in newspaper articles, corresponds the speaker's "here-and-now".

The aspectual viewpoint component, on the basis of the information of the tense component and a set of heuristics, is responsible for the identification of the viewpoint aspect. It associates to every (tensed) eventuality its interval representation, and consequent visibility of beginning and ending points, and the related quantification over the eventuality. Provided the relative non-homogeneity between tense forms and aspectual viewpoint, we have decide to limit the distinctions to two main classes, namely IMPERFECTIVE and PERFECTIVE, since they can be most easily associated with tense forms and their corresponding morphology. More precise values, like HABITUAL and PROGRESSIVE, are associated only in presence of their corresponding periphrases[28]. The set of phasal (or aspectual) periphrases is part of the analysis of the viewpoint aspect since phasal verbs focus on a part of the interval representation of the eventuality and fix in a clear way either the beginning or ending point (or both) of the interval representation of the eventuality which is governed by the phasal verb. When in presence of a phasal verb, the viewpoint component will also determine the temporal relation between the interval point of the eventuality which is focused and the *Rpt* of the eventuality itself. In this case each phasal verbs is associated with a heuristic which according to the semantics of the phasal verbs itself instantiates the temporal relation between the focused point(s) and the *Rpt*. An example of this mechanism is illustrated below[29]:

(5.15) (DCT = 2009-01-30) Marco iniziò a correre alle 15:00.
Marco began to run at 15:00.

[27] When it does not represent an instance of the *futuro-nel-passato*.

[28] See section 3.3.2.2, chapter 3.

[29] All temporal relations will be expressed by means of the associated labels as illustrated in Table 2.1 on page 29, in chapter 2. Thus, in the example 5.17, o reads as overlap, s as start and $\prec$ as before.

Module 2: $e_1 = ((E_1 \equiv Rpt_1) \prec S)$ [tense interpretation]
$Imperf(I)[\exists I_1(\forall J(C(e) \wedge J \subseteq I_1) \longrightarrow \exists e_1 \wedge (Rpt_1\ o\ I_1) \wedge (t_1 \prec I_1)]$ [partial viewpoint]
Heuristic Phasal Verb: e_1 `is governed by a phasal verb`
`AND phasal verb` = INIZIARE
`then` $(t_1\ s\ Rpt_1)$
$Imperf(I)[\exists I_1(\forall J(C(e) \wedge J \subseteq I_1) \longrightarrow \exists e_1 \wedge (Rpt_1\ o\ I_1) \wedge (t_1 \prec I_1) \wedge (t_1\ s\ Rpt_1)]$
[complete viewpoint aspect]

In case the viewpoint value associated with tense is different with respect to the default one, as reported in Table 3.5 on page 72, this component makes this information available.

The lexical aspect component is responsible for the identification of the actual, i.e. in context, lexical aspectual value of the eventualities. Its input is represented by (i.) the output of the previous two components of Module 2, (ii.) the event detector of Module 1 and (iii.) the syntactic structure of the sentence in which the eventuality is located. A set of compositional rules with different scope and order of activation, as we have described in chapter 3 applies and provide as output the in-context lexical aspect value and its associated temporal interval representation. Its values are STATE, ACTIVITY, SEMELFACTIVE, ACCOMPLISHMENT, ACHIEVEMENT.

The main results of the analysis of this internal submodules is the formalization of each eventuality in its corresponding interval representation. In example 5.16 we illustrate how the output of these three components is structured for the event e_1 ("*è stato ucciso*" [was killed]) from the text/discourse in 5.13:

(5.16) $((E_1 \equiv Rpt_1) \prec T_1)$ [tense interpretation]
$Perf(I)[\exists I_1 \exists e \wedge (Rpt_1 \subseteq I_1) \wedge (t_1 \leq I_1 \leq t_2))] \wedge$ [viewpoint interpretation]
$I_1 = Achievement^{[+telic][-durative]} \longrightarrow$
$[(\mathrm{t}_1 \leq I_1 \leq t_2) \wedge (t_3 \leq I_1^{'}) \wedge (\exists t((t \subseteq I_1) \wedge ((t_1 = t) \vee (t_2 = t) \wedge (t_2 \prec t \prec t_3)))]$
[lexical aspect]
$[(E_1 \equiv Rpt_1) \wedge ((t_1 \leq Rpt_1 \leq t_2) \wedge\ ((t_3\ m\ t_2)$
$\wedge (t_3 \leq I_1^{'})) \wedge (\exists t((t \subseteq Rpt_1) \wedge ((t_1 = t) \vee (t_2 = t))_{ACHIEVEMENT})) \prec T_1]$ [Module 2 output for the tense, viewpoint aspect and lexical aspects components]

The output of these three components is necessary for two processes: firstly, associated with the output of the temporal expression component of Module 1, it can be used to determine the temporal relations between temporal expressions and eventualities in presence of an implicit signals, since it provides all the necessary information for the activation of the lambda abstraction which expresses their semantics, and secondly, it is used to activate the components of Module 3 only when they can provide a reliable output.

Module 2 is also responsible for the identification of the temporal relations between eventualities and bare temporal expressions. The temporal relations which are assumed to be valid are all Allen's'13 interval relations[30] and the restricted set of 8 relations between instants and punctual intervals[31]. The mechanism works on a clause-by-clause basis. This means, that the identification of the temporal relations between the eventuality and the temporal expression is activated only if both appears in the same clause. Using a sentence level may generate ambiguities since it can be the case that more than one temporal

[30] Allen's *equal* relation is called *simultaneous*.

[31] The relations between instants are used to deal with the so-called instantaneous eventualities, namely achievements and semelfactives

expressions is present in a sentence and they may refer to two distinct eventualities. The identified constituents from Module 1 are associated with a full syntactic parsing of the text/discourse in analysis. The temporal relation is then computed only between the eventuality and the temporal expression constituents which are directly linked. The final assignment of the temporal relation is performed in three different ways:

- if no implicit or explicit signals are present: a set of heuristics based on parameters which take into account the ontological type of the two constituents, tense and viewpoint aspect, and the temporal relation between the clausal temporal expression and the DCT apply. The possible temporal relations are based on the 13 intervals relations and the 8 relations between punctual events and intervals[32] (Allen & Hayes, 1989). As a general condition, the tensed eventuality and the temporal expression must stand in the same temporal relation with the DCT. For instance, if the eventuality in analysis is a perfective activity, whose tense is *passato composto*, thus standing in a precedence relation with the DCT, and its directly related temporal expression is an interval which stands in a precedence relations with the DCT, then the only possible temporal relation which can apply is Allen's *during/contains*[33]. In case a contradiction between the two elements should arise[34], the system will apply a set of normalization heuristics which aim at identifying possible different temporal meaning of the tense. If the contradiction can be resolved, the computation of the temporal relation is performed, otherwise the system will fail and no relation between the eventuality and the temporal expression is computed. It is important to point out that if a different temporal interpretation is identified, then the viewpoint and lexical aspect component are re-analyzed in order to be compliant with the new tense value.
- presence of phasal (aspectual) verbs: in this case, a simple set of heuristics apply. Phasal verbs are responsible for focusing on one phase of the temporal development of the eventuality. Once the eventuality and the temporal expression have been identified as directly linked, according to the type of phasal verbs which governs the eventuality and the type of temporal expression, the temporal relation between the two entities is computed. These types of temporal relations normally anchor in a clear way either the beginning or ending point, or both on the time line in a precise way. This will provide important information for the inferencing module, i.e. Module 4, to complete the temporal processing. An example of how this type of heuristics works is illustrated below:

  (5.17) (DCT = 2009-01-30) Marco iniziò a correre alle 15:00.

  Marco began to run at 15:00.

  Module 1: e_1 = "iniziò a correre" default actionality ="ACTIVITY"; T_1 = 2009-01-30_DCT type = `DATE`; T_2 = XXXX-XX-XXT15:00 type = `TIME`; $T_2 \prec T_1$

  Module 2: $e_1 = ((E_1 \equiv Rpt_1) \prec S)$ [tense interpretation]

[32] The 8 relations are *before/after*, *meets/is_met_by*, *simultaneous*, *during*, *starts*, *finishes*. See also section 2.3.3.2, chapter 2.

[33] This a binary relations. Consequently, if we take as first element of the relation the eventuality and as second the temporal expression we would obtain E_1 *during* T, while viceversa is T *contains* E_1.

[34] We are referring to futurate or past readings of the *presente*. Normally, these readings are activated in presence of a temporal expression which changes the actual temporal meaning of the tense with respect to that associated with the surface form, thus creating a contradiction between the temporal meaning of the eventuality and the temporal expression.

$Imperf(I)[\exists I_1(\forall J(C(e) \wedge J \subseteq I_1) \longrightarrow \exists e_1 \wedge (Rpt_1\ o\ I_1) \wedge (t_1 \prec I_1) \wedge$ $(t_1\ s\ Rpt_1)]$ [viewpoint aspect]

$I_1 = Activity^{[-telic][+durative]} \longrightarrow [(\mathrm{t}_1 \prec I_1 \prec t_2) \wedge (\forall t((t \subseteq I_1) \wedge (t_1 \prec t \prec t_2))]$ [lexical aspect]

Heuristic 1: e_1 `is introduced by a phasal verb`

`phasal verb` = INIZIARE `AND` (T_1 = TIME `AND value = ``YYYY-MM-DDThh:mm''`)

then $t_1 = T_1 \wedge Rpt_1\ s\ T_1$

- in case there is a signal, the two other internal components are activated, in particular:

  (i.) with an explicit signal (and no phasal verb): the explicit signal component is activated. Explicit signals express their semantics in a unique way. Though in **Formula 2**, they have been considered a salient source of information in absence of other more specific information (tense, viewpoint aspect, lexical aspect and temporal expressions), we claim that as far as the temporal relation between an eventuality and a temporal expression is concerned they qualify as the most salient type of information without conditions. In particular, in case an explicit signal introduces a temporal expression, the knowledge of the syntactic dependencies between the two elements is necessary and sufficient to establish the temporal relation between the two constituents due to the semantics of the signals itself. Consequently, the set of possible relations is reduced to the meanings of the explicit signals.

  (ii.) with an implicit signal: the implicit signal component is activated. The component takes in input the analysis of the tense, viewpoint and lexical aspect components and also the output of the temporal expression component of Module 1. A set of heuristics which take in account the type of the temporal expression involved, tense, viewpoint and lexical aspect, and the dependency structure applies. The combination of this information is necessary and sufficient in order to infer the semantics of these type of signals. Once the semantics is established, the temporal relation between the event and the temporal expression is obtained. In this case, the knowledge of the relation between the temporal expression and the DCT is not necessary. To exemplify this mechanism consider the first sentence of 5.13. The information we have at disposal are the output of Module 1 and the output of the internal components for tense and aspect of Module 2:

  (5.18) Un giovane di 19 anni è stato ucciso nella notte.

  Module 1: T_1 = 1986-10-03_DCT type = `DATE`; T_2 = "notte" value =02-10-1986TNI type = `TIME`; $(T_2 \prec T_1)$.

  Module 2: $[(E_1 \equiv Rpt_1) \wedge ((t_1 \leq Rpt_1 \leq t_2) \wedge (t_3 \leq I_1')) \wedge (\exists t((t \subseteq Rpt_1) \wedge ((t_1 = t) \vee (t_2 = t))_{ACHIEVEMENT})) \prec T_1]$

  Implicit signals: *nella* [in]:

  `if` $e_1 = Perf_{ACHIEVEMENT}$ `AND` $T_2 = TIME_{INTERVAL}$

  `then` $(E_1\ d\ T_2)$

The heuristics for determining the semantics of the implicit signals in these cases have been developed by means of an extensive corpus study. Its results and the details of the heuristics for the most frequent implicit signals we have identified is reported in appendix A. In this case, all 13 intervals' relations and the 8 instants - punctual intervals' ones apply. In case a signal should not code a temporal relation but express the duration of an eventuality (this is rather common with signals like *di* and *a*) the relation expressed is *hold*.

5.3.3 Module 3: relations between eventualities

The third Module is responsible for the identification of the temporal relations which may hold between eventualities. Each component of the module present a set of heuristics which, when activated, provide as output the temporal relation value(s). The heuristics are divided into two main groups: one for complex sentence contexts and the other for adjacent eventualities in main sentences, since, as we have claimed in chapter 3 and with the support of the empirical data collected, the mechanisms for determining the temporal relation differs for these two type of contexts. In the remaining of this chapter, we will concentrate on the computation of temporal relations between adjacent eventualities. As for the temporal relations in complex sentences, we have described the general mechanism for setting the A textual parameter for the dependent clause, but further elements influence their computation, in particular the semantic type of the main verb and the constraints it imposes on the tense and mood of the dependent clause. Due to reasons of time, we do not present a complete analysis for these cases, which are left open to future research.

The four internal components are mutually exclusive one with respect to the other. The general principle which guides their functioning can be stated as follows: "*if, on a certain level, the information is the same, then look for more specific one in other levels, otherwise failure is possible*". This can be conceived as being at the basis of the mechanisms governing the activation of the various heuristics of the internal components of Module 3. Each component is activated if and only if a set of preconditions is respected, otherwise the temporal ordering is completely inferred by means of the external component. The list of preconditions for each of the components is the following:

Explicit signal precondition : there must be an explicit signals which directly connect two eventualities;

Tense precondition : the basic tense meaning of the eventualities must be different;

Viewpoint Aspect precondition : the viewpoint values of the eventualities must be different;

Lexical Aspect precondition : the lexical aspect values must be different according to a coarse grained distinctions, namely state *vs.* event (and viceversa). In presence of sequences of events, the fine grained distinctions (i.e. activity, accomplishment and achievement and semelfactives) cannot be considered as a crucial information because the commonsense knowledge associated to the events' meaning is more salient.

It is important to point out that each component will select only the relevant information necessary to the functioning of its heuristics from the output of Module 2. For instance, the tense component will consider as crucial input the tense analysis and the interval representations; the explicit signal will limits to the identification of the interval representations to relate; the viewpoint and lexical aspect components will rely on the viewpoint and lexical aspect analysis.

The rhetorical relation component, which structure discourse, is the most specific as far as the identification of temporal relations is concerned, when all other components fail to provide a reliable ouput. We have considered it as an external module because the identification of discourse rhetorical relations is based on different strategies than those used for dealing with the linguistic information. Thus, it is plausible to consider it as a separate level of analysis with its own peculiarities. Nevertheless, its contribution to the identification of temporal relations, though not primary, cannot be ignored.

Assuming as valid a reduced set of rhetorical relations between discourse segments, we can associate each of them with a specific temporal relation as follows. In the descriptions, X and Y stand for discourse segments or units, while X_e and Y_e represent the main eventualities in the discourse segments.

- Narration: the narration relation is characterized by a coherent sequence of events; associated temporal relation:

$$\text{Narration (X; Y)} \longrightarrow \mathrm{X}_e \prec Y_e$$

- Elaboration: discourse segments standing in an elaboration relation, each describe barely the same event, thus their times are the same; no temporal relation can be stated, unless one of the two eventualities stands in a *part_of* relation with the other, according to which a general temporal relation of overlap is assumed[35]:

$$\text{Elaboration}_1 \text{ (X; Y)} \longrightarrow \mathrm{X}_e \textit{ No Temporal Relation } Y_e$$

$$\text{Elaboration}_2 \text{ (X; Y)}_{part\_of} \longrightarrow \mathrm{X}_e \; o - oi \; Y_e$$

- Result: it expresses a cause - consequence relation, thus cause precedes effect:

$$\text{Result (X; Y)} \longrightarrow \mathrm{X}_e \prec Y_e$$

- Explanation: it denotes a Result relation but with inverse ordering of the discourse segments, i.e. first effect and then cause:

$$\text{Explanation (X; Y)} \longrightarrow \mathrm{X}_e \succ Y_e$$

- Parallel and Contrast: it relates discourse segments with a common topic or a contrast between two different actions. The only temporal relation is that constrained by tense which identifies the general temporal dimension of the eventualities. The precise temporal relation remains underspecified. This corresponds to the activation of all possible temporal relations as proposed by Allen (1983):

$$\text{Parallel (X; Y)} \longrightarrow \mathrm{X}_e \textit{ Underspecified Temporal Relation } Y_e$$

- List and Enumeration: it relates discourse segments which provide a list or an enumeration of facts.; no temporal relation can be inferred between these types of discourse segments:

$$\text{List (Enumeration) (X; Y):} \longrightarrow \mathrm{X}_e \textit{ No Temporal Relation } Y_e$$

[35]The overlap relation is a coarse-grained temporal relation though not obtained from conceptual neighbors. The external module cannot access the information from the other modules and this prevents the possibility of identifying more fine grained values for this general ovelap, namely a distinction between *overlap*, valid between durative interval events, and *during*, valid between a punctual interval and a durative event.

5.3.3.1 Computing temporal relations between adjacent eventualities

We assume as basic temporal relations all Allen (1983)'s 13 interval relations. The measure of the duration of eventualities is represented, again, by means of the predicate *hold*.

In the text/discourse context, the computation of temporal relations is between adjacent eventualities. Module 3 is not activated if both adjacent eventualities are connected to a temporal expression. In this case the temporal relations between the eventualities is inferred by means of the relations between the temporal expressions, and will be identified by Module 4. Each component applies different heuristics. As a general principle, the temporal relations between two adjacent eventualities are computed by considering the relations between the beginning and ending points of their interval representations, according to the relations illustrated in Table 2.1 presented in chapter 2, section 2.3.2.2. However, much of this information is missing or only vaguely present in the text/discourse. The empirical data collected show that even in presence of information which may restrict the choice of the the temporal relation, disagreement still exists. In the Experiment 2, the subjects totally agree on the temporal relations only in 50% of the discourse segments; the remaining 50% has clusters of temporal relations, as illustrated in Figure 5.3.

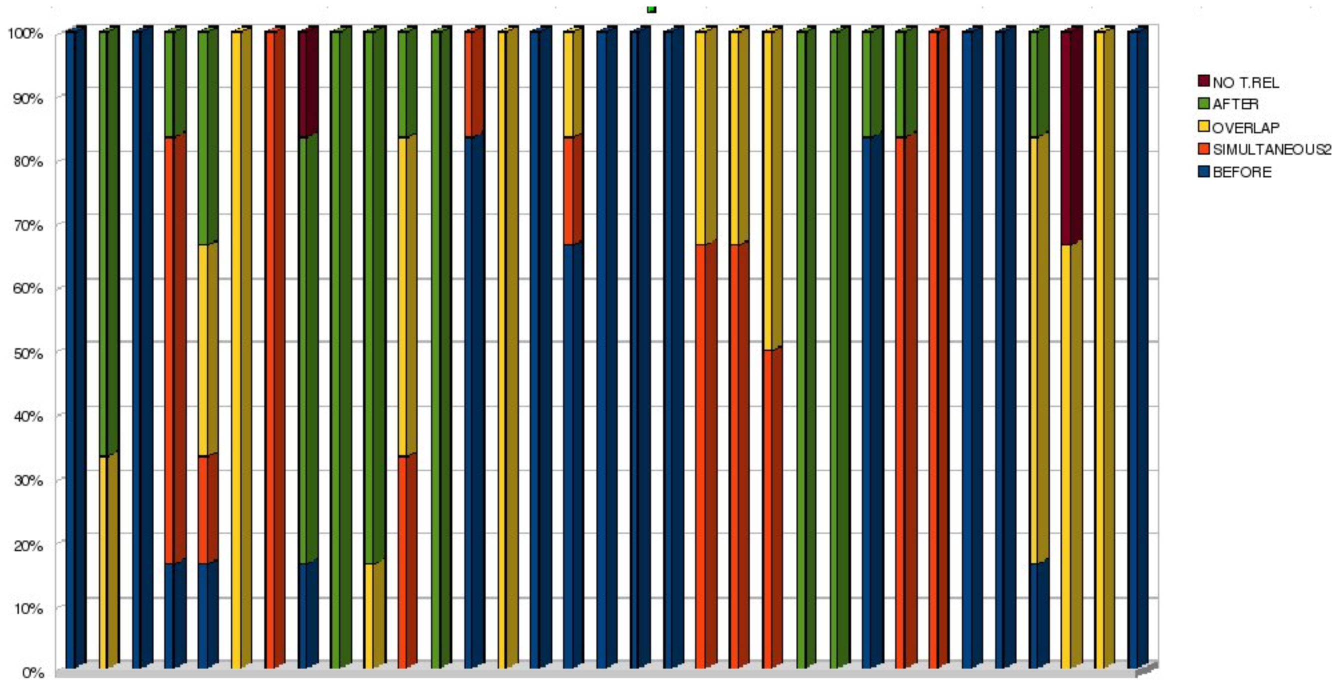


Figure 5.3: *Distribution of the subjects judgements per temporal relation for each discourse segments in the Experiment 2.*

Vagueness, partial ordering and missing information are intrinsic to text/ discourse. The representations that we, as humans, construct when decoding a text/discourse are at best only approximate. In order to deal with this issue, the final output of the components can differ in terms of the preciseness of the temporal knowledge expressed so that we can have:

- precise temporal knowledge; and
- coarse grained temporal knowledge.

Precise temporal knowledge occurs when a single temporal relation can be stated, while we have coarse-grained knowledge when more than one temporal relation can be inferred. In this case, multiple temporal relations do not represent contradicting temporal representations, but related or conceptually adjacent temporal relations, as it can be inferred also by observing the main clusters in Figure 5.3 on the preceding page. Instead of expressing these types of temporal relations by means of disjunctive finely grained relations, we can make use of coarse grained knowledge based on the notion of conceptual neighbors. The main advantage of such a representation is twofolded : on the one hand, the model is somehow cognitively similar to the temporal representations that humans may have, and, on the other hand, it avoids that the inferencing module may fail to complete the whole set of temporal relations.

When analyzing the temporal polysemy for the *imperfetto*, we have stated that two temporal relations are a conceptual neighbor if they can be directly transformed one into the other by continuously deforming the events in a topological sense, that is by lengthening, shortening or moving one event with respect to the other. Under this perspective, all Allen's' 13 temporal relations we have assumed as valid can be described in terms of conceptual neighbor relations. In fact, considering an interval A as fixed and an interval B as undergoing transformation in topological sense, we can easily observe how starting from the relation of precedence, we can arrive to the relation of succession. A graphical representation of this process is illustrated in Figure 5.4 from Freska (1992). The transforming eventuality is the one depicted in a dumbbell-shaped line, while the fixed one as a rectangular. The circles represent the temporal relations arranged according to their conceptual neighbours. Time is assumed to move from left to right.

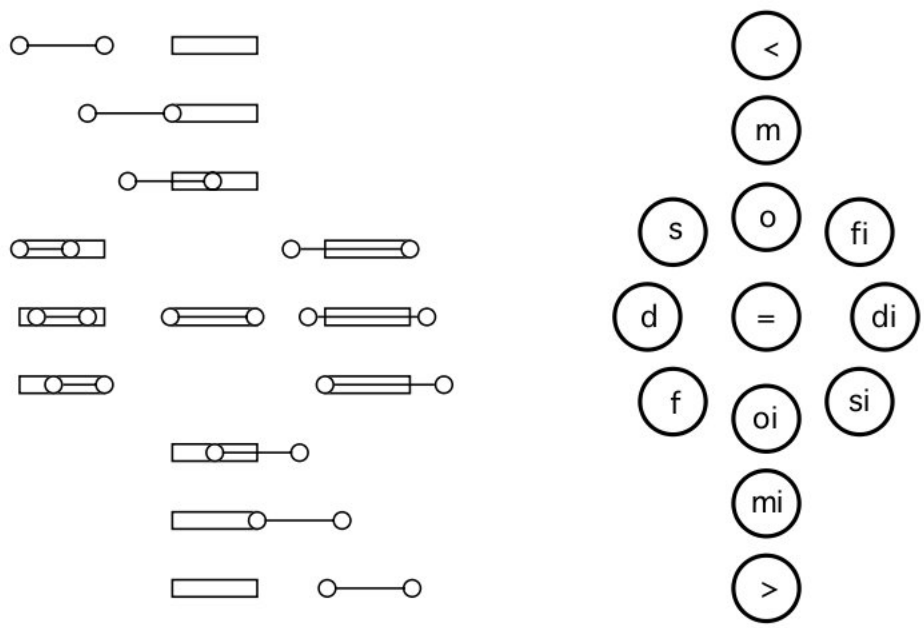


Figure 5.4: *Temporal relation between two event arranged according to their conceptual neighborhood [Freska (1992): 213].*

The shift from a relation to another is gradual. This means that two relations are conceptual neighbors only if they can be transformed in one another directly. Thus, *precedence* and *meet* are conceptual neighbors, but this does not hold for *precedence* and *overlap* since transformation can take place only through the *meet* relation. Two axioms are related to the use of conceptual neighborhood as proposed by Freska (1992):

Conceptual Neighborhood Axiom 1 : incomplete knowledge about temporal relations is coarse grained knowledge if and only if the union of at least two disjunctions of finely grained temporal relations form a conceptual neighbors.

Conceptual Neighborhood Axiom 2 : a set of disjunctions of finely grained temporal relations forms a conceptual neighbor if and only if they are path-connected through conceptual neighbors relations.

On the basis of these statements, in case that a unique temporal relation cannot be inferred the output of the internal components will be expressed by means of coarse-grained temporal relations based on conceptual neighbors. In Figure 5.5 extracted from Freska (1992), we illustrate the set of Allen's relations re-organized in the lights of conceptual neighbors with their corresponding labels.

ol	*older*	< m o fi di
hh	*head to head with*	si = s
yo	*younger*	d f oi mi >
sb	*survived by*	< m o s d
tt	*tail to tail with*	fi = f
sv	*survives*	di si oi mi >
pr	*precedes*	< m
bd	*born before death of*	< m o fi di si = s d f oi
ct	*contemporary of*	o fi di si = s d f oi
db	*died after birth of*	o fi di si = s d f oi mi >
sd	*succeeds*	mi >
ob	*older & survived by*	< m o
oc	*older contemporary of*	o fi di
sc	*surviving contemporary of*	di si oi
bc	*survived by contemporary of*	o s d
yc	*younger contemporary of*	d f oi
ys	*younger & survives*	oi mi >

Figure 5.5: *Coarse grained temporal relations arranged on conceptual neighborhood [Freska (1992): 219].*

To avoid failure, we claim that the temporal relations between adjacent eventualities are all computed with respect to the *Rpt*s. In case of a perfect eventuality, since the system is not able to discriminate between the general perfective and the perfect viewpoint, the whole set of possible temporal relations (that between an eventuality and the E moment of the event, and that between the eventuality and the contingent state) will not be performed. As a general strategy, we will consider clear-cut cases of perfect eventualities (e.g. *passato composto + DA +* $DURATION_{quantified}$) as having stative lexical aspect by taking in account only the contingent state. In the following paragraphs, we will describe the functioning of the tense, viewpoint and lexical aspect components.

Tense The tense component implements a set of heuristics, based on the empirical data and theoretical assumptions. As we have previously claimed tense is a necessary and sufficient source of information for the identification of temporal relations only when the temporal semantics of the adjacent tensed eventualities are different (different relationships between the E moment and the deictic centers, S and, when present, R, and different relationships between the textual anchor A and the moment of reference, Rpt). The relationships between beginning and ending points of the intervals' representations is performed on this basis.

To illustrate the functioning of the tense component consider a discourse sequence of the kind *passato composto*$_{e1}$ - *trapassato* I_{e2}, with no temporal expression associated to the eventualities and no explicit signals. The tense component first checks if its precondition is respected, then if so, as it is in our example, it will apply the corresponding heuristics for setting the A parameter according to the tense pattern of the eventualities to compute the temporal relation:

- discourse sequence: *passato composto*$_{e1}$ - *trapassato* I_{e2}
- $e_1 = ((E_1 \equiv Rpt_1) \wedge (Rpt_1 \prec A) \wedge (A \prec S) \wedge (t_1 \leq Rpt_1 \leq t_2))$ [Input from Module 2]
- $e_2 = ((E_2 \equiv Rpt_2) \prec A) \bullet (A \prec S) \wedge (Rpt_2 \prec A) \wedge (t_3 \leq Rpt_1 \leq t_4))$ [Input from Module 2]
- tense component: `if` *trapassato I* `is the second tense and` *passato composto* `is the first tense`
  `then` $A_{trapassatoI} = Rpt_1$
  $((E_1 \equiv Rpt_1) \wedge (Rpt_1 \prec A) \wedge (A \prec S)) \wedge (t_1 \leq Rpt_1 \leq t_2)) \wedge ((E_2 \equiv Rpt_2) \prec Rpt_1) \bullet (Rpt_1 \prec S) \wedge (Rpt_2 \prec Rpt_1) \wedge (t_1 \prec t_3) \wedge (t_2 \prec t_4) \wedge (t_1 \prec t_4) \wedge (t_2??t_3))$
- output: $((Rpt_2 \prec Rpt_1) \vee (Rpt_2\ m\ Rpt_1) \vee (Rpt_2\ o\ Rpt_1))$

As it appears the output does not provide a unique temporal relations due to the missing information between the ending point of the event at the *passato composto* and the beginning point of the event at the *trapassato I*, i.e. $(t_2??t_3)$. To reduce the number of possible temporal relations preference rule apply. The set of preference rules have been elaborated following the proposal of the tense temporal polysemy with minor modifications in order to be compliant with the tense constraint[36]. In particular, for sequences of *passato composto* - *trapassato I*, the preference rule states that the reliable temporal relation is that of precedence:

- output: $((Rpt_2 \prec Rpt_1) \vee (Rpt_2\ m\ Rpt_1) \vee (Rpt_2\ o\ Rpt_1))$
- Preference Rule: `if the sequence is` *passato composto* - *trapassato I*
  `then reduce the output to` $Rpt_2 \prec Rpt_1$
- final output: $(Rpt_2 \prec Rpt_1)$

The role of preference rules is crucial to reduce the number of temporal relations. It is important to point out that preference rules do not apply for all tense patterns. For instance with the *futuro composto* and the *futuro nel passato*, where the relationship between E and S cannot be reliable stated, we claim that no preference rules apply and that the output of the component is obtained by disjunctive finely grained relations then re-arranged on the basis of conceptual neighbors.

[36]On the basis of the results for the saliency of the sources of information from the Experiment 2, relatively polysemic tense patterns are not processed by the tense component, due to the fact that they do not respect the tense constraint.

Viewpoint Aspect The viewpoint aspect component will provide the analysis of temporal relations between adjacent eventualities with different viewpoint aspect. The identification of temporal relations is obtained by means of heuristics which are developed on the possible temporal relations either between the beginning points or between the ending points of the interval representations of the eventualities. Recalling the properties of bounded and unbounded interval representations and the functions α and ω on the accessibility of beginning and ending points of all types of intervals (section 2.3.3 chapter 2), it is evident that the only available relationships are either those between the beginning points or those between the ending points. Notice that these relationships are mutually exclusive: either only between the beginning points or between the ending points.

This component takes in input the analysis of the viewpoint and lexical aspect from Module 2. Tense is not needed since for the activation of the viewpoint aspect component the two eventualities must have same tense meaning and thus are already located on one common temporal dimension with respect to the DCT, i.e. the here-and-now of the texts/discourses.

The output of the viewpoint component is represented by coarse grained knowledge expressed by means of conceptual neighbors. Anyway, there is one case in which a clear-cut, i.e. precise, temporal relation is made available as output, and it is restricted to the following viewpoint and lexical aspect combinations, namely:

- PERFECTIVE$_{achievement|semelfactive}$ - PROGRESSIVE = SIMULTANEOUS. In this case the ending point of the two "instantaneous" eventualities is conceived as being simultaneous with the focus point of the eventuality at the progressive. The relation is claimed to be maintained in case of inversion of the two viewpoints pattern (PROGRESSIVE - PERFECTIVE$_{achievement|semelfactive}$); e.g.:

  (5.19) Marco raggiunse la cima$_{e_1_Perf(ACHIEVEMENT)}$. Giovanni stava correndo$_{e_2_PROGR.}$.

  Marco reached the top. Giovanni was running.

  $e_1 \equiv e_2$

- PERFECTIVE$_{activity|accomplishment}$ - PROGRESSIVE = DURING. In this case, due to the durative feature of these event types, the perfective events are conceived as being included in the interval representations of the perfective eventuality. We have excluded the possibility of a *meet* relation between the accomplishment and the progressive eventuality, since this relations is possible only in case that the progressive eventuality were the contingent state of the accomplishment event, but states cannot occur at the progressive. The inverse pattern of viewpoint values will correspond to the DURING_INV (*di*) relation; e.g.:

  (5.20) Marco corse$_{e_1_Perf(ACTIVITY)}$. Giovanni stava andando al negozio$_{e_2_PROGR.}$.

  Marco ran. Giovanni was going to the shop.

  $e_1\ d\ e_2$

All other viewpoint (and lexical aspect) combinations provide coarse grained knowledge, which is expressed by means of conceptual neighbor relations. The relations are computed by means of a constraint based on the order of presentation of the two interval viewpoints which accounts for which points' relationships to choose, i.e. either that between the beginning points or that between the ending points. For clarity's sake, we illustrate in Table 5.13 on the next page the set of possible viewpoint combinations, the relationship between the beginning points (t_1 for the first interval and t_3 for the second interval) and that between the ending points (t_2 for the first interval and t_4 for the second interval) of the two intervals, the finely grained relations associated with them and the coarse grained ones which represent the final output. Finally, in case the identified viewpoint is HABITUAL, the viewpoint component will not conclude the analysis, but will transform the eventuality(ies) at the HABITUAL viewpoint in the associated complex state S and passes the information to the lexical aspect component.

Table 5.13: *Temporal relations and constraints for eventualities with different viewpoint aspect.*

Viewpoint values and order of presentation	**Point relations**	**Possible finely grained relations**	**Final output**
PERFECTIVE - IMPERFECTIVE	$t_2 \prec t_4$	$\prec$, *m*, *o*, *s*, *d*	**sb**
IMPERFECTIVE - PERFECTIVE	$t_1 \prec t_3$	$\prec$, *m*, *o*, *fi*, *di*	**ol**

Lexical Aspect This component, as already stated, is responsible for the identification of the temporal relations on the basis of a coarse grained distinction of the eventualities ontological status, namely that between states and events. The identification of the temporal relations between these two types of eventualities can be performed by taking into account two parameters:

- the viewpoint values of the two eventualities, i.e. whether they are both imperfective or both perfective
- the relations between beginning and ending points of the two interval representations

The event subtypes, such as achievement, accomplishment, activity and semelfactive, are not taken in account as salient information for the identification of temporal relation on the basis of the following observations:

- in order to be processed by the lexical aspect component they must occur at the perfective viewpoint;
- we need to state in a principled way the relations between at least two point relations between the event interval representations, namely those between the ending point of the first interval (t_2) and the ending point of the second (t_4) and that between the ending point of the first interval (t_2) and the beginning of the second (t_3), but this cannot be done *a priori*;
- even if we maintain the distinction between durative and instantaneous events as the relevant information, we will not be able to determine the relations between the beginning or ending points of the intervals without taking in account the pragmatic, or commonsense, knowledge associated with the event semantics[37]. In absence of this information, the 8 possible relations[38] between a durative interval and a punctual one are all valid and cannot be re-organized in terms of conceptual neighbours, leading to an underspecified temporal representations which make any form of reasoning impossible.

[37]Eventualities are not intrinsically oriented like time. See also chapter 2, section 2.3.2.2.
[38]See section 2.3.3.2, chapter 2.

On the basis of the two parameters we have identified it is possible to determine two principled point relations (or constraints) between the interval representations and thus determine two coarse grained temporal relations. In this case, the order of presentation of the eventuality is irrelevant. In Table 5.14, we illustrate the constraints according to the order of presentation, the possible finely grained temporal relations and the corresponding coarse grained one; t_1 and t_2 are, respectively, the beginning and ending point of the first interval, while t_3 and t_4 those of the second.

Table 5.14: *Temporal relations and constraints for eventualities with different lexical aspect (STATE vs. EVENT).*

Lexical Aspect values	Constraints	Possible finely grained relations	Final output
STATE$_{IMPERFECTIVE}$ - EVENT$_{IMPERFECTIVE}$	$t_1 \prec t_4 \wedge t_2 \prec t_3$	*o, fi, di, si,* $\equiv$, *f, d, s, oi*	**ct**
STATE$_{PERFECTIVE}$ - EVENT$_{PERFECTIVE}$	$t_2 \prec t_3$	$\prec$, *m, o, fi, di, si,* $\equiv$, *s, d, f, oi*	**bd**

The mechanisms illustrated for the various components are supposed to work in absence of clear-cut information on the anchoring of the beginning and ending points of the two adjacent eventualities. The only way to introduce more specific information on these points is by means of temporal expressions or explicit signals. As for the latter, we have claimed that, when present, they will provide a unique temporal relation according to their semantics. For the former, when two adjacent eventualities are each connected to a temporal expression, Module 3 does not activate and the computation is provided by Module 4. When more specific information on these elements is available, the various components are still activated according to their general constraints though using this information to compute the temporal relations. In these cases, the more the information on the time anchors of the points of the interval representations is specific, the more finely grained is the output of the component. In Table 5.15 on page 154[39] we report the fundamental point relations between the interval representations in order to obtain either a unique temporal relation or a coarse grained one based on conceptual neighbors. In absence of the crucial point relation the computation of temporal relations will fail both for finely grained and for coarse grained ones.

5.3.4 Module 4: Inferring temporal relations

Module 4 is responsible for the inferencing process of temporal relations. This module takes in input both the output of Module 2 and that from Module 3 and activates two different types of inferencing mechanisms according to which module provides its output.

When Module 2 provides the input, it means that the eventualities are all connected by means of a temporal relation to a corresponding temporal expression. In this case, Module 4 activates a set of inferencing rules according to which the relations between the various temporal expressions are transferred to their connected eventualities as well. For instance, if we have two eventualities e_1 and e_2, each of them connected to a temporal expression, T_1 and T_2 respectively, then the temporal relation between the temporal expressions is known as part of the ouput of Module 1; e.g. $T_1 \prec T_2$. From Module 2 we know the temporal relation that each temporal expression has with its connected eventuality; e.g.

[39] This Table is obtained by exploiting observations from Freska (1992) and Schilder (1997)

$Rpt_1 \; d \; T_1$ and $Rpt_2 \; s \; T_2$. Finally, Module 4 associates the temporal relation between the two temporal expressions directly to the two eventualities, obtaining $Rpt_1 \prec Rpt_2$.

Things are more complicate when the input comes from Module 3. In this case, Module 4 looks for couples of adjacent eventualities with one of them in common. Once identified, it will activate inferencing rules based on Allen's transitivity table (Table 2.6 on page 35). Nevertheless, working with coarse grained relations, it is necessary to provide a new transitivity table which could allow to preserve the insights of Allen's table and the conceptual neighbors based output. Such a table has been already developed by Freska (1992), and we report it in Figure 5.6 on the next page.

5.3.5 Underspecified representations: focusing on different time granularity

Our model lacks a strategy to deal with eventualities realized by nouns, adjectives and prepositional phrases: no principled way to determine their temporal relation has been determined, nor it can be done without making to much reliance on on commonsense knowledge.

In this section, we want to introduce a strategy based on Mani (2007) of folding such approximation into a formal model. This type of approach is necessary in order to avoid failure and to deal with all possible realizations of an eventuality.

Event nouns do not present directly information on their temporal location (they do not have tenses). The identification of the temporal relations which they may activate requires an extended use of commonsense knowledge. There are two ways in which event nouns may be linked on the time line:

- event nouns as arguments of phasal verbs;
- by means of modifiers, namely (i.) Nominal Tense modifiers (Nordlinger & Sadler, 2003; Simone, 2006), that is adjectives like "*ex*", "*futuro*" [future], "*attuale*" [current], which modify a temporary state nouns (e.g. "*proprietario*" [owner], "*presidente*" [president] ...) and locating them on the time axis, and (ii.) direct relation with a temporal expression, realized by means of a prepositional phrase of type "di + TimEx" directly attached to the noun, , e.g. "*l'assemblea di oggi*" [today's meeting].

In this case, even the exploitation of discourse relations may fail, since, as we have explained, discourse relations are instantiated between the main eventualities of the various discourse segments, which very rarely are represented by the event nouns. To provide a uniform treatment for these entities, we propose to apply an abstract device elaborated by Mani (2007): a Chronoscope. A Chronoscope "allows a temporal representation (a set of events and their temporal relations) to be viewed based on temporal abstraction" [Mani (2007): 127].

One of the main advantages of abstraction, is that the information can be viewed at different levels of granularity. This means that temporal abstraction allows to collapse or zoom temporal relations to different time granularities. For instance a temporal representation "spanning several years could be abstracted at different grain size, e.g. time units such as year month, week, or day" [Mani (2007): 132].

The time granularity, g, of an event e corresponds to the time unit, U, to which it can be associated provided a temporal relation, TR. In addition, time units can be mapped to other time units with different granularity following a hierarchical order, according to

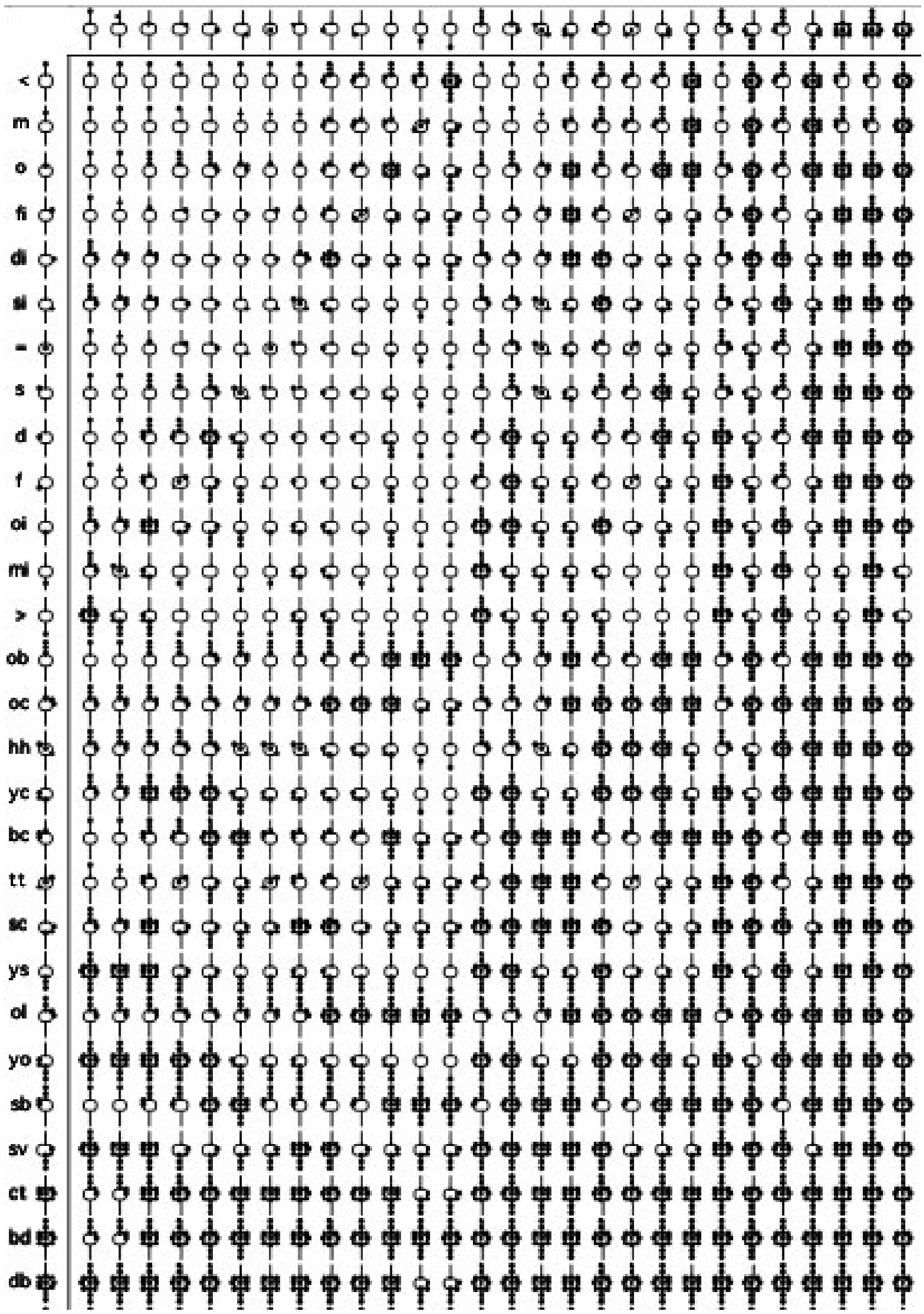


Figure 5.6: *Transitivity Table for the temporal relations including neighbors relations) [Freska (1992): 227.]*

which a time unit of granularity U_i stands in a temporal relation of *during*[40] (as defined by Allen (1983)) with a time unit of granularity U_{i+1}. This means that a temporal expressions t expressing a time unit of granularity **D**ay stands in a *during* relation with a time unit expressing of higher granularity level, namely that of **M**onth. For instance, a temporal expressions like "*28 January 2009*" can be mapped to a time unit with granularity **M**onth, thus transforming it into "*January 2009*", which can be further mapped to a time unit with granularity **Y**ear, trasforming it into "*2009*", and so on and so forth. It is imporatnt ot point out that, similarly to the axioms of conceptual neighborhood, no jump between time units is allowed. Thus, a time unit with granularity U_i cannot be directly mapped to a time unit of granularity U_{i+2}, for instance a day (**D**) cannot be directly mapped to a year (**Y**). The Chronoscope requires that we index temporal relations to a certain level of granularity g which holds for any kind of temporal relations (TR). This means that if a certain TR holds between two eventualities at a time granularity g, to be preserved it must also hold at a time granularity $g+1$, otherwise the two events are conceived as being equi-granular. A consequence of equi-granularity with respect to the same time unit, is that the equi-granular events can be viewed as simultaneous, according to the following axiom:

Axiom 1 (equi-granularity entails simultaneity) :
$\forall x \forall y \; x \sim_{during-g} y \supset simultaneous_g(x, y)$

The only temporal relation which is maintained at all level of granularity is that of simultaneity. Playing with granularities, we can perform different level of temporal processing either more fine grained or more coarse grained. Event nouns will be put in relation with the other eventualities on the basis of their granularity level. Thus, in our account event nouns (and all other parts-of-speech or phrases which can express a tenseless eventuality) will be considered as simultaneous with the verbal eventualities with same granularity level per time unit. This implies that the fine-grained distinction between tensed eventualities will be maintained and preserved, and, at the same time, there is no need to make reference to commonsense knowledge in order to extend the model to event nouns as well. In addition to this, the possibility of varying the granularity level of the associated time units of the eventualities, allow to zoom or enlarge the temporal representations to any temporal grain size. To illustrate how this mechanism can work consider the following example. The eventualities are in bold, the temporal expressions in italics and the signals are underlined.

(5.21) La Repubblica *2009-02-01*$_{T0}$
..Secondo Al-Arabya, **la tregua**$_{e1}$ **entrerà in vigore**$_{e2}$ a partire da$_{s1}$ *giovedì*$_{T1}$. Hamas **ha anche accettato**$_{e3}$ di **far controllare**$_{e4}$ la frontiera tra l'Egitto e Gaza dai rivali di Fatah, la formazione del presidente dell'Anp Abu Mazen, **estromessa**$_{e5}$ dalla Striscia a$_{s2}$ *giugno del 2007*$_{T2}$. **Il monitoraggio**$_{e6}$ della frontiera tra il Sinai e Gaza per **impedire**$_{e7}$ **il traffico**$_{e8}$ di armi per Hamas attraverso i tunnel che **attraversano**$_{e9}$ il confine è la principale **richiesta**$_{e10}$ israeliana.

La Repubblica 2009-02-01$_{T0}$
..According to Al-Arabya, ***the truce***$_{e1}$ *will* ***go into effect***$_{e2}$ *from*$_{s1}$ *Thursday*$_{T1}$. *Hamas* ***has accepted***$_{e3}$ *Fatah, the militia of the Anp president Abu Mazen* ***expelled***$_{e4}$ *by the Strip* *in*$_{s2}$ *June 2007*$_{T2}$, ***to check***$_{e5}$ *the frontier between Egypt and Gaza.* ***The monitoring***$_{e6}$ *of the frontier between the Sinai and Gaza* ***to***

[40]The temporal relation of *during* can be considered as semantically equivalent to the relation "is_a_part_of".

***prevent**$_{e7}$ **the traffic**$_{e8}$ of weapons for Hamas through the tunnels that **cross**$_{e9}$ the border is Israeli main **request**$_{e10}$.*

Applying the heuristics illustrated above we will obtain the following temporal relations between the various tensed eventualities and temporal expressions:

- $(T2\ di\ e5) \prec ((T0 \equiv e9) \succ (e3 \equiv e4)) \prec (T1\ s\ e2)$

At this point, we are going to identify the time granularity (U_g) associated to the events and their temporal relations:

- $\exists$ T $\mathrm{U}_{MONTH\_2007-06}(e5\ d\ T2)$
- $\exists$ T $\mathrm{U}_{DAY\_2009-02-01}[(e9 \equiv T0) \wedge (e3 \equiv T0) \wedge (e4 \equiv T0)]$
- $\exists$ T $\mathrm{U}_{DAY009-02-05}(e2\ si\ T1)$

Once each event is associated to its time granularity, all other realizations of eventualities are assumed to have the same time granularity of the tensed verb sentence in which they occur. Being equi-granular, from **Axiom 1** above we conclude they are simultaneous with the their corresponding eventuality, thus obtaining:

- $\exists$ T $\mathrm{U}_{MONTH\_2007-06}(e5\ d\ T2)$
- $\exists$ T $\mathrm{U}_{DAY\_2009-02-01}[(e9 \equiv T0) \wedge (e3 \equiv T0) \wedge (e4 \equiv T0) \wedge (e9 \equiv (e10,\ e6,\ e7, e8))]$
- $\exists$ T $\mathrm{U}_{DAY009-02-05}(e2\ si\ T1) \wedge (e2 \equiv e1)$

These formulas correspond to a complete treatment of all eventualities involved in a text/discourse. By exploiting the equi-granularity axiom, the inferencing mechanisms and the different granularity of temporal relations are preserved.

It is interesting to notice, as Mani (2007) points out, that all eventualities at the same time granularity level can be further abstracted by means of characterization. A characterization of type (e, E) "is an abstract event corresponding to the individual correlate of some proper subset of events in E" [Mani (2007): 133]. In our example, the three sets of events can be formalized into three different characterizations, namely E1, E2 and E3, respectively. The temporal relations between the eventualities in the characterizations disappear and the only available temporal relations are those between the characterizations. In our case, provided the associated level of time granularity with each characterization, we obtain: $E1 \prec E2 \prec E3$. Moreover, applying again the equi-granularity axiom, which allows to create a hierarchy of partitions of temporal representations, and coercing the various eventualities to different time granularities, it is possible to obtain more abstract temporal representations based on characterizations. This can be obtained, following Mani (2007), by a function Z_g(TempRepr), which allows zooming to any grain size thus shifting the granularity level of the temporal representations. For instance, if we set the time granularity to **M**onth, and then coerce to this value the granularity of the characterizations E2 and E3, we will obtain the following representation:

- $\exists$ T $\mathrm{U}_{MONTH\_2007-06}\ E1$
- $\mathrm{Z}_{MONTH\_2009-02}\ (E2 \equiv E3)$
- $E1 \prec (E2 \equiv E3)$

Each characterization, can be decomposed into its singleton elements. The most interesting observation, in this case, is represented by the fact that temporal representations and temporal relations can be varied in terms also of the granularity level of the associated time units. This way of modeling and representing temporal relations can be used to manipulate and change the temporal representations in order to obtain always a positive and reliable output.

5.4 Conclusion

In this chapter, we have examined a complex set of entities and their relations. We have proposed a computational model grounded on empirical data and defined a methodology for its functioning. We claim that one of the main results of this work is represented by the unified approach under which all sources of information involved in the processes of marking out and identifying temporal relations have been treated, analyzed and finally formalized in components for the model.

The results from the experimental studies have shown how the temporal representations that we, as humans, construct are mainly coarsely grained representations, which can be refined in presence of elements which may guide the interpretation process towards a unique value. We have also claimed that the various sources of information can be classified on a hierarchical structure based on the saliency of their contribution. The saliency-based hierarchy has shown how commonsense knowledge is more salient than linguistc information only if this latter does not offer more specific cues. Moreover, the different granularity levels of representation of the temporal relations are a strategy to avoid failure both in the computation and during the inferencing process, and a way to mimick the functioning of our cognitive system.

The empirical data also offer important elements for the development and refinement of temporal annotation schemes. In particular, it emerges that the set of possible temporal relations should be well balanced in order to allow either fine-grained temporal analysis when the cues allow it or coarse grained ones in their absence. The gold standard in temporal annotation is represented by the only annotated corpus available, namely the TimeBank (Pustejovsky et al., 2003b) which reports a K value as low as 0.55 on the annotation of temporal relations and employs only finely grained temporal relation for the annotation. A data which is in line with the results from the two experiments. It is reasonable to state that better results, in terms of agreement on temporal relations, could be obtained by applying coarser-grained set of temporal knowledge, as it has been done for the TempEval Task. However, due to the fact that explicit coarse grained temporal relations could be difficult to annotate, a good strategy to maintain this level of analysis and avoid biases for the annotators could be to keep the annotation of temporal relations on finely grained values and then collapse the disagreements into coarse grained values based on conceptual neighborhood during the post processing phase.

Previous approaches and models for the computation of temporal relations have proved useful starting points but, from a certain point of view, the model we have developed represents a point of departure from them since, on the one hand, all sources of information are treated and processed, and on the other hand, theoretical shortcomings have been re-analyzed and corrected. The model can be easily implemented either by exploiting machine learning techniques or rule-based approaches. Our proposal is that in order to obtain the best results, a merging of the two techniques is the best solution.

One of the main results of the model is its completeness. In fact, we claim that the activation of the various modules and the fact that all sources of information relevant in the process of inferencing temporal relations are taken into account represents its strength and predictive power, thus avoiding lots of the shortcomings of previous models and frameworks.

Some elements need more studies and further research. In particular, the mechanisms dealing with complex sentence contexts need to be better specified. A possible solution can be represented by a classification of the eventualities on the line of the TimeML annotation scheme, so that reasoning to infer the temporal relations in these types of contexts could be performed better. Though, it is true that the ordering of the A textual anchor is always principled in complex sentence contexts, some verbs seem to influence the temporal interpretation according to their semantics (e.g. *sperare* in "*Spero che tu venga*" [I hope that you come], where it seems that the event in the dependent clause stands in a succession relation with the event in the main clause). Further research is also needed for the so-called Temporal Movement and Extension events. During the corpus study, we have identified some of them and their analysis seems to suggest that a special set of rules should apply to deal with them since they do not represent the main eventuality which stands in a temporal relation in the text/discourse (which can be either the grammatical subject or the direct object). This calls for a device in the Event Detector component to identify these kind of events and not recognized them as eventualities which should be made available to the following modules and components and extract their intrinsic temporal information.

In the second part of this work, as already stated, we will present two applicative devices which can be considered as the implementation of the components of Module 1.

Much work is needed, in particular to verify the validity of the model it is necessary to create a TimeBank for Italian as well. This project is, at the moment, in its very beginning: so far, we have collected the corpus, composed by 179 articles from newspaper articles, comparable in size and content with the English corpus. A partial analysis of this corpus has been already performed, in particular as far as the morphosyntactic and shallow parsing levels are concerned. Moreover, in order to obtain an annotated corpus comparable with the English one, the TimeML markup language has been adapted to Italian (in appendix C we will illustrate the guidelines for the Italian TimeML). So far only 10 thousand words have been annotated, a size too small to be considered as a reliable gold standard for evaluating a complete automatic system.

In the early 1990s, the arrival of machine learning techniques applied to C.L. systems has represented an big change for the development of this field of study and research. However, the process of modelization and formalization, which has represented the core of the C.L. since its beginning in the early 1950s, has been more and more abandoned and people have concentrated more and more on the systems' performance. This is becoming a new limit for this discipline, in particular for the interpretation of the mistakes produced by the systems. In our opinion to implement a system, a modelization of how the system should be structured in the lights of real data from language is the first and necessary step for improving its robustness. The specific techniques with which an actual systems is implemented are then only secondary and to a certain extent suggested by the proposed modelization.

A further advantage of this model is its being relatively language independent, a point which could facilitate its portability to languages other than Italian. The general architecture of the model is *de facto* language independent, since it is grounded on the saliency-based hierarchy of the sources of information. The only required modifications are represented by the mechanisms which govern the internal components. As for the temporal relations and the inferencing process no modification is required.

Table 5.15: *Fundamental points' relations and associated temporal relation (t_1 and t_2 stand for beginning and ending point of the first interval; t_3 and t_4 stand for beginning and ending point of the second interval.*

	t_1, t_3	t_2, t_4	t_1, t_4	t_2, t_3
eq	$\equiv$	$\equiv$		
o	$\prec$	$\prec$		$\succ$
oi	$\succ$	$\succ$	$\prec$	
m				$\equiv$
mi			$\equiv$	
b				$\prec$
bi			$\succ$	
d	$\succ$	$\prec$		
di	$\prec$	$\succ$		
s	$\equiv$	$\prec$		
si	$\equiv$	$\succ$		
f	$\succ$	$\equiv$		
fi	$\prec$	$\equiv$		
ol	$\prec$			
yo	$\succ$			
hh	*equiv*			
tt		$\equiv$		
sb		$\prec$		
sv		$\succ$		
pr				$\leq$
sd			$\geq$	
bd		$\prec$		
db				$\succ$
ct			$\prec$	$\succ$
ob	$\prec$	$\prec$		
ys	$\succ$	$\succ$		
oc	$\prec$			$\succ$
sc		$\succ$	$\prec$	
bc		$\prec$		$\succ$
yc	$\succ$		$\prec$	

Part II

Computational Applications

Introduction

The second part of this work is dedicated to the introduction and presentation of two computational applications which we have developed.

One of the major issues of this work is represented by the absence of a consistent and relevant annotated corpus of Italian to be used to implement and evaluate automatic systems. So far, no Italian corpus has been completely annotated with temporal information[41].

In the previous part we have remained silent on the output representation of the model, with the exception for the fact that temporal relations are to be represented on a graph format. We have shown how the various components perform the analysis of the relevant information, but we have not stated what is the final format representation of the output. In principle, different types of representations can be associated to the model's output. Instead of creating a specific representation format, we propose to use a *de facto* standard, namely TimeML[42] (Pustejovsky et al., 2003c). Consequently, the applicative devices developed will implement TimeML specifications as their output format.

In the following chapters we will present a working prototype of a temporal expression tagger for Italian and a general strategy for the identification and classification of eventualities which exploits a powerful lexical resource of Italian.

[41] The only exception is represented by the I-CAB corpus (Magnini et al., 2006) for temporal expressions

[42] TimeML is evolving into an international standard, ISO-TimeML , as part of an international ISO project on semantic annotation.

Chapter 6

TETI: A TimeML compliant Temporal Expression Tagger for Italian

6.1 Introduction

The identification of temporal expressions represents a part of the first module of the model. Temporal expressions, as already stated and as the data suggest, can be considered a relatively high salient source of information for temporal relations. Their role in text/disocurse is twofolded: on the one hand, they code strict temporal information by signalling a portion of time, i.e. an interval or an instant, on a hypothetical time line, and, on the other hand, they instantiate temporal links both with eventualities and with other temporal expressions.

As we stated in chapter 3, in C.L. temporal expressions correspond to a restricted set of words which denote a temporal entity, i.e. an interval or an instant, and which usually correspond to the set of lexical items used to measure time or to indicate a particular portion of it.

The task of automatically extracting temporal expressions can be divided into four subtasks:

- recognizing and bracketing the portion of text which denote the temporal expression;
- extracting the features (type of time unit, referential status, and presence of modifiers);
- computing the interval of reference on the time line;
- resolving the temporal expression, i.e. normalize the value to a standard output format.

Our tagger so far is set to deal with the first two subtasks, i.e. recognition and bracketing, and extraction of the features, and it implements the TimeML (Pustejovsky et al., 2003c) specifications for temporal expressions.

In the rest of this chapter we will describe the TimeML `TIMEX3` tag for temporal expressions, the methodology followed in order to built the tagger and, finally, we will present an evaluation of its performance.

6.2 TIMEX3 tag: temporal expression annotation in TimeML

The specifics of the TimeML tagset for annotating temporal expressions do not simply extend or modify previous tags for this annotation task, namely the `TIMEX` tag in STAG (Setzer, 2001) and the `TIMEX2` tag in TIDES (Ferro et al., 2001, 2002), but present some interesting differences which have been introduced in order to improve the representational and informational strength of the tag. Provided the fact that our tagger is not able at the moment to perform all the four subtasks, we will illustrate only those parts of the `TIMEX3` tag specifications which are relevant for the comprehension of the functioning of the tagger .

The `<TIMEX3>` tag is used to mark up any temporal expression referring to:

(a.) Day times (*mezzogiorno, 3, la sera, la mattina ...*);

(b.) Dates of different granularity: days (*ieri, 8 Gennaio 1980, venerdì scorso, sabato ...*), weeks (*la prossima settimana, la seconda settimana del mese ...*), months (*tra due mesi, il mese prossimo, l' Agosto del 1980 ...*), seasons or business quarters (*la scorsa primavera, lo scorso semestre, il primo trimestre, il bimestre ...*), years (*1980, l'anno scorso, ...*), centuries, ...

(c.) Durations (*due mesi, cinque ore, nei prossimi anni, il periodo ...*).

(d.) Sets (*una volta al mese, ogni martedì ...*).

The surface-oriented approach to the tagging of expressions in TimeML implies that the annotation of temporal expressions is based (i.) on the constituent structure and (ii.) on the granularity of the time units and their relations. In Table 6.1 a simple classification of the different time unit granularities is reported.

Table 6.1: *Time units classification.*

t<**day**	**day**≤t≤ **month**	**month**≤t≤ **year**	*t* >**year**
alba	*domani*	*estate*	*lustro*
mezzogiono	*fine settimana*	*semestre*	*secolo*
notte	*giornata*	*anno*	*biennio*
hh:mm:ss	*domani*	*1984*	
minuto	*il primo di dicembre*	*Febbraio*	
	martedì		

The span of the tag must correspond to one of the following categories:

- **Noun Phrase**: *lunedì, mese, la scorsa estate...*
- **Adjectival Phrase** *annuale, estivo, mensile, quotidiano...*
- **Adverbial Phrase** *oggi, ieri, finora...*
- **Time/Date Patterns**: *31-12-2006, 14.30, 24/08 ...*

A standard `TIMEX3` tag will look like as in the following example:

(6.1) *il pomeriggio.*

```
<TIMEX3>il pomeriggio</TIMEX3>
```

(6.2) *01/12/80*

```
<TIMEX3>01/12/80</TIMEX3>
```

When a temporal expression is introduced by a preposition, that is when it corresponds to the NP of a PP, or by subordinating conjunction, these parts-of-speech are not to be included into the TIMEX3 tag. This is due to the fact that relevant temporal prepositions and other signals are marked with a tag of their own[1], thus:

(6.3) *nel pomeriggio.*

```
nel
<TIMEX3>pomeriggio</TIMEX3>
```

(6.4) *per l'autunno.*

```
per
<TIMEX3>l'autunno</TIMEX3>
```

The only exceptions are represented by the prepositions "*circa*", "*intorno a*" and "*verso*" which must be included into the extent of the tag because they have a role in the normalization of the timex.

When temporal expressions are realized by multiword expressions, like "*per ora*" [for the moment], "*dopo domani*" [the day after tomorrow], "*fin ora*" [up to now], and similar the whole expression is considered as a single time unit. Consequently, all elements forming the temporal expressions must be included into the tag, as illustrated in the following examples:

(6.5) *per ora.*

```
<TIMEX3>per ora<TIMEX3>
```

(6.6) *dopo domani.*

```
<TIMEX3>dopo domani<TIMEX3>
```

When modifiers are present, both pre and post-modifiers, they must be included into the tag (examples 6.7 and 6.8). Postmodifiers denoting an eventuality are not included into the TIMEX3 tag (example 6.9). Appositive constructions are considered as post-modifiers, and thus they are included into the tag span. Nevertheless, if the appositive clause contains a lexical trigger for temporal expressions, two distinct TIMEX3 tags must be created (example 6.10).

(6.7) *lo scorso trimestre.*

```
<TIMEX3>lo scorso trimestre</TIMEX3>
```

(6.8) *il mese scorso.*

```
<TIMEX3>il mese scorso</TIMEX3>
```

(6.9) *il giorno della partenza.*

```
<TIMEX3>il giorno</TIMEX3>
della partenza
```

[1]All signals of a relations between two entities are marked with the SIGNAL tag. See appendix C for details.

(6.10) *gli anni ’60, gli anni del libero amore.*

```
<TIMEX3>gli anni ’60</TIMEX3>
<TIMEX3>gli anni del libero amore</TIMEX3>
```

When two consecutive temporal expressions are encountered, different rules apply for the tag span according to the type of relation which exists between the two temporal expressions. In these cases:

- the temporal expressions will be marked up in a single tag if:
  - (i.) the two expressions belong to the same temporal unit, as illustrated in Table 6.1 on page 158, or if they are related by a merological relation of *part_of*, or if they correspond to a clock time:

    (6.11) *venerdì sera.*

    ```
    <TIMEX3>venerdì sera</TIMEX3>
    ```

    (6.12) *venerdì ore 11.*

    ```
    <TIMEX3>venerdì ore 11</TIMEX3>
    ```

    (6.13) *martedì 26 giugno*

    ```
    <TIMEX3>martedì 26 giugno</TIMEX3>
    ```

    (6.14) *giugno 1969.*

    ```
    <TIMEX3>giugno 1969</TIMEX3>
    ```

    (6.15) *alle 13 e 56.*

    ```
    alle
    <TIMEX3>13 e 56</TIMEX3>
    ```

  - (ii.) the second temporal expression is introduced by the prepositions *di* or *del* and it represents a definite time specification:

    (6.16) *la mattina del 20 giugno.*

    ```
    <TIMEX3>la mattina del 20 giugno</TIMEX3>
    ```

    (6.17) *ottobre del 1963*

    ```
    <TIMEX3>ottobre del 1963</TIMEX3>
    ```

    (6.18) *alle 11 di ieri mattina*

    ```
    alle
    <TIMEX3>11 di ieri mattina</TIMEX3>
    ```

- Two tags must be created:
  - (i.) when two temporal expressions are in an anchoring relation with each other:

    (6.19) *due settimane da oggi*

    ```
    <TIMEX3>due settimane</TIMEX3>
    da
    <TIMEX3>oggi</TIMEX3>
    ```

    (6.20) tre giorni prima di ieri

    ```
    <TIMEX3>tre giorni</TIMEX3>
    prima di
    <TIMEX3>ieri</TIMEX3>
    ```

  - (ii.) when the temporal expressions are separated by an intervening element, like temporal prepositions (with the exception of *di*) or conjunctions:

    (6.21) *venerdì sera alle 20.00.*

```
<TIMEX3>venerdì sera</TIMEX3>
alle
<TIMEX3>20.00</TIMEX3>
```

(6.22) *ieri alle 11.00.*

```
<TIMEX3>ieri</TIMEX3>
alle
<TIMEX3>11.00<TIMEX3>
```

It is important to stress the difference between temporal expressions of the form *NP+ PP*, where the head of the PP is realized by the prepositions "*di*" or "*del*", and those cases where the head of the PP is realized by other prepositions, like "*a*" or its contracted variants. In the former case, the expressions are viewed as belonging to the same syntactic constituent and they stand in a specification relation, while in the latter the temporal expression realized by the PP can attach either to the NP constituent or to a higher syntactic constituent, like the IP or the VP, thus justifying the creation of two different tags.

6.2.0.1 What NOT to tag

Among non markable time expressions, together with those expressions which can have a temporal meaning but are not considered trigger words[2], are also included (non markable elements are in bold):

- Frequency expressions, when no time period is given:

  (6.23) *L' Italia diventata campione del mondo per* ***quattro volte****.*

  (6.24) *I gestori si sono mostrati* ***spesso*** *inclini alla cautela.*

- Sequencing and ordering expressions:

  (6.25) *Le perizie erano state* ***inizialmente*** *predisposte dal presidente.*

- Manner adverbs:

  (6.26) *La vendita sarà annunciata a Roma e a Londra* ***contemporaneamente****.*

  (6.27) ***Subito*** *soccorsa dai medici presenti nel villaggio.*

- Non-quantifiable durations:

  (6.28) *Un investimento da liquidare* ***a breve termine****.*

  (6.29) *Attendevano* ***da tempo*** *lo sblocco delle certificazioni.*

- Proper names that contain or comprise a time expression but denote named entities or similar:

  (6.30) **Settembre Nero**.

  (6.31) *Domani aprirà la mostra "****Il secolo*** *breve".*

  (6.32) *"****1984****" è un libro di George Orwell.*

[2]For instance, nouns like *scuola* [school]. See section 3.2, chapter 2.

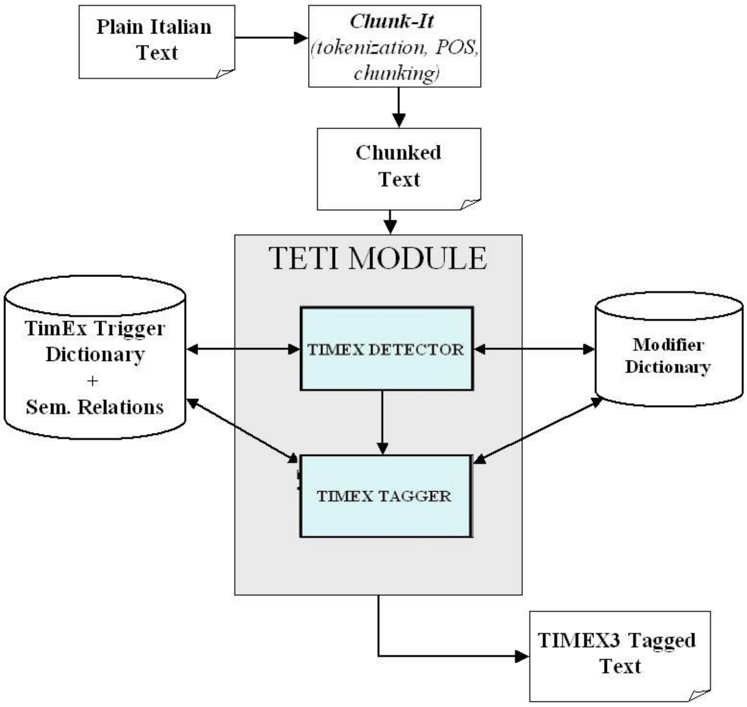


Figure 6.1: *The architecture of the system.*

6.3 System architecture and methodology

Previous systems for temporal expression recognition and normalization[3] have been implemented in large part by means of finite state transducers or rule-based taggers. These type of approaches are the most useful for this task. In fact, the relative limited set of words which are considered to denote a temporal expression suggests that rule-based systems can be implemented with a small effort and provide good results[4]. In general, a tagger is an algorithm which associates to every word in each sentence of a corpus a label. Our tagger performs this labelling actions with a restricted set of words, namely temporal expressions, by associating them the TimeML `TIMEX3` tag.

The general architecture of the tagger is illustrated in Figure 6.1. The graphical illustration does not correspond completely to the temporal expression component in Module 1 of the model since it lacks the normalization component which has no been implemented yet.

The tagging program takes in input a document which has been tokenized into words, tagged for part-of-speech and assembled in chunks by a shallow parser (Lenci et al., 2003)[5]. The tagger relies on two main components: an identifier of temporal expressions (TIMEX DETECTOR) and a grammar (TIMEX TAGGER). The grammar, which combines a general condition for activation and a set of local rules, is responsible both for the bracketing and for the identification of the features of the temporal expressions. Both components

[3] Filatova & Hovy (2001); Wilson et al. (2001); Martínez-Barco et al. (2002); Negri & Marseglia (2004); Schilder (2004); Saquete et al. (2006).

[4] We are not claiming that machine learning systems are not good at this task, but simply that provided the particular structure of this task a rule-based system is the best choice.

[5] The chunker' s evaluation in terms of precision and recall are P = 90.65 and R = 91.62.

are linked to two external resources: a dictionary of temporal expression trigger words augmented with semantic relations (TimEx Trigger Dictionary) and a dictionary of modifiers (Modifier Dictionary).
Formally the functioning of the tagger can be represented by means of a push-down automaton which can be described by the following formula:

$$M = V, R, Q, q_0, Z, F, t \tag{6.33}$$

where:

- V is the input alphabet, corresponding to the dictionary of temporal expression triggers;
- R is the stack alphabet, corresponding to the local rules;
- Q is the number of states, corresponding to the number of rules, including local conditions and bracketing rules necessary to obtain the output;
- q_0 is the initial state, which corresponds to the general condition;
- Z is the first symbol at the beginning of the stack, which is activated after the initial general condition and corresponds to the first local rule of the grammar;
- F is the collection of all terminal states of the automaton, and corresponds to the possible chunk combinations which are necessary to assign a `TIMEX3` tag;
- t is the number of transitions necessary in order to arrive to a terminal states, i.e. the number of rules and local conditions which are applied in order to obtain in output a `TIMEX3` tag.

In comparison with other rule-based systems, like Martínez-Barco et al. (2002); Negri & Marseglia (2004), which use in input the simple morphological analysis level, i.e. parts-of-speech, the choice of using in input chunked texts is strictly related to the fact that the textual extent of the `TIMEX3` tag corresponds to a limited and well defined set of phrases and the output of a shallow parser represents an approximation of the target phrases thus facilitating the writing of the rules.

In order to write the rules and adapt the `TIMEX3` specifications to Italian we have performed a corpus exploration. The corpus used is that we have collected for the creation of the Italian TimeBank, which, as already stated, is composed by 179 articles, for a total of 62 thousands words, of Italian newspapers. The corpus have been analyzed by the shallow parser and then we have automatically extracted those constituents which could contain a temporal expression as their head, including also prepositional chunks, for a total of five different chunk types, namely nominal chunks, adverbial chunks, adjectival chunks, prepositional chunk and *di*_chunks, which are a subclass of prepositional chunks whose preposition head is *di* and its contracted variants. The extracted chunks have been connected to a semantic lexical resource, SIMPLE/CLIPS (Ruimy et al., 2003), and augmented with ontological information from the resource, by associating the head noun of each chunk to its ontological type. By means of a simple query, all instances of temporal expressions have been extracted by restricting the nouns head to the type "TIME", which, in SIMPLE/CLIPS, is defined as all nouns referring to temporal expressions. This subsets of chunks have been manually checked to exclude instances of false positives. As a result we have identified a total of 1485 chunks of potential temporal expressions. A first interesting result is represented by the distribution of the constituents: more than 60% (968 over 1485) is realized by prepositional chunks (including the class of *di*_chunk), followed by the class of nominal (254) and adverbial chunks (195), and finally by the class of adjectival chunks (68). The data suggest that the vast majority of temporal expressions is introduced by a temporal prepositions. This has an important consequence for the development of our rules, since the tagger in order to be compliant with the TimeML specifics must distinguish the real temporal expressions from the class of signals which are not be considered as part of the `TIMEX3` tag but are marked with a tag of their own, namely the `SIGNAL` tag.

Analyzing the various chunks, we have identified four main patterns of chunks which may correspond to a `TIMEX3` tag, namely:

Pattern 1 : a single chunk; e.g.: *ieri*$_{ADV\_C}$, *lunedì*$_{N\_C}$, *di domenica*$_{DI\_C}$, *il semestre*$_{N\_C}$, *nello stesso periodo*$_{P\_C}$...

Pattern 2 : a combination of two consecutive chunks; e.g.: *sabato*$_{N\_C}$ *notte*$_{N\_C}$, *il mese*$_{N\_C}$ *scorso*$_{ADJ\_C}$, *la mattina*$_{N\_C}$ *di venerdì*$_{DI\_C}$...

Pattern 3 : a combination of three consecutive chunks; e.g.: *gli ultimi*$_{ADJ\_C}$ *tre mesi*$_{N\_C}$ *dell'anno*$_{DI\_C}$...

Pattern 4 : a combination of four consecutive chunks; e.g.: *il primo semestre*$_{N\_C}$ *fiscale*$_{ADJ\_C}$ *dell' anno*$_{DI\_C}$ *scorso*$_{ADJ\_C}$...

In principle, it is also possible to have two further patterns which may be obtained by the composition of five or six consecutive chunks and which correspond to temporal expressions of the kind "*gli ultimi*$_{ADJ\_C}$ *tre mesi*$_{N\_C}$ *del primo semestre*$_{DI\_C}$ *fiscale*$_{ADJ\_C}$ *dell' anno*$_{DI\_C}$" and "*gli ultimi*$_{ADJ\_C}$ *tre mesi*$_{N\_C}$ *del primo semestre*$_{DI\_C}$ *fiscale*$_{ADJ\_C}$ *dell' anno*$_{DI\_C}$ *scorso*$_{ADJ\_C}$". Such complex chunk patterns have not been identified in the corpus but though their existence cannot be excluded *a priori*, they have been considered as possible patterns as well.

Our development efforts concentrated on writing rules based on these patterns. One of the main advantages of working with chunks and their possible combinations is the reduced number of rules for tagging temporal expressions since the longer is the pattern, the fewer are the type of chunks involved. For instance, temporal expressions realized by **Pattern 4** have a variability of realization only for the first chunk, which can alternate among an N_C, or a DI_C, or a P_C chunk. The realization of the remaining three chunks is always the same, that is, ADJ_C, DI_C and ADJ_C.

A consequence of the corpus analysis is the creation of the two external resources: the temporal expression trigger dictionary, TimEx Trigger Dictionary, and the modifiers' dictyionary, Modifier Dictionary. In the next section we will illustrated their structure and the information they make available to the tagger.

6.3.1 The external lexical resources

The two dictionaries represent two key elements for the correct function of the tagger. Both dictionaries have been created in a semi-automatic way and then manually postprocessed for checking wrong or missing information.

The TimEx Trigger Dictionary is composed by 157 lexical entries corresponding to a comprehensive list of words denoting temporal expressions, including proper names of national holidays and festivities. The dictionary is not simply a list of lemmas but it represents a repository of information on temporal expressions. Every entry in the dictionary has the following structure:

- the lemma and its associated part-of-speech;
- the absolute reference type of the trigger word, in particular if the trigger word is an absolute temporal expression or a relative one;

- the default type according to the TimeML specifications, i.e. whether the temporal expression corresponds to a calendar date (DATE), a clock time or a part of the day (TIME), a duration (DURATION), or a set of times (SET);
- the basic time format and value according to the ISO 8601 standard which is associated to the trigger word on the basis of its semantics; for instance a trigger word like "*domani*" [tomorrow] has an associated time format corresponding to that of a calendar date, i.e. `YYYY-MM-DD` where the values for the year, month and day remain underspecified since it is not possible to associate a specific value to any of them in a principled way. Notice the difference with a trigger word like "*Natale*" [Christmas] which has the same time format as "*domani*" [tomorrow] but can be associated with a more specific value where only the year is underspecified e.g. `YYYY-12-25`;
- a description of the semantic of the trigger word, when possible, by means of a metalanguage;
- the associated granularity level of the time unit expressed by the trigger word, i.e. whether the time word denotes a hour (**TH**), a day (**D**), a part or time of the day (**TOD**), a day of the week (**DOW**), a year (**Y**), a decade (**DE**), a century (**C**) and so on an so forth
- ontological information, expressed by the "*is_a*" relation whose primitives are represented by the value *interval* and *instant*, in compliance with the ontology of temporal entities we have described in chapter 2;
- a set of 7 semantic relations automatically obtained from the combination of ItalWordNet and SIMPLE/CLIPS, comprehending both classical lexical semantics relations like synonymy, parthood, hyponymy and hyperonymy, and temporal relations like *after* and *before*. This set of relations connects the lemmas of temporal trigger words with each other and extends the relations to all the other features which are associated with that lemma, thus forming a rich semantic network which offers important information both for the bracketing task and the normalization process. For instance, knowing that a trigger word like "*sera*" [evening] stands in a *part_of* relation with "*venerdì*" [Friday] implies that their time units stand in the same relation as well. This set of relations has important consequences for the bracketing phase since it avoids that the two trigger words are assigned to two different `TIMEX3` tag labels and also facilitates the creation of normalization rules.

An instance of how a dictionary entry looks like is reported in example 6.34. For clarity's sake, when presenting the semantic relations we have not listed all the lemmas with which the entry is connected but only a reduced sample:

(6.34) lemma = LUNEDI' [

part of speech: NN

absolute reference: relative

default type: DATE b XXX YYYY-MM-DD DOW XXX N3942

basic time format and value: YYYY-MM-DD

semantic description: WEEK $\subset$ (DAY_1)

time unit granularity level: DOW

is_a: INTERVAL

is_a_part_of: settimana, mese, anno . . . ; *has_hyperonym*: giorno; *has_hyponym*: oggi, domani, vigilia, ieri, Natale; *has_as_part*: mattina, pomeriggio, alba, ora . . . ;

before: martedì; *after*: domenica
]

The modifiers' dictionary is composed by 63 lexical entries. It contains two classes of modifiers: those whose semantics is essential in order to assign an absolute value to relative temporal expressions, like "*scorso*" [last], *passato* [past/last], "*in corso*" [current] and similar, and those modifiers which code a vague quantification over the temporal expressions, like "*circa*" [about], "*non più di*" [no more than], "*non meno di*" [less than], "*verso*" [towards] and similar. This second type of modifiers has a special role in determining the meaning of temporal expressions, since they introduce fuzziness in the intended values, in particular, with respect to when the denoted time period starts and ends. For instance, a temporal expression like "*i primi anni Sessanta*" [the early Sixties] is rather vague with respect to what part of the decade is referring to. It could be a period ranging from 1961 to 1965, or even a smaller one, from 1961 to 1963. Due to the fact that an absolute calendar date or duration cannot be reliably assigned to these expressions, it has been decided, since the development of `TIMEX2` tag, to express this intrinsic vagueness by means of a dedicated attribute, `mod`, which is implemented in the `TIMEX3` tag as well . In addition to this, due to the very limited set of vague modifiers, they have been associated with standard values. Modifiers are certainly more important in the normalization phase rather then in the bracketing one, but observing the various patterns (**Pattern 1 - 4**) we can notice that the chunker output does not always clusters all modifiers into the same chunk. Consequently, even in the bracketing phase being aware of the fact that the head of a chunk represents a modifier of a temporal expression is necessary in order to be compliant to the TimeML specifications.

The entries in the modifier dictionary have a common structure but differentiate with each other according to their type as we have described above. Thus, every modifiers has:

- lemma and part of speech;
- information on its position, i.e. if it is only a premodifier or a postmodifier, or both;

Then the entries differentiate for other information. Modifiers which are essential to the identification of the absolute value of the temporal trigger word have information necessary for the normalization process in terms of general rules and, when possible, the associated temporal relation with respect to the anchor. An instance of an entry of modifiers of this kind is represented in example 6.35.

(6.35) lemma = SCORSO [
position: PREMODIFIER — POSTMODIFIER
normalization value: CurrentTimEx_granularity - 1_anchorValue_granularity
temporal relations: BEFORE_anchor
]

The meaning of the normalization value is an approximation of the semantics of the modifier. In this case, it means that the presence of "*scorso*" requires that the value of the associated temporal expression can be obtained by subtracting 1 to the anchoring temporal expression at the time unit granularity level. For instance, if we have a temporal expression like "*lo scorso anno*" [last year], from the temporal expression trigger dictionary we know that the time unit of this temporal expression has granularity **Y**ear and a time format of type `YYYY`. Once the anchor is identified, which is usually an absolute temporal expression, the value of the temporal expression is obtain by subtracting 1 to the anchor value at the same time unit granularity level, which in this case is **Y**.

Vague modifiers have the associated standard value which has to be added to the dedicated attribute in the `TIMEX3` tag. In example 6.36 we illustrate the structure of an entry of vague modifiers:

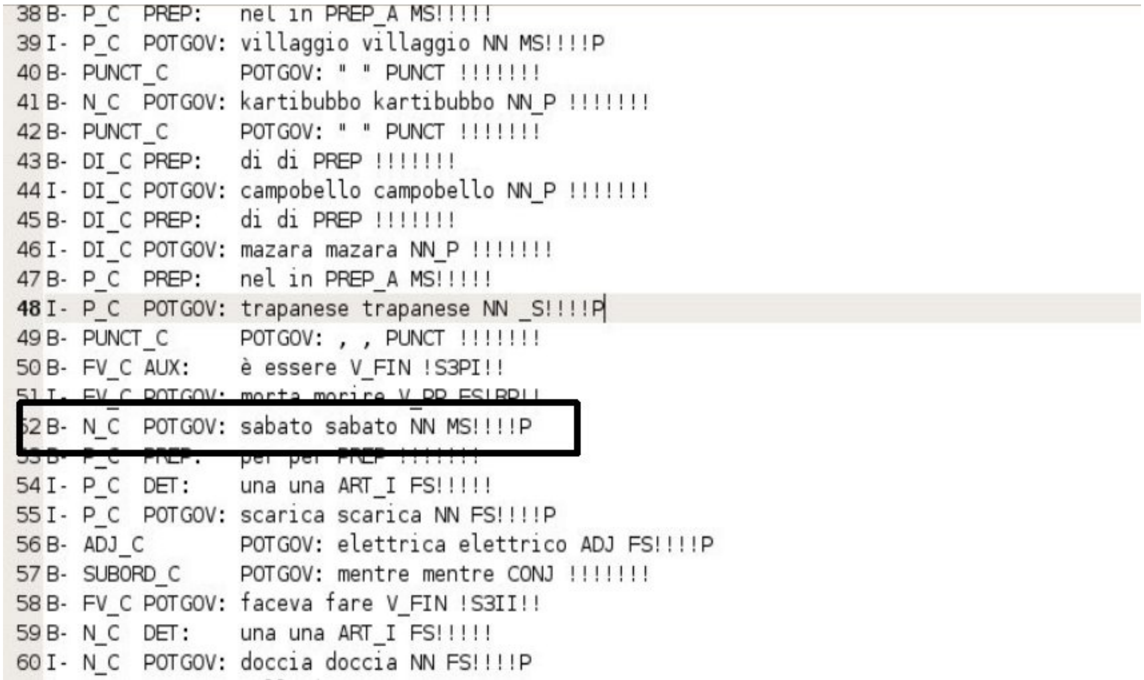
(6.36) lemma = META' [
position: PREMODIFIER
mod attribute value: MID
]

As for numbers, only ordinal numbers have been introduced in the dictionary. We have restricted the set of ordinal numbers to the first four, since these are the most used in temporal expressions. These types of modifiers are twofolded: on the one hand, they can contribute to the identification of the absolute value of a relative expression, like in "*il primo giorno dell'anno*" [the first day of the year], and, on the other hand, they indicate a particular period of time, as in "*il primo trimestre*" [the first quarter]. In addition, when they occur at the plural, they assume the status of vague modifier, as in "*i primi mesi dell'anno*" [the first months of the year], and are associated with a default value of the `mod` attribute. Introducing these modifiers as two distinct entries is not the best way to deal with them, since it will complicate the dictionary lookup mechanisms creating unnecessary complexities for the system. We have then opted for a different solution, that is to remain silent in the dictionary about this double values of this set of modifiers and shift the issue of values' assignment to the normalization phase. Thus, ordinal numbers are present in the dictionary but the set of information associated with them is restricted to the lemma, part-of-speech and position.

6.3.2 Detecting and tagging temporal expressions and signals

The recognition of the chunk patterns corresponding to `TIMEX3` tags is performed by means of local rules which work, as previously stated, on a limited number of chunks, that is those which may have as their head a temporal expression trigger word. The TIMEX DETECTOR component analyzes the chunked text which it receives in input and identifies both the temporal expression trigger words and the modifiers by means of a lookup in the dedicated dictionaries. When a positive match is found, it marks the chunk head with this information. In case the chunk head is a temporal trigger word the detector extracts all the additional information necessary for the bracketing phase, such as the granularity value of the time unit and the default type of the trigger word. This information represents the input for the second component, the TIMEX TAGGER which applies the recursive rules.

The TIMEX TAGGER has two types of conditions which must be satisfied in order to activate the grammar rules responsible for the bracketing and the creation of the corresponding `TIMEX3` tag. The first is a general condition which states that the head of the chunk in analysis must correspond to a temporal trigger words. The second are local conditions on the type of chunk which contains the trigger word, and the head of the immediately previous and immediately following chunks. The local rules are activated only if the general condition has a positive match. If the local conditions are true, the tagger activates the corresponding grammar rules for the bracketing, otherwise it looks for other local conditions and related grammar rules. The final output of the tagger is a a chunked text with an additional layer of annotation represented by the `TIMEX3` tag. In case no positive match for the local conditions can be identified, the tagger will fail and



```
38 B- P_C  PREP:    nel in PREP_A MS!!!!!
39 I- P_C  POTGOV: villaggio villaggio NN MS!!!!P
40 B- PUNCT_C      POTGOV: " " PUNCT !!!!!!!
41 B- N_C  POTGOV: kartibubbo kartibubbo NN_P !!!!!!!
42 B- PUNCT_C      POTGOV: " " PUNCT !!!!!!!
43 B- DI_C PREP:   di di PREP !!!!!!!
44 I- DI_C POTGOV: campobello campobello NN_P !!!!!!!
45 B- DI_C PREP:   di di PREP !!!!!!!
46 I- DI_C POTGOV: mazara mazara NN_P !!!!!!!
47 B- P_C  PREP:   nel in PREP_A MS!!!!!
48 I- P_C  POTGOV: trapanese trapanese NN _S!!!!P
49 B- PUNCT_C      POTGOV: , , PUNCT !!!!!!!
50 B- FV_C AUX:    è essere V_FIN !S3PI!!
51 I- FV_C POTGOV: morta morire V_PP FS!RP!!
52 B- N_C  POTGOV: sabato sabato NN MS!!!!P
53 B- P_C  PREP:   per per PREP !!!!!!!
54 I- P_C  DET:    una una ART_I FS!!!!!
55 I- P_C  POTGOV: scarica scarica NN FS!!!!P
56 B- ADJ_C        POTGOV: elettrica elettrico ADJ FS!!!!P
57 B- SUBORD_C     POTGOV: mentre mentre CONJ !!!!!!!
58 B- FV_C POTGOV: faceva fare V_FIN !S3II!!
59 B- N_C  DET:    una una ART_I FS!!!!!
60 I- N_C  POTGOV: doccia doccia NN FS!!!!P
```

Figure 6.2: *Chunked input for temporal tagger.*

no `TIMEX3` tag is assigned. However, even in case of failure, a partial output is always provided and is represented by the output of the detector component. In this way, it is possible to check which local conditions or rules are missing and integrate them into the tagger.

To illustrate in details the functioning of the tagger we will present the rule for recognizing temporal expressions belonging to **Pattern 1**, i.e. temporal expressions corresponding to a single chunk, like "*sabato*" [Saturday], "*ieri*" [yesterday] and similar. The rule is illustrated in example 6.37.

(6.37) R3

```
COND ( POTGOV_lemma equals timexTrigger )
( and
       ( or ( POTGOV_CHUNK equals N_C )
            ( POTGOV_CHUNK equals ADV_C )
            ( POTGOV_CHUNK equals ADJ_C ) )
       ( not ( POTGOV_CHUNK has PREMODIF )
       ( not ( POTGOV_lemma CHUNK-1 equals modifTrigger ) )
       (or ( not ( POTGOV_lemma CHUNK+1 equals timexTrigger ) )
            ( not ( POTGOV_lemma CHUNK+1 equals modifTrigger ) ) )
)
              then
         CREATE TIMEX3_tag
         (and (BEGIN_AT B_CHUNK)
                (END_AT E_CHUNK) )
```

```
B- P_C PREP: nel in PREP_A MS!!!!!
I- P_C POTGOV: villaggio villaggio NN MS!!!!P
B- PUNCT_C POTGOV: " " PUNCT !!!!!!!
B- N_C POTGOV: kartibubbo kartibubbo NN_P !!!!!!!
B- PUNCT_C POTGOV: " " PUNCT !!!!!!!
B- DI_C PREP: di di PREP !!!!!!!
I- DI_C POTGOV: campobello campobello NN_P !!!!!!!
B- DI_C PREP: di di PREP !!!!!!!
I- DI_C POTGOV: mazara mazara NN_P !!!!!!!
B- P_C PREP: nel in PREP_A MS!!!!!
I- P_C POTGOV: trapanese trapanese NN _S!!!!P
B- PUNCT_C POTGOV: , , PUNCT !!!!!!!
B- FV_C AUX: è essere V_FIN !S3PI!!
I- FV_C POTGOV: morta morire V_PP FS!RP!!
B- N_C POTGOV: sabato sabato NN MS!!!!P B-TIMEX3
B- P_C PREP: per per PREP !!!!!!!
I- P_C DET: una una ART_I FS!!!!!
I- P_C POTGOV: scarica scarica NN FS!!!!P
B- ADJ_C POTGOV: elettrica elettrico ADJ FS!!!!P
B- SUBORD_C POTGOV: mentre mentre CONJ !!!!!!!
B- FV_C POTGOV: faceva fare V_FIN !S3II!!
B- N_C DET: una una ART_I FS!!!!!
```

Figure 6.3: *Final output of the TETI Tagger.*

As already explained, the tagger takes in input a chunked text, as illustrated in Figure 6.2 on the facing page, and then activates the detector component which identifies the temporal trigger words and modifiers.

In this, small excerpt the only trigger word is "*sabato*" [Saturday] (in the box in Figure 6.2). The tagger is activated and first checks if the general condition is true, i.e. if the head of the chunk is a temporal trigger words. This corresponds to the second line in the example 6.37, i.e. `COND ( POTGOV_lemma equals timexTrigger )`. Once a positive match is found, the local rules are activated, and, as illustrated in example 6.37, the tagger checks that (i.) the type of chunk in which the temporal trigger words is located which could be either a nominal chunk, or an adjectival one or an adverbial one; that (ii.) the head of the previous chunk (`POTGOV_lemma CHUNK-1`) is not a modifier, and that (iii.) the head of the following chunk (`POTGOV_lemma CHUNK+1`) is neither a modifier or another temporal trigger words. If all local rules are true, then it creates the `TIMEX3` tag, which in this case coincides with the temporal trigger chunk ((`BEGIN_AT B_CHUNK`) and (`END_AT E_CHUNK`)). The final output is illustrated in Figure 6.3

The system does not limit itself to the recognition of timexes, but it recognizes and marks signals as well. In fact, the input provided by the chunks allows to detect the temporal prepositions that introduce the timex triggers, which are annotated with their corresponding tag, i.e. SIGNAL, according to the TimeML specifications.

The tagger works with a limited set of 33 rules, including three rules for temporal expressions realized by time or date patterns, which are retrieved by means of regular expressions and a special rule which checks the second following chunk to deal with temporal expressions belonging to Pattern 4 and, possibly, to Pattern 5 and Pattern 6, i.e. five or six consecutive chunks which forms a unique `TIMEX3` tag.

In Annex B, we will report the entire set of rules implemented by the tagger.

6.3.3 Semantic relations: a strategy to improve reliability

The major novelty introduced in this work is represented by a cluster of semantic restrictions which must be satisfied during the bracketing phase in order to be compliant to the TIMEX3 specifications. To illustrate how these restrictions work, consider the following examples:

(6.38) il venerdì$_{N_C}$ sera$_{N_C}$.
Friday evening.

(6.39) il periodo$_{N_C}$ 93$_{N_C}$ - 94$_{N_C}$.
the period 93 - 94.

According to TimeML TIMEX3 specifications, in the example 6.38 we have two temporal expressions which are in a *part_of* relation one with each other. Consequently, **Pattern 2** applies and we have to create a unique TIMEX3 tag as the following, i.e `<TIMEX3> il venerdì sera </TIMEX3>`. On the contrary in the example 6.39, we have three autonomous temporal expressions, and **Pattern 1** applies. In absence of rules which include the contribution of semantic relations between the temporal expression trigger words, we will have only one correct tagging, namely:

- if the rules allow the application of **Pattern 2** to two consecutive N_Cs, then only example 6.38 would be correctly tagged, while example 6.39 will result as wrong: `*<TIMEX3>il periodo 93</TIMEX3> - <TIMEX3> 94 </TIMEX3>`;
- if the rules don't allow the application of **Pattern 2** to two consecutive N_Cs, then only example 6.39 would be correctly tagged, while example 6.38 will result as wrong: `*<TIMEX3>il venerdì</TIMEX3> <TIMEX3>sera</TIMEX3>`.

As a general procedure, the tagger when identifies the presence of two consecutive temporal trigger words, first checks for the chunk type of the two trigger words, and if they are of the same type, then applies rules which take into account the semantic relation between the two trigger words. Since these relations are projected over the entire set of information which forms an entry in the TimEx Dictionary, it is sufficient a further lookup in the dictionary for the relevant semantic relation between the two trigger words to obtain the correct tagging. An example of the rules which are augmented with semantic relations is reported in example 6.40, which corresponds to the rule used to deal with TIMEX3 tags corresponding to **Pattern 2**, e.g. "*venerdì sera*" [Friday evening]

(6.40) R21

```
COND ( POTGOV_lemma equals timexTrigger )

(and
       (not (POTGOV_lemma CHUNK-1 equals modiftrigger))
       ((POTGOV_lemma CHUNK+1 equals lextrigger)
                         then
                      (GET GRAN
                       GET DEFAULT TYPE))
       (not (POTGOV_CHUNK has PREMODIF))
       (or  (POTGOV_CHUNK+1 equals N_C)
            (POTGOV_CHUNK+1 equals ADV_C))
      (not (POTGOV_CHUNK+1 has PREMODIF))
```

```
(POTGOV_CHUNK equals N_C))
 (COND
         1((and (equals (SEM_RELATION POTGOV_CHUNK)
                     (has_as_part (LEXTRIG_CIBLE POTGOV_CHUNK+1))


                (equals (DEFAULT_TYPE POTGOV_CHUNK)DATE))
                (or (equals (DEFAULT_TYPE POTGOV_CHUNK+1) DATE))
                    (equals (DEFAULT TYPE POTGOV_CHUNK+1) TIME))

                    then
                     CREATE TIMEX3
                    (and (BEGIN_AT B_POTGOV_CHUNK)
                         (END_AT E_POTGOV_CHUNK+1)))
                 2 (( and (CREATE TIMEX3
                    (and  (BEGIN_AT B_POTGOV_CHUNK)
                          (END_AT E_POTGOV_CHUNK))
                    (and  (BEGIN_AT B_POTGOV_CHUNK+1)
                            (END_AT E_POTGOV_CHUNK+1))
                  )))
```

6.4 System evaluation

In order to verify the reliability of the system we have done an evaluation session. We have manually annotated[6] with the TimeML specifications a subset of 42 articles (16 thousand words) from the Italian treebank (Montemagni et al., 2003), containing a total of 367 temporal expressions. Due to the fact that the normalization phase has not been implemented yet, the system has been evaluated both with respect to the general task of recognition and bracketing of temporal expressions and for the subtask of modifier recognition. The evaluation of the bracketing comprehends also an evaluation of the system with respect to the tagging of the `SIGNAL` tag. In fact due to the input format, a wrong tagging for signals, corresponds to a wrong bracketing of the temporal expressions. In Table 6.2 we report the results obtained by the system.

The columns COR and MISS and INC report, respectively, the number of items correctly identified, those not recognized by the system but present in the corpus and, finally, the number of items both incorrectly annotated and false positives. The overall evaluation of the system is computed in terms of precision (P), recall (R) and F-measure (F). In a classification task as the one we have performed, the Precision for a class is the number of true positives (i.e. the number of temporal expressions correctly identified by the tagger and assigned the `TIMEX3` tag) divided by the total number of elements labeled as belonging to the class (i.e. the sum of true positives and false positives, which are other elements incorrectly labelled as temporal expressions). Recall in this context is defined as the number of true positives divided by the total number of elements that actually belong to the class (i.e. the sum of true positives and false negatives, which are the temporal expressions which were not identified by the tagger but should have been). The F-measure is the harmonic mean of precision and recall. Precision and recall are computed at the

[6]The annotation tool used is *Callisto* from MITRE.

Table 6.2: *TETI evaluation results.*

Tag	TOT.	COR	MISS	INC	P	R	F
TIMEX3	367	321	35	66	82.95	90.17	86.41
TIMEX3:modifier	90	55	12	23	82.09	70.51	75.86

tag level, this means that for every instance of a temporal expression correctly bracketed we have assigned one point, in case of partial identification we have assigned zero points.

As for Italian, to our knowledge, four systems have been developed for the task of recognition and normalizations of temporal expressions and three of them implement rule-based methods. Unfortunately, these systems implement the `TIMEX2` specifications which differ from TimeML `TIMEX3` ones with respect to the bracketing of temporal expressions, thus preventing a comparison of the systems' performance.

6.5 Comments and Future Work

The results demonstrate a good overall performance of the system. The error analysis, however, shows that there is still room for improvements. The relative low number of missing temporal expressions is only in a minimal part a result of missing entries in the TimEx Dictionary. A source of errors is the presence of elliptic phrase heads as in *almeno* 4_{N_C} *o 5* $giorni_{N\_C}$, "at least 4 or 5 days", where the first chunk misses the time word trigger. Another source of errors is represented by the relative high number of false positives. These are instances of numeric expressions which have a pattern similar to calendar and time temporal expressions. These errors are mainly due to the fact that we have used regular expressions to identify these kinds of temporal expressions. A possible strategy to avoid these errors could be represented by a more fine-grained POS tagset which could distinguish between bare numeric data and numeric data which correspond to temporal expressions. Apparent dates, i.e. proper names with a temporal expression composing it, like in *Il Sole - 24 Ore*, are not always recognized by the chunker as named entity and, thus, are incorrectly tagged as temporal expressions. The error analysis has also indicated that some rules need refinements, in particular when date patterns and semantic relations co-occur. In fact, the former are missing from the TimEx Dictionary, and this calls for a strategy to insert them. Finally, the incorrect identification of the SIGNAL tag has contributed to worsening the results preventing a correct bracketing. Most of them are multiwords like *fino a*, "up to", or *rispetto a*, "(with) respect to", which are not recognized as such by the chunker.
As for modifiers the results are less satisfying. We have identified only 90 temporal expression with at least a modifier in it. Only 55 of them have been identified by system, thus suggesting that some rules which deal with modifiers need to be refined. Moreover, most modifiers are not identified by the systems (column INC) resulting in an incorrect tagging for this subtask. The missing modifiers correspond to numeric values, namely cardinal numbers expressed by words. A possible, though time consuming, solution could be to insert them in the modifiers'dictionary. On the other hand, we claim that the best solution is to exploit the information provided by the chunked text, in particular their position in the chunk, which corresponds to the premodifier position, and the part of speech, which clearly state that these words are numbers, thus improving the tagging.

Though the results are pretty good, improvements are needed in order to reduce the number of false positives, which may bias further processes of temporal analysis, like the identification of the temporal relations between an eventuality and a temporal expression. Further research is needed to complete the tagger, in particular for the normalization phase. Provided the good results obtained by using rules for detecting and bracketing, we suggest that this methods could be useful for the normalization phase as well. In order to obtained a good normalizer some issues must be resolved, in particular as far as the identification of the correct anchor is concerned. In this sense previous studies on anaphoric definites[7], represent a starting point for the identification of reliable heuristics for anchor detection.

[7]Caselli & Prodanof (2005)

Chapter 7

Using Lexical Resources for Identifying and Classifying Eventualities

This chapter[1] concentrates on the elaboration of computational strategies which rely on the use of lexical resources as means to facilitate the identification of eventualities and their classification in the perspective of Open-Domain Question-Answering systems. The process of event detection is the first step to be accomplished in order to identify temporal relations because it is on the linguistic realizations of these entities that the model presented in chapter 5 is to be applied.

One of the main issues related to the identification of eventualities is the identification of their status in the real world, i.e whether they happened or not. If, from a certain point of view, temporal relations can be established *a priori* between eventualities, a bulk of information necessary to use temporal relations in a correct way is represented by the set of inferences that we perform during the process of decoding, i.e. understanding of the text/discourse, relative to the **modality** with which the eventualities are presented in the text. With the term modality we refer to the that facet of illocutionary force associated with an utterance/sentence, signalled mainly by grammatical devices (i.e. mood), that expresses (i.) the illocutionary point or general intent of a speaker, and (ii.) the speaker's degree of commitment to the expressed proposition's believability, obligatoriness, desirability, or reality. Though these kinds of information are to be computed by a specific component, we claim that a good event detector component should be able to provide a preliminary set of information which can be used to determine the modality relations between eventualities. In the following sections we will present a strategy based on the use of a lexical resource, SIMPLE/CLIPS (Ruimy et al., 2003), which aims, on the one hand, to the development of heuristics for the identification of eventualities and, on the other hand, to exploit the associated semantic classes of the eventualities to facilitate the activation of automatic procedures for the detection of the associated modality, and thus reasoning with eventualities **and** time.

[1]A reduced version of this work has been presented at the 4^{th} International Workshop on Generative Lexicon (G.L. 2007), held in Paris, 10-11 May 2007, and conducted in collaboration with Irina Prodanof, Nilda Ruimy and Nicoletta Calzolari.

7.1 The Event Detector Component

In the description of our model, we have stated that in Module 1 we have two main components, one for temporal expressions detection and normalization, and the other responsible for event detection and classification of eventualities by assigning them the default lexical aspect value.

The Event Detector takes in input chunked, i.e. shallow parsed, text and on this basis it starts the identification of those chunked head which can have the status of eventuality. As we have illustrated in chapter 3 eventualities can be realized in language in a quite varied way. Prototypically, eventualities are associated with verbs, which usually denotes an action, an occurrence, or a state of being. But nouns as well can indicate events. Nouns represents the most challenging part of speech class within which eventualities can be realized. As we have already stated, nouns can realize eventualities in three different ways (Gross & Kiefer, 1995): we can have (i.) deverbal nouns, obtained through a nominalization process from verbs; or (ii.) nouns which are not derived from a verb and have an eventive reading as one of their meaning - these are the class of second order nominal identified by Lyons (1977); and finally (iii.) nouns which normally denote objects but which are assigned an eventive reading either through the process of type-coercion, or through the processes of logical metonymy or coercion induced by temporal prepositions (Pustejovsky, 1995). Finally, adjectives as well can give rise to instances of eventualities, namely those which describe a (temporary or permanent) property or describes a state of being.

The process of event detection is restricted to a limited set of parts of speech, namely verbs, adjectives, and nouns. However, the only reliable identification of events which can be performed, though with some *caveats*, based on this simple analysis is that of eventualities realized by verbs. The main issue to be resolved is the assignment of the status of eventuality to nouns and adjectives.

It is well known in literature (Ross, 1973; Clark & Clark, 1979; Hopper & Thompson, 1984, 1985; Simone, 2006) that the three basic parts of speech, namely adjectives, verbs and nouns, can be organized in *continua*, and that even inside each class it is possible to identify more refined and elaborated *continua*. For instance, it is possible to identify a nouniness *continuum* and verbiness *continuum*. The identification of the various *continua* suggest that there is a principled way to identify the occurrences of nouns as events, and also for adjectives. However, the elaboration of computational strategies based on these *continua* is not a trivial task. Consider, for instance, what Simone (2006) define as nouns with verbal coefficient, like process nominalizations and nominal infinitives. These two sets of nouns should qualify in unique way as eventualities, since inherit from their corresponding verbs the argument structure and some features related to viewpoint and lexical aspect, and consequently their identification could be performed by means of a detailed morphological analysis. Unfortunately, it is not so. If we exclude nominal infinitives, nominalizations do not always have an eventive reading, though they are the reification of the corresponding verbal events. For instance, a process noun like "*sorsata*" [sip] can be interpreted either as "the act of V" or as a mass noun identifying a quantity of liquid which is swallowed by an individual. Similar observations could be done for other nominalizations. On the other hand, we can have what Lyons (1977) has identified as second-order nominals which do not present a morphological structure different from that of more prototypical nouns like "*sedia*" [chair] or "*cane*" [dog], and their eventive reading is not their only lexical property. In such cases, what is necessary for the identification of the eventive status of nouns is a combination of the possible meanings of the noun and a knowledge of the argument structure of the governing verb. Finally, we can have instances of type coercion which forces the eventive reading of non-eventive nouns, like in the following example:

(7.1) Marco ha finito **il libro**$_{EVENT}$.
Marco finished the book

In this case, a morphological analysis is not relevant since the type coercion is performed by the semantic types of the arguments associated with the phasal/aspectual verb "*finire*" [finish].

As it appears from these observations, the sources of knowledge which are necessary to assign the status of eventuality to nouns, and for extension to adjectives, are varied and require different levels of linguistic knowledge, stemming from knowledge of the associated meanings of eventualities and semantic types, up to knowledge of the verbs' argument structure and the semantic types of the arguments.

In order to keep under control all these levels of information, we propose a connection of the Event Detector component to an external lexical resource, such as SIMPLE/CLIPS, which may offer the set of information required in order to perform the task of event identification and classification. In the next section we will illustrate the main characteristics of this lexical resource and how heuristics based on chunks for event detection could be elaborated by exploiting the resource.

7.2 SIMPLE/CLIPS: a brief review

The SIMPLE/CLIPS database (Lenci et al., 2000; Ruimy et al., 2003) was developed in the framework of the SIMPLE project, a language engineering project founded by the European Commission aimed at building a wide-coverage, multipurpose and harmonised computational semantic lexical linked to the morphological and syntactic ones elaborated for the PAROLE project[2]. The Italian component of the SIMPLE/CLIPS was further developed in a national project, CLIPS. SIMPLE/CLIPS is so far the largest computational lexical knowledge base of the Italian language, containing over 45 thousands lemmas, for verbs, nouns and adjectives, and more that 57 thousands word senses.

In order to develop both heuristics and procedures to use the lexical resource, it is necessary to illustrate its internal organization, with particular attention to the way in which semantic information is encoded and its connection with the other layers of representation.

7.2.1 Semantic information in the SIMPLE/CLIPS database

The theoretical linguistic background used to develop the database is an extended version of Pustejovsky (1995)'s Generative Lexicon. The Generative Lexicon approach defines the semantic of a lexical unit as a structure involving different components. One of them, the *qualia* structure, is a rich and structured representation of the relational force of a lexical unit. This structure allows to overcome an overloading of hyperonymic relations, i.e. one-dimension inheritance, thus enabling the expression of orthogonal aspects of a lexical unit sense.

Traditional semantic descriptions of lexical units are generally organized in terms of taxonomic relations, since many lexical unit senses can be entirely described by means

[2]PAROLE and SIMPLE have involved 12 European languages, namely: Catalan, Danish, Dutch, English, Finnish, French, German, Greek, Italian, Portuguese, Spanish and Swedish.

of one-dimensional hierarchical relations to other lexical units, namely expressed by the "*is_a*" relation. However, there exists a substantial amount of word senses denoting a more complex bundle of lexical orthogonal dimensions which cannot be exhaustively captured by a mere hyperonymic relation. For instance, if we consider artifact-denoting words, like "*violino*" [violin/fiddle], their characterization as types of concrete entities cannot be considered as sufficient. The qualia structure, on the other hand, allows multidimensionality of meaning by means of the four qualia roles[3] which express essential aspects of a word's meaning. Each lexical entry in SIMPLE/CLIPS is constituted by the word sense and is called a semantic units, or *SemU*. Each qualia role have been extended with a set of subtypes, giving rise to the *extended qualia structure* which play a crucial role in defining the distinctive properties and differentiating the degree of internal complexity of each semantic unit.

7.2.1.1 The SIMPLE/CLIPS Ontology

In the SIMPLE/CLIPS lexicon, the semantic units are classified according to the semantic type system. The type system reflects the Generative Lexicon assumption that lexical items are multidimensional entities which present various degrees of internal complexity and thus call for a lexical semantic description able to account for different ranges of meaning components. The SIMPLE/CLIPS ontology consists of 153 language- and domain-independent semantic types designed for the multilingual lexical encoding of concrete and abstract entities, events and properties. The SIMPLE/CLIPS semantic types are not all structurally equivalent, they are of two different kinds:

- simple (i.e. one-dimensional) types, which can be fully characterized in terms of a hyperonymic relation, e.g.: the semantic type EARTH_ANIMAL is a subtype of ANIMAL, which, in its turn, is a subtype of LIVING_ENTITY; and
- unified (i.e. multi-dimensional) types, which can only be identified through the combination of a subtyping relation and the reference to orthogonal (telic or agentive) dimensions of meanings, e.g.: CHANGE_OF_LOCATION is a unified type which inherits the properties of its supertype CHANGE but also an agentive dimension of meaning. Similarly, the type INSTITUTION is defined as a subtype of ABSTRACT_ENTITY which encompasses agentive and telic dimensions as well.

The type system hierarchy is dominated by four nodes, namely (i.) ENTITY, which provides the minimal information and encode very abstract word meaning, (ii.) CONSTITUTIVE, for word meanings which are intrinsically constitutive, like "*modo*" [way], (iii.) AGENTIVE, for word senses which lexically instantiate the agentive quale, like "*causa*" [cause] and finally (iv.) TELIC, which encodes semantically underspecified nouns and with a bare telic meaning, like "*scopo*" [aim]. Five direct subtypes of the top node ENTITY are identified:

[3]The four qualia roles are:

- *Agentive*: it provides information about an entity's origin or its coming about;
- *Constitutive*: it expresses the entity's composition, its constitutive elements;
- *Telic*: it specifies an entity's purpose or function;
- *Formal*: it identifies an entity with respect to other entities; in a sense it identifies its position within ontology types.

- CONCRETE_ENTITY: this type and its subtypes encode all living entities, physical objects, artifacts, materials and substances, natural and artifactual locations, and food:
- PROPERTY: it encodes, together with its subtypes, physical, psychological and social properties;
- ABSTRACT_ENTITY: it encodes abstract entities, with more specific types for the domain of human activity, movements of thought, institutions, conventions moral standards and time-denoting events;
- REPRESENTATIONS: it encodes, with its associated subtypes, information denoting words, languages, signs, units of measure and numbers;
- EVENT: together with its subtypes allows the encoding of all event-denoting semantic units, regardless of their part of speech.

As for adjectives, the top level ontology distinguishes between INTENSIONAL, i.e. non-predicating adjectives, and EXTENSIONAL types. The latter semantic type, EXTENSIONAL, has been designed to reflect the ontology of property denoting nouns. On the other hand, the INTENSIONAL type, which subsumes six subtypes, encodes adjectives modifying the head noun from different perspectives, comprising temporal modification, speaker's commitment to the truthfulness of an event or its occurrence, relational modification and manner modifiers.

According to the philosophy governing the SIMPLE/CLIPS ontology, a semantic type is not simply a label to be associated to a word meaning but it is rather the repository of a structured set of semantic information. Therefore, the membership of a word sense in a semantic type inherently triggers the instantiation of a rich bundle of semantic features and relations that represent the type-defining information that intrinsically characterizes the ontological type.

7.2.1.2 A SIMPLE/CLIPS entry: information content

A SIMPLE/CLIPS lexical entry consists of a bundle of information, expressed in terms of valued features and relations between semantic units. For each entry it is possible to identify up to eight different levels of information, including:

- Type assignment and type hierarchy information: as we have illustrated semantic types are organized in term of a hierarchical ontology, and as already stated, assigning a semantic type to an entry implies the inheritance of the type hierarchy information. Type assignment is provided by means of a feature whose attribute depends on whether the type is *simple* or *unified*;
- Domain: it supplies information on the topic of the text in which the semantic units is more likely to occur. It has a set of 350 possible domains;
- Qualia structure: it describes and captures the different meaning dimensions of a semantic unit. Only the relevant qualia role necessary to describe the meaning of lexical units are filled;
- Regular polysemy: polysemous meanings of a lexical unit and homonyms are encoded in different types and are not related to one another. On the other hand, systematically related senses of nouns are described according to a set of 20 well-established sense alternation classes. As for adjectives two regular polysemous classes have been identified, namely the alternation between nationality and style, and that between

temperature and behaviors. This kind of sense ambiguity, which give rise to complex types, has been captured by means of links between the different semantic units of a lexical entry. The link is expressed by the name of the pair of semantic types to which the alternative senses belong to.

- Synonymy: the synonymic relation is assigned to the semantic units encoded in the top types of the ontology for which taxonomic relations do not make sense, and also for highly polysemous adjectives;
- Derivational Information: cross-categorial information, such as derivations, are marked by means of links relating the derived semantic units to its base one. A set of relations allows to distinguish between different types of derivation. Focusing on the use of the resource we are proposing the most interesting types of derivations are deverbal nominalizations, which are expressed at different levels from bare event nominalization to process nominalization, and state nominliazations.
- Semantic Features: they are a set of features which allow the retrieval and clustering of entries encoded in different semantic types but still sharing a common meaning component. Specific to the description of event-denoting semantic units is the feature *event_type* which informs on the lexical aspectual properties (state, process (unbounded), transition (bounded)) of events;
- Argument structure: it represents one of the main interesting level of information of the SIMPLE/CLIPS resource. Each predicative semantic unit, be it a verb, deverbal, deadjectival or simple noun, is assigned a lexical predicate. For verbs and simple, i.e. non derived, predicative nouns, the predicate names coincides with the semantic unit naming, e.g. *SemU* correre $\longleftrightarrow$ *Pred* correre. On the other hand, deverbal nouns share with their verbs the same predicates, thus "*accusatore*" [accuser], "*accusato*" [accused] and "*accusa*" [accusation] all point to the verb predicate "*accusare*" [to accuse], no matter their semantic type. Moreover, each predicative semantic unit is assigned a predicate-argument structure in terms of predicate's arity, semantic role[4] and semantic type preference of each argument. For instance, The predicate for "*guidare*" [to drive] contains two arguments. The first argument has the semantic role "Agent" and two semantic preferences, corresponding to two ontological semantic types, "Human — HumanGroup". The second argument has the semantic role "Patient" and preference for the semantic type "Vehicle". It is worth noting that the encoding of preferences on arguments entails that the lexical resource provides information not only on word senses (ontological classification and rich semantic description) but also on their semantic context, which could be useful in detecting eventualities.

As it appears from this brief review, the information in the SIMPLE/CLIPS lexicon can be used in order to develop a set of heuristics which may facilitate the recognition of event-denoting words. In particular, the fact that the various semantic representation and levels of information are encoded in separate slots in every entry allows the use and activation of the required information only when necessary.

[4]The set of semantic roles is based on a predefined list of roles based on EAGLES recommendations, available at *http://www.ilc.cnr.it/EAGLES/browse.html*

7.3 Detecting eventualities by exploiting SIMPLE/CLIPS

In order to verify if the lexical resource could prove useful for the identification of eventualities, we have performed two annotation experiments. In both experiments, three subjects with knowledge in Linguistics were submitted with a set of texts from our corpus, for a total of 9649 words. The annotators were provided with a reduced set of annotation guidelines extracted from TimeML and adapted to Italian[5]. In TimeML every instance of possible linguistic realizations of eventualities is annotated with the dedicated tag, namely `EVENT`. The annotation is based on the notion of *minimal chunk*, because higher constituents may contain more than one event expression. This means that only the head of the event denoting chunk will be marked up. As for states, only a limited set of them is annotated, namely temporary states. The three subjects were asked to annotate all the reserved words, i.e. verbs, nouns, and adjectives, which may realize an eventuality. In the first experiment, the annotators have to perform the annotation without any help from external resources, but simply relying on their intuitions. On the contrary, in the second experiment, we have asked the annotators to use as an active interface the SIMPLE/CLIPS lexicon. In this way, they had at disposal a structured database of information which provides them with information for every lexical item about its senses and ontological types, thus making the eventive readings of nouns always available. The results of the experiments are reported in Table 7.1.

Table 7.1: *Identifying Events - Results from the annotation experiments*

	Test 1 - no external resource	**Test 2 - SIMPLE/CLIPS as active interface**
Numbers of Event Identified	881	1027
Accuracy Rate	72.35%	81.17%

As the figures show, we can observe that the use of SIMPLE/CLIPS has a positive effect since we register an increase both in the absolute number of eventualities identified by the subjects and also in the accuracy rate of the identification, i.e. the agreement of the subjects on the fact that a certain lexical item is an eventuality. The results from the first experiments have shown that the main issue related to the identification of eventualities is related to the eventive status of nouns like "*assemblea*" [meeting], "*tragedia*" [tragedy], "*problema*" [problem/issue], "*allarme*" [alarm], including deverbal nouns, like "*incremento*" [rise], "*riduzione*" [reduction], "*accordo*" [agreement], "*pagamento*" [payment] and similar, which, in the generative Lexicon, are instances of dot types.

In this theoretical framework, dot types or complex types are one of the three ontological types[6] in which the domain of individuals is classified. The distinguishing feature

[5]For a detailed description on the annotation of eventualities according to the TimeML specifications and their adaptations for Italian readers are referred to appendix C.

[6]The other two types are Natural and Artifactual. The first type refers to atomic entities consisting of reference to Formal and Constitutive qualia roles; e.g.: "*albero*" [tree], "*leone*" [lyon], "*acqua*" [water]. Artifactual types denote concepts making reference also to Telic (purpose or function), or Agentive (origin) qualia; e.g. "*panino*" [sandwich], "*coltello*" [knife], "*bottiglia*" [bottle]. Artifactual types have an asymmetric internal structure which is made up of a head type, responsible for the definition of the nature of the entity, and a tail, which is responsible of the various generic explanatory causes of the entity of the head type. The two elements composing an artifactual type are unified by a type constructor, $\otimes$,

of dot types is represented by the fact that they are reifications of multiple types, bound by a coherent relation. The inherent polysemy of this class of individuals gives rise to a symmetric internal structure consisting of two types clustered together by the type construction • (i.e. dot), which reifies the two elements into a new type. For instance, the semantic description of a noun like "*assemblea*" [assembly/meeting] is composed by clustering together two distinct aspects of the object, namely *human_group* and *event*, i.e. *assemblea* = (*human_group* • *event*). The selection of one of the two types as the current reading of the lexical item is performed in the co-text by means of selecting predicative phrases, through an operation called Dot Exploitation. This operation can be performed both on the left context or on the right context with respect to the predicative phrase, as illustrated in the following examples:

(7.2) L'assemblea ha deliberato l'aumento di capitale. `human_group`
The assembly deliberated on the increase on capital.

(7.3) L'assemblea è convocata per domani. `event`
The meeting will be held tomorrow.

One of the main advantages of using SIMPLE/CLIPS as an active interface is represented by the fact that the two readings of *assemblea* reported in the examples 7.2 and 7.3, are presented to the annotators as two distinct semantic units. In this way the information from the resource ontology reduces possible commonsense knowledge differences among the annotators in terms of consciousness of the possible readings of dot types nouns, providing them with the same bulk of semantic information associated to a lexical unit. Of course SIMPLE/CLIPS is not perfect, as all human created resources. Some lexical units were missing and in some cases the information in the resource was only partially present for all levels. However, provided the intrinsic limitations of a resource, the results obtained are good and have also offered a method for developing an automatic procedure for exploiting the lexicon. A further result of this study is represented by a first evaluation of the resource itself, which needs refinements and the inclusion of more lexical units in order to be used by an automatic system.

7.3.1 Developing a procedure for using SIMPLE/CLIPS for event detection compliant with TimeML

In this section we will illustrate the general procedure to be implemented to exploit the SIMPLE/CLIPS lexicon for identifing eventualities. The procedure is largely based on the results obtained from the two experiments described in the previous section.

The general strategy to be applied in order to exploit the SIMPLE/CLIPS lexicon is that of allowing the Event Detector component to perform an automatic lookup in the resource, extract the relevant information and then assign the status of event to the head word of the chunk in analysis. One of the main issue related to the use of this lexical resource is the fact that to a single lexical unit may correspond more than one semantic units, with all the associated bunch of information. This calls for the elaboration of different strategies to be applied to the different parts of speech which may realize an eventuality. The use of shallow-parsed text as input of the Event Detector is still considered as a sufficient level of analysis for the identification of event denoting words but it needs to be integrated with a minimum of dependency parsing information in order

called tensor which introduces qualia relations to the head type. Thus, for instance, the representation of a lexical item as "*coltello*" [kinfe] is the following: *coltello* = *phys_object* $\otimes_{TELIC}$ *cut*.

to avoid failure and reduce disambiguities. On the basis of the observations presented in section 7.1, each part of speech calls for the application of specialized strategies which must extract from the resource only the subset of relevant information necessary to accomplish the task. Under this perspective the identification of eventualities becomes a two-step process: a first general lookup in the resource will assign all possible semantic types associated to every lexical entry, then, according to the specific chunk, disambiguation strategies will be applied and the relevant information extracted.

7.3.1.1 Verbal Eventualities

Once a verbal chunk is identified the chunk head, which corresponds to the verb lemma, is searched into the SIMPLE/CLIPS lexicon. When a positive and unique match is found, the system will extract in order:

- the value of the *event_type* which will represent the default lexical aspectual value on the basis of which further heuristics will be applied in order to compute the in-context actual value; and
- the corresponding semantic type;

The associated event tag will be assigned only to the chunk head and not the the entire chunk, thus respecting the annotation methodology of TimeML.

On the contrary, if a verb lemma has more than one semantic units, i.e semantic types, different disambiguation strategies apply. In particular:

- if the associated semantic types represent an instance of a regular polysemy, i.e. an alternation between inchoative or causal construction, then the system will assign the higher node as valid semantic type and extract the corresponding *event_type* value. For instance, the verb "*calciare*" [to kick] is assigned in the lexicon to two semantic types: *Cause_motion* and *Move*, where the causative alternation is encoded as a subtype of the *Move* type. In these case, the system will always assign as semantic type the hierarchically higher type in the ontology, and extract the associated *event_type* information assuming it as the default type. Thus if "*calciare*" is identified, the system will assign it the *Move* semantic type, and its *event_type*, i.e. process;
- if the associated semantic types are all subtypes of the a higher node in the ontology and none of them represents an instance of a regular polysemy, then the system will assign as valid the higher available node which subsumes all the specific subtypes. For instance, the verb "*dire*" [to say/to tell] has two semantic types in the lexicon, one as *Directive_Speech_Act*, when the verb is used to order something to someone, and the other as *Speech_Act*, when the verb is used in its general meaning of communicating by means of the voice. In these case, since the same lexical entry has both general and specialized readings, we claim that the difference between the two types is not relevant. Similarly to the regular polysemous verbs, we assume as valid the more general semantic type, on the basis of the hierarchical organization of the ontology. Consequently, for the verb "*dire*" [to say/to tell], the semantic type to be assigned will be *Speech_Act* and its encoded value for *event_type*;
- finally, if the difference between the subtypes involves the presence of subtypes which belongs to different top nodes of the EVENT node, then we claim that the only available solution is represented by the use of a context-sensitive (bayesian) word sense disambiguator trained on the SIMPLE/CLIPS semantic types, which by taking into account the context, i.e. a window of preceding and following chunks, is able to

assign the most probable sense, i.e. semantic types. After this operation, the system can extract the associated *event_type* and assume it as default lexical aspect.

A possible strategy to facilitating the creation of such sense disambiguator could be represented by a mapping between the SIMPLE/CLIPS semantic types and ItalWordNet senses. Two experiments in this sense have been already conducted by Roventini et al. (2007), for concrete entities, and by Roventini & Ruimy (2008) for eventualities and have reported very interesting results, in particular in the perspective of enlarging the entries in both resources, thus increasing their coverage.

In order to be compliant with the TimeML output format for eventualities, a special set of heuristics and procedures for the lexicon lookup should be developed, in the following cases:

(i.) verbs which may give rise to light verb constructions, like *fare* [to do], *dare* [to give], *mettere* [to put] followed by a noun, either deverbal or not;

(ii.) causative constructions with "*FARE/FARSI + V/ADJ*" [to do + V/ADJ];

(iii) modal periphrases like "*essere in grado di + V*" [to be able to/can + V], "*andare + V*" [to go + V], and "*avere + da + V*" [have to/must + V]; and

(iv.) constructions with the verb "*essere*" [to be].

In these cases the simple analysis of the verb chunk is not sufficient and may lead to incorrect identification and tagging of eventualities.

7.3.1.2 Nominal Eventualities

The lookup of possible eventualities realized by nouns is performend on nominal chunks (N_C) and prepositional phrase chunks (PP_C and di_C).

We claim that a list of stopwords must be created in order to avoid incorrect matches, in particular for those entries under the PHENOMENON subtype of the EVENT node. In fact, under this node we can find entries like "*nuvola*" [cloud] which of course is a natural phenomenon but it is not an event, unless in a specialized domain where it can receive an eventive reading.

The lookup procedures for nouns is very similar to the one performed for verbs. When one of the eligible chunks is individuated, the chunk head, which corresponds to the noun lemma, is searched into the SIMPLE/CLIPS lexicon. If a positive match is found, the system will check the number of associated semantic types, which correspond to the number of semantic units, i.e. senses, of the noun, and their position in the SIMPLE/CLIPS ontology. In case none of them belong to the node EVENT, the system will discard the chunk.

On the contrary, different strategies apply in case a semantic type is an eventive one. If this is the only available type, then the identification is straightforward, and following the TimeML specifications the noun head is assigned the event tag. Things are more complicated when more semantic types are available and at least one of them belong to the node EVENT. In this case, the most reliable solution is, again, the use of a (bayesian) word sense disambiguator.

7.3.1.3 Adjectival Eventualities

This class of eventualities is, from a certain point of view, the easiest to be identified. On the basis of the TimeML guidelines, the set of adjectives which can have an eventive reading is restricted mainly to deverbal adjectives. On the basis of the the output of the shallow parser we have used (Lenci et al., 2003), the lookup process will be performed at different levels, namely (i.) on isolated adjectival chunks, (ii.) on the premodifier positions of nominal chunks and, finally, (iii.) on isolated participial chunks, since this latter type of chunks may contains adjectives ending in "*-to*" and "*-nte*"[7] . Once the adjective lemma is identified, the lookup in the SIMPLE/CLIPS lexicon is performed. When a positive match is identified, the system will not extract the semantic type, but will look into the semantic relations for the derivation information. Only if the adjective lemma is a deverbal one, then it is tagged as an event.

7.3.2 Implementing the Event Detector component: a simulation

In this section we will present a simulation of the functioning of the procedure described above. We have selected a brief text from our corpus, containing a total of 96 words, including punctuation marks, and automatically analyzed by means of a suitcase of natural language processing tools for Italian[8] implemented at the ILC-CNR in Pisa, up to the shallow parser level (i.e. chunked text). The text analyzed is part of the corpus we have collected and is reported below. In bold character we have marked what we have considered as having the status of eventuality, so that a preliminary evaluation of the coverage of the resource can be established.

(7.4) LA REPUBBLICA 01/07/1986
Cresce la Wabco Westinghouse.
TORINO - Ancora un anno di **risultati** positivi per la Wabco-Westinghouse, che ha **chiuso** il 1985 con un utile netto di 5714 milioni. Ciò **consente** la **distribuzione** di un dividendo di 2100 lire (600 in più del 1984).
Il fatturato consolidato è **stato** di 102 miliardi, contro i 95 dell'**esercizio precedente** e l'utile netto **consolidato** ha **raggiunto** i 6,7 miliardi, con un incremento del 27 per cento sul 1984.

Wabco Westinghouse grows.
TURIN - Another year of positive results for Wabco-Westinghouse, which has closed the 1985 budget with a clean profit of 5714 million. This allows the distribution of a dividing of 2100 lire (600 more than in 1984).
The consolidated billing is of 102 million, against the 95 of the last financial year, and the clean profit topped 6.7 billion, with a 27 per cent increase with respect to 1984.

The chunked text has been connected with the SIMPLE/CLIPS lexicon by means of a script, which extracts the reserved chunk heads and checks for their presence in the resource. The output is a chunked text augmented with SIMPLE/CLIPS semantic types. A sample of the output is illustrated in Figure 7.1 on the next page, where the SIMPLE/CLIPS semantic types are inserted next to the chunk heads for which at least a correspondance was found.

34 chunk heads have been checked in SIMPLE/CLIPS as eligible to the status of eventuality. We have obtained a positive match, i.e. presence of a lexical unit, for 26 of them.

[7] These types of adjectives may be considered as conversions from the corresponding participial forms, past participle for the adjectives in "*-to*", and present participle for the adjectives in "*-nte*".

[8] http://foxdrake.ilc.cnr.it/webtools/

```
 1 B-  N_C  POTGOV: repubblica repubblica NN FS!!!!P        Human_group     Geopolitical_location   Institution
 2 B-  N_C  POTGOV: 01/07/1986 01/07/1986 NN_P __!!!!!
 3 B-  PUNCT_C      POTGOV: . . PUNCT !!!!!!!
 4 B-  FV_C POTGOV: cresce crescere V_FIN !S3PI!!   Change_of_State Change_of_Value Purpose_Act
 5 B-  N_C  DET:    la lo ART_D FS!!!!!
 6 I-  N_C  POTGOV: wabco wabco NN_P !!!!!!!
 7 B-  N_C  POTGOV: westinghouse westinghouse NN_P !!!!!!!
 8 B-  N_C  POTGOV: torino torino NN_P __!!!!P      Geopolitical_location   Human_group
 9 B-  SYM_C        POTGOV:   SYM !!!!!!!
10 B-  ADV_C        POTGOV: ancora ancora ADV !!!!!!P
11 B-  N_C  DET:    un un ART_I MS!!!!!
12 I-  N_C  POTGOV: anno anno NN MS!!!!P    Unit_of_measurement     Time
13 B-  PART_C       PREP:   di di PREP !!!!!!!
14 I-  PART_C       POTGOV: risultati risultare V_PP MP!RP!!        State   EVENT
15 B-  ADJ_C        POTGOV: positivi positivo ADJ MP!!!!P
16 B-  P_C  PREP:   per per PREP !!!!!!!
17 I-  P_C  DET:    la lo ART_D FS!!!!!
18 I-  P_C  POTGOV: Wabco-Westinghouse wabco-westinghouse NN_P __!!!!!
19 B-  PUNCT_C      POTGOV: , , PUNCT !!!!!!!
20 B-  N_C  POTGOV: che che PRON __!!!!P
21 B-  FV_C AUX:    ha avere V_FIN !S3PI!!
22 I-  FV_C POTGOV: chiuso chiudere V_PP MS!RP!!    Change  Cause_Change    Aspectual       Cause_Aspectual Experience_Event
23 B-  N_C  DET:    il il ART_D MS!!!!!
24 I-  N_C  POTGOV: 1985 1985 C_NUM !!!!!!!
25 B-  P_C  PREP:   con con PREP !!!!!!!
26 I-  P_C  DET:    un un ART_I MS!!!!!
27 I-  P_C  POTGOV: utile utile NN MS!!!!P  Amount
28 B-  ADJ_C        POTGOV: netto netto ADJ MS!!!!P
29 B-  DI_C PREP:   di di PREP !!!!!!!
30 I-  DI_C PREMODIF:       5714 5714 C_NUM !!!!!!!
31 I-  DI_C POTGOV: milioni milione NN MP!!!!P      Amount
32 B-  PUNCT_C      POTGOV: . . PUNCT !!!!!!!
33 B-  N_C  POTGOV: ciò ciò PRON _S!!!!P
34 B-  FV_C POTGOV: consente consentire V_FIN !S3PI!!       Cause_Act
```

Figure 7.1: *Output obtained after the lookup in the SIMPLE/CLIPS lexicon.*

As for the remaining chunk heads, 7 of them are missing from the resource, i.e. their lemmas are not coded. Most of them (3 nominal heads) are named entities corresponding to the proper name of the company, 1 corresponds to a calendar pattern, 2 correspond to the lemma "*consolidare*". Only 1 chunk involved the presence of a construction with the verb to be, which as we have stated above requires special heuristics.

Filtering the semantic types associated to the chunk heads, we have obtained 9 possible eventive chunk heads. For clarity's sake, we have reported them in Table 7.4 on page 194. Five of them have associated a unique semantic type which is part of the EVENT node in the SIMPLE/CLIPS ontology and have been marked as events. Among the remaining 4 chunk heads, we have 3 verbal eventualities and 1 possible nominal one. In both cases, the only available disambiguation procedure is represented by the application of a (bayesian) word sense disambiguator. In fact, the verbal eventualities have a set of semantic types which differ one with respect to the other also for the main EVENT subtype nodes of the ontology, thus making impossible the application of the first two disambiguation strategies we have illustrated in section 7.3.1.1. Since no word sense disambiguator trained on the SIMPLE/CLIPS types is available, we have manually assigned the correct semantic type. In addition to this, we have also manually extracted the information related to the associated *event_type* where present.

Comparing the system's simulation with respect to the manually annotated text, we can observe that in terms of absolute numbers, the system's simulation has identified the same number of eventualities, excluding the event realized by the verb to be, i.e. *è* ***stato***. However, going into the details, things are bit more complicated. Using an automatic system for identifying both part of speech and chunk types can be useful but also a possible source of errors. For instance, in our text the noun "*risultati*" [results] have been analyzed as the past participle of the corresponding verb and not as the noun which has two associated semantic types, namely *State*, representing the meaning of the deverbal noun, and *Amount*, describing the number obtained by a mathematical operation. Moreover, the SIMPLE/CLIPS resource needs refinements in terms of semantic types associated with the various lemma in order to be used by an automatic system, in particular with deverbal nouns. For instance, the only semantic type available for "*incremento*" [rise] is *Cause_Change_of_Value*, while the amount reading is completely absent. Provided the disambiguation procedures, the system would consider "*incremento*" [rise] always as an eventive nominal overextending the notion of nominal eventualities. Similarly, *distribuzione* [distribution] has only the eventive reading. The issue of the coverage of the resource in terms of lexical items, i.e number of lemmas, is of utmost importance. As it emerged from the annotation experiment, lots of lexical entries are missing, and need to be integrated. Nevertheless, the implementation of specific research heuristics, as we have described, allow the use of the lexicon as an active resource and not as a dictionary.

A further advantage of the SIMPLE/CLIPS lexicon is represented by the fact that the encoded semantic relations by means of the extended qualia structure, allow also the identification of coreferential eventualities. In particular, we are referring to cases of bridging anaphors, i.e. full definite NPs, with a verbal event as their antecedent. To clarify this concept, consider the example in 7.5; the eventualities are in bold:

(7.5) La ditta **ha elevato il capitale**$_j$ nel 1994. **Questa ricapitalizzazione**$_j$ **ha permesso** di **emettere** obbligazioni per 21.9 miliardi.

The firm raised in 1994 its shared capital. This recapitalization allowed the emissions of bonds for 21.9 billions.

As we have signalled by means of the pendix $_j$, two eventualities are coreferential, namely the verb phrase "*elevare (il capitale)*" [to raise (the shared capital)] and the noun phrase "*questa ricapitalizzazione*" [this recapitalization]. The noun phrase qualifies as an instance of a bridging anaphor which refers to an object only indirectly introduced into the common ground as the result of mentioning a related object, which, in this case, is an event. Exploiting SIMPLE/CLIPS extended qualia structure, in particular the Agentive relation of *Result_of*, we can recover this coreferential relation. An interesting result of this operation is that the identification of coreferential eventulities may have a positive effect on the temporal processing as well. In fact, on the one hand, it will reduce the number of eventualities to relate, and, on the other hand, it allows the identification of inferred temporal relations between eventualities even in absence of specific linguistic information. For instance, knowing that a particular element stands in a *Result_of* relation with an other element means that the two items stand in a precedence relation. A first attempt of this application has been performed on pure bridging anaphors. The results obtained, though not satisfying (on a total of 129 couples of bridging anaphors - anchors, only 17 of them could have been resolved automatically by means of the qualia relations present in SIMPLE/CLIPS), are promising.

7.4 TimeML event classes: making explicit the illocutionary force of the eventuality

In the previous sections we have illustrated how a general procedure for the use of a complex lexicon resource like SIMPLE/CLIPS could be implemented. We have presented the set of information available in the resource and suggested how they could be exploited for the task of event identification. We want to stress the fact that this is a theoretical development which needs further research and that different techniques may be applied for the same task, but we claim that, in particular for nominal and adjectival eventualities, the lookup in a lexical resource is a necessary strategy to reduce ambiguity and improve event identification.

A further advantage of linking lexical entries from texts/discourse to a lexical resource like SIMPLE/CLIPS is represented by the fact that we are enriching the text with semantic information which can be further exploited to perform other tasks. For instance, the information from the extended qualia structure may be further used to expand queries in Question-Answering, a procedure which may facilitate the identification of the correct answer, or it can be used to identify parthood relations between eventualities and, thus, facilitating temporal reasoning and the identification of inferred temporal relations. However, one of the biggest advantages of assigning a SIMPLE/CLIPS semantic types to eventualities is represented by the fact that they can be associated, i.e. mapped, on specific classes, as those proposed by the TimeML specifications, which facilitate the identification of the expression of an eventuality as being realis, irrealis, reported, intensional, factive and similar.

The bare detection and assignment of the lexical aspect values can be considered as a necessary and sufficient information for the temporal processing of texts, provided the rstrictions we have illustrated in chapter 5. However, this level of analysis is not sufficient if we want to exploit the temporal information and integrate the model as a specialized component of more complex computational systems, like Open-Domain Question-Answering. Consider, for instance, this example:

(7.6) L'Italia ha rafforzato la propria politica di risanamento e ha cercato di ridurre il deficit nel 1994.

Italy strengthened its balancing policy and tried to reduce the debt in 1994

(7.7) Quando l'Italia ha ridotto il deficit?

When did Italy reduce the debt?

Applying our computational model for temporal processing, we will obtain the following analysis (the representation is simplified to maintain the readability):

- (((*ha rafforzato* [strengthened]) ≡ (*politica* [policy])) *ct* ((*ha cercato* [tried]) *pr* (*ridurre* [reduce]))) *o* (1994).

On the basis of the pure temporal analysis which could be obtained by applying the model, the answer to our question would be "*nel 1994*" [in 1994]. But this is not the correct one. As example 7.6 shows in certain context temporal information alone does not represent the required level of information in order to express other important relationships between eventualities, like entailment/contradiction relations or other types of inferencing relations which are normally computed during the process of text/discourse understanding. In fact, by reading example 7.6 we cannot state if the event of reducing the debt has taken place or not. What we know is simply that the Italian government has tried to do that.

In order to provide the correct answer, a Question-Answering system must perform some kind of reasoning on the type of eventualities, i.e. it must take into account the nature or illucutionary force of the eventuality. The Event Detector component can perform this type of analysis only partially, relying on the associated information from mood. But mood is not always sufficient to state if an event has really occurred or not. A more fine-grained analysis of the semantics of the eventualities is needed, and this lead to the following question:

Question 7 : what kind of classification is the most convenient to perform reasoning with eventualities?

A reliable answer to this question is provided by the TimeML event classes. The set of classes identified, only seven, is rather different and reduced with respect to other proposals, like Levin's classes (Levin, 1993), but can be proved to be sufficient and necessary to express all other inferencing relations, with the exclusion of the temporal ones, which are necessary to allow reasoning processes by automatic systems. The main advantage of using this classification is the fact that these classes partially characterize the nature of an event as being irrealis, factual, possible, reported and intensional. A combination of the various event classes with information from the mood of the tensed eventuality will then provide the system accurate information of the modality value of the eventualities in analysis, thus avoiding incorrect answers to the question in example 7.7.

In TimeML, each eventuality is assigned to one of the following classes, namely:

- REPORTING: it comprehends eventualities which describe the action of a person or an organization declaring something, narrating an event, informing about an event, and similar, e.g.: *dire, spiegare, raccontare, affermare, notizia, commento...*;
- PERCEPTION: it comprehends eventualities which involve the physical perception of another eventuality; e.g.: *vedere, guardare, osservare, ascoltare, sentire,...*;

- ASPECTUAL: these events code information on a particular phase or aspect in the description of an eventuality. They are a grammatical device which code a kind of temporal information and focus on different facets of the eventuality interval representation. They may signal one of the following aspects:

  (a.) Initiation: *iniziare*, *incominciare*. . . .

  (b.) Reinitiation: *rincominciare*. . . .

  (c.) Termination: *smettere*, *terminare*, *cessare*, *interrompere*.

  (d.) Culmination: *finire*, *completare*. . .

  (e.) Continuation: *continuare*, *andare avanti*. . . .

- I_ACTION and I_STATE: these two classes represent eventualities which give rise to an intensional context. In TimeML the concept of intensionality is rather extended with respect to classical examples of propositional attitudes and formal semantics. In particular, we can state that every eventuality which has a proposition or a fact, or a property denoting argument introduces an intensional context. Under this perspective, almost every lexical item that takes a clausal or a predicative argument should be seen as intensional. In a rather simplified way, we can claim that every eventuality which has in complement position another eventuality is classified either as an I_ACTION or an I_STATE. The I_ACTION class is reserved to events, while the I_STATE class is reserved to states. Nominal events as well, and in particular nominalizations, can be classified as I_ACTION or I_STATE; e.g.: *cercare, provare, tentare, indagare, ricercare, progettare, promettere, offrire, assicurare, temere, odiare, essere preoccupato, aver paura, spaventarsi, dovere, potere, volere* . . . ;

- OCCURRENCE: this class includes all other types of events describing situations that happens or occurs in the world; e.g.: *mangiare, crescere, leggere, dormire, uragano,*. . . ;

- STATE: in TimeML, as already stated, only the subset of temporary states is annotated. However, for the purpose of this chapter, we can avoid the details of the annotation schemes, and claim that stative predicates are assigned to this class.

In order to express the associated modality existing between two eventualities, TimeML employs a special link, called `SLINK`, i.e. subordinating link. In this way modality relations between eventualities are explicitly signalled and made available for developing reasoning mechanisms. For instance, in the example described in 7.6, the eventualities will be classified as follows:

- *ha rafforzato* [strengthened] = I_ACTION;
  politica [policy] = OCCURRENCE;
  (ha cercato [trying] = I_STATE;
  ridurre [reduce] = OCCURRENCE.

Making explicit the `SLINK` relations between the eventualities, we will obtain the following inferences on the modality relations between the eventualities: (i.) the fact that the balancing policy had been strengthened, and that (ii.), unless other and more specific information are made available, that the Italian Government has tried to reduce the debt, but we do not know if it succeeded. The verb "*cercare*" [to try] gives rise to an *intensional context*, whose meaning is, in terms of Montague Intentional Logic, a function from possible worlds to truth values. This means that it is not possible to reliably and uniquely entail that the debt was reduced[9]. The set of information then available to perform reasoning is twofolded: on the one hand, temporal relations, and on the other hand, information on the modality between eventualities. Combining the two set of information, we will obtain the following representations:

- (((*ha rafforzato* [strengthened]) ≡ (*politica* [policy])) *ct* ((*ha cercato* [tried]) *pr* (*ridurre* [reduce]))) *o* (1994). [temporal information]

- ((*ha rafforzato* [strengthened]) $factive_{SLINK}$ (*politica* [policy])) ∧ ((*ha cercato* [tried]) $intensional_{SLINK}$ (*ridurre* [reduce])). [modality information]

Consequently, when this set of information is combined together with reasoning mechanisms and analyzed by a Question answering system the best possible answer to "when did Italy reduce the debt?", then it is represented by the entire sentence "it has tried to reduce the debt in 1994", and not the bare calendar date.

One of the main issues related to the identification of TimeML classes is that they are based on a combination of semantic and syntactic criteria. In addition to this, there is not a strict one-to-one relationship between eventuality and TimeML class. For instance, a verb like "cercare" [to look for/ to try] can belong to two different classes, namely I_ACTION and OCCURRENCE, according to the associated semantic type of its argument, as illustrated in the following examples:

(7.8) Marco **ha cercato** il cane. → `OCCURRENCE`
Marco looked for the dog.

(7.9) Marco **ha cercato** <u>lo scontro</u> con la polizia. → `I_ACTION`
Marco looked for a battle with the police.

Event classification could represent a further source of disagreement between annotators, thus reducing the reliability of an annotated corpus for the development of automatic systems. A possible solution to this issue can be the exploitation of the semantic types of SIMPLE/CLIPS. Our working hypothesis is that it could be possible to associate, i.e. to map, each event class in TimeML with one or more semantic types from the SIMPLE/CLIPS ontology.

7.4.1 Improving Event Classification by means of SIMPLE/CLIPS semantic types

The mapping has been conducted using both the previously annotated Italian texts for eventualities and the annotation from the TimeBank. During the mapping phase, we have assigned the classes to the eventualities identified by means of the SIMPLE/CLIPS lexicon. In this phase, the use of the TimeBank was necessary because it is the only available "gold standard" for this kind of annotation and it provides what can be considered as positive examples. For each event-denoting word we kept track of the SIMPLE/CLIPS

[9]Nothing prevents us from assuming forms of reasoning based on non-monotonic logic whereby the opaque referential reading of intensional context is not available, which exploits Grecian maxims of conversation. Such choices, however are not relevant at this moment.

entry's relevant information for its TimeML classification (i.e. semantic type and supertype, event type, semantic features and relations, and argument structure). Only a subset of the semantic features and *qualia* relations have been considered as relevant.

We have observed how the semantic information plays a primary role in the assignment of the TimeML classes. However, the semantic characteristics of an eventuality are not always necessary and sufficient conditions for its classification. Other levels of linguistic information, like syntactic dependencies, verb form realization (finite *vs.* non finite forms) and argument structure, may influence the class assignment or work as discriminating cues. During the mapping we noticed that the information provided by each lexical entry worked like a sort of default template window for classification which needed to be integrated with co-textual information to assign the proper class. In Table 7.3 on the next page, we report the mapping results obtained for each event class in TimeML and SIMPLE/CLIPS semantic types. In the third column (Restrictions) we have illustrated the restrictions necessary for the assignment of that class. The default classes, i.e. the classes to be assigned if the restrictions is not respected are either OCCURRENCE for events or STATE for states. Finally, the mapping is valid only for verbal and nominal eventualities.

In order to verify the validity of the mapping between the TimeML classes and the SIMPLE/CLIPS semantic types, we have conducted two set of experiments. In the first experiment, a set of three expert annotators were provided with tevent annotated texts and asked to classify them by using the TimeML definitions. In the second experiment, the annotators were provided with the set of heuristics elaborated during the mapping process and were allowed to use the SIMPLE/CLIPS lexicon as an active interface. During this experiment they had to identify the correct SIMPLE/CLIPS semantic type and then assign the TimeML classes. The results of the two experiments are reported in Table 7.2.

Table 7.2: *Classifying Events - Results from the annotation experiments*

	Test 1 - TimeML Guidelines	**Test 2 - SIMPLE/CLIPS Mapping**
K-value	0.7	0.84

It is interesting to notice how the agreement on event classification obtained by applying the heuristics is by far better than that obtained by the bare application of the TimeML guidelines (K = 0.84 *vs.* K = 0.7). Furthermore, we have registered a reduction of the number of events classified as OCCURRENCE (from 60.61% to 50.44%) and I_STATE (from 8.51% to 5.45%) and an increase for the STATE and I_ACTION classes (from 16% to 19.23% and from 4.99% to 11.88%, respectively) with respect to the first experiment .

Combining the experimental results and the restrictions identified during the mapping process, we can quite reliably state that the assignment of the TimeML event classes requires the presence of a local context dependency parser (i.e. mini-parser). With the expression *local context* we refer to the fact that the dependency parsing operates on a clause-by-clause basis and builds the dependency relation only between the elements which have been identified as eventualities in the same clause and then applies the heuristics assigning the corresponding TimeML class. Moreover, operating on a clause-by-clause basis allows also to create specialized mini-parsers which receives in input different chunk types, thus generating specialized output according to the "main" chunk type, i.e. verbal, nominal or prepositional, and the information obtained from the lexical resource on the chunk head, namely the associated argument structure and preference types.

Table 7.3: *Mapping TimeML classes to SIMPLE/CLIPS semantic types*

TimeML Class	**SIMPLE/CLIPS Semantic Types**	**Restriction**
REPORTING	*Speech_Act*; *Cooperative_Speech_Act*; *Reporting_Event*	No restriction
OCCURRENCE	*Cause*; *Phenomenon*; *Wheather_verbs*; *Disease*; *Stimuli*	No restriction
PERCEPTION	*Perception*	It must have an eventuality as one of its argument
ASPECTUAL	*Aspectual*, *Cause_Aspectual*	No restriction
STATE	*State*, *Identificational_State*, *Constitutive_State*, *Stative_location*, *Stative_possession*	No restriction
STATE	*Cause_Relational_Change*, *Cause_change_of_state*, *Change_of_state*, *Cause_natural_transition* and any other semantic type	Semantic relation of *Resulting_state* and verb realized by a Past Participle
I_STATE	*Cognitive_Event*, *Judgement*, *Experience_Event*, *Modal_Event*, *Psychological_Event*, *Relational_State*	It must have an eventuality as one of its argument
I_ACTION	*Commisives*, *Directives*, *Expressives*, *Declaratives* and any semantic type excluding those for REPORTING, STATE, ASPECTUAL, I_STATE, PERCEPTION	It must have an eventuality as one of its argument

7.5 Concluding Remarks

In this chapter we have elaborated a set of procedures to integrate the information encoded into a complex lexical resource like SIMPLE/CLIPS for the implementation of an Event Detector component.

We have proved, by means of two sets of annotation experiments, the validity of using a lexical resource both for identifying and classifying eventualities compliant with the TimeML output format. One of the main advantages of having eventualities linked to a semantic lexicon is represented by the fact that each eventualities is augmented with real semantic information. This kind of information is encoded in the SIMPLE/CLIPS lexicon as the event type, i.e. default lexical aspect, and by the set of semantic features and qualia relations.

The experiments have also provided us with a first evaluation of the resource. Lots of elements need to be revised and corrected, in particular we have registered missing senses, errors in the identification of the event type of eventualities (namely mistakes between process and transition events), and lots of underspecified generalizations for the preference type for the semantic roles. A possible solution to improve the resource and correct these issues could be represented by extensive corpora data analyzed by means of stochastic algorithms.

An Event Detector component is a complex component which requires different sources of information such as knowledge of the part of speech, type of chunk, dependency relations between the elements, and information of the possible semantic types of a lexical unit. With respect to previous event detector components, which considered as eventualities only verbs, the more we enlarge the set of parts of speech which can assume the status of eventuality, the procedures for their detection and classification are complex. In order to obtain this set of information different tools, like a part of speech tagger, a chunker, a mini-dependency parser and a context-sensitive word-sense disambiguator must be integrated one within the other. To preserve the portability of the various tools, their outputs should be underspecified with respect to the representation format, thus facilitating their adaptation to a specific format. In our case, the specific format is represented by the TimeML specifications, but this is a choice, nothing prevents us from elaborating a different output format and different tagging instructions and classes of eventualities.

A further step in this work is represented by the implementation of the procedure into an automatic system and its evaluation against a human-based annotated corpus for eventualities. Part of this work is currently under development, both for the implementation phase (Del Gratta et al., 2008), and for the creation of the annotated corpus, i.e. the Italian TimeBank project.

Table 7.4: *List of chunk heads with at least an eventive semantic type*

Chunk head and type	**SIMPLE/CLIPS Information**
FV_C POTGOV: cresce crescere	*Change_of_State*, *Change_of_Value*, *Purpose_Act*
PART_C POTGOV: risultati risultare	*State*
FV_C POTGOV: chiuso chiudere	*Change*, *Cause_Change*, *Aspectual*, *Cause_Aspectual*, *Experience_Event*
FV_C POTGOV: consente consentire	*Cause_Act*
N_C POTGOV: distribuzione distribuzione	*Transaction*
DI_C POTGOV: esercizio esercizio	*Institution*, *Relational_Act*, *Act*
ADJ_C POTGOV: precedente precedente	deverbalAdjective
FV_C POTGOV: raggiunto raggiungere	*Modal_Event*, *Change_of_Location*
P_C POTGOV: incremento incremento	*Cause_Change_of_Value*

Chapter 8

Conclusions

In this work we have developed a computational model for automatically extracting temporal information from open domain texts/discourse of Italian.

We have revisited the theoretical literature on the temporal analysis of texts and also computational approaches which have provided us with the theoretical tools necessary to develop a model which is linguistically grounded and whose implementation is not only possible but aims at robustness. The model is conceived in the perspective of being applied to other computational systems, namely Open-Domain Question Answering and Information Retrieval. Working with this general perspective has suggested the use of a modular architecture, so that different types of information can be selected and extracted when required and used as inputs to further processing and reasoning mechanisms.

The model is composed by four modules and each of them is specialized for a particular analysis. The modules are all connected one with the other, whereby the output of one module represents the input of the following one. In this way, we are splitting the analysis in different steps trying to represent the incremental processing of texts/discourses that humans perform. A further advantage of this modular composition is represented by the fact that we can always obtain an output. In this way failure of analysis is reduced and even if the processing provides partial information it can be used by other systems.

However, this work may offer a contribution also to theoretical linguistics analysis. The process of revision of the Italian language sub-systems (chapter 3, section 3.3.2) which are used to code temporal relations has offered a deep revision of existing literature and has tried to overcome limitations or wrong statements. In particular, we claim that some of the most innovative and interesting insights are represented by the analysis of tense semantics. The identification of the A textual parameter which is distinguished from the moment of reference, *Rpt*, and from the second deictic center, R is of utmost importance since it sheds new lights on the debate on the anaphoric status of tense and proposes a different and innovative interpretation of Reichenbachian moment of reference. The presence of the A anchor splits the original Reichenbachian moment of reference R into three points with different roles and statuses, namely:

- *Rpt*, the moment of reference, which corresponds to the referential property of tense, i.e. to the fact that it can collocate an eventuality in one of the three temporal dimensions of Past, Present or Future. The *Rpt* is responsible for signalling the temporal focus in which the eventuality occurs;

- R, a second deictic anchor which is necessary to describe the temporal meaning of some tenses, as proposed by Comrie (1985);

- A, the textual temporal anchor which is responsible for putting tenses in relation in a text/discourse. The anchor has two different types of setting according to the fact that a tense occurs in a complex sentence or in a discourse segment. In the latter context, it can be set in a principled way only in presence of tense shifts or smooth tense shifts.

As for tense and the hypothesis of its anaphoric status, we have claimed that it can be considered as valid only in the weak interpretation of the term "referring". On the basis of our proposal of the constraints for a principled setting of the A textual anchor and the role of the *Rpt* as the temporal focus, we can elaborate on the similarity of the behaviour of tense and definite NPs as proposed by Webber (1988). In particular we are going a little bit further with respect to Webber's analysis by claiming that tense has a similar behaviour to a special class of definite noun phrases, namely that of bridging anaphors. Bridging anaphors are a special class of anaphoric definites since, on the one hand, they have their own referential properties, and, on the other hand, they give rise to an indirect anaphoric link to a previously mentioned entity in the text/discocurse. Thus for instance in the following example:

(8.1) Siamo andati a fare *un picnic*$_j$, ma ho dimenticato di mettere *le birre*$_j$ nella borsa frigo.
We went for a picnic, but I forgot to put the beers in the cooler.

the noun phrase "*le birre*" [the beers] can be considered as an anaphoric bridging on the indefinite "*un picnic*" [a picninc]. In fact, it has its own referential properties, since it denotes a specific object, but at the same time it refers back to the indefinite noun phrase by means of a relation, which can be identified as a lexical relation of parthood since beers can be part of the picnic supplies one usually prepares. Relations between bridging definites and their anchors can be of different kinds, namely lexical, if the bridge, i.e. the inferencing mechanisms to be activated, exploits lexical relations, or based on commonsense knowledge.

In discourse contexts, tense can be assumed to have a similar behaviour. The analysis we advance is the following:

- tense has its own referential properties, which is represented by the *Rpt*;
- as bridging anaphors, sequence of tenses tend to refer indirectly one to the other, so that to create multiple bridges. However, sequences of eventualities at the same tense, which do not allow a principled assignment of the A parameter, identify a general temporal focus, since all their reference points, *Rpt*s, are collocated in the same temporal dimension providing a continuation of the general temporal focus. On the contrary, in presence of shifts in tense, the temporal focus of the two eventualities differs. Their *Rpt*s are collocated in two different dimensions and we are facing cases of either of a shift in the focus or a continuation (for smooth tense shifts). With a continuation of the general temporal discourse focus as the one coded by smooth tense shifts, the information provided by tense semantics is not enough to build the bridge necessary to put in relations the various eventualities. To do that operation we need to make use of other, more specific, sources of information like the viewpoint aspect, the lexical aspect or the shared knowledge of the world. On the contrary, in presence of tense shifts, and consequently a change in the temporal focus, tense semantics offers all the necessary and sufficient information to built the bridge and temporally relate the eventualities.

Going even further with this similarity, and recalling the strategy of varying the granularity level of the temporal representations, as suggested by Mani (2007), we can state that tense in sequences of same tensed eventualities (both absolute and smooth) has a behavior similar to bridging definites which can be resolved by making use of commonsense knowledge. The only information that tense offers is that the eventualities are all coreferential, i.e. simultaneous, one with each other with respect to a general and larger i.e. coarse grained, temporal focus. On the other hand, a shift in tense and the corresponding shift in the general and local temporal focus offer the interpreter the information required to build the bridge without too many efforts.

The experimental data have provided us with important information on the saliency of the sources of information for recovering temporal relations. We have been able to elaborate a saliency based hierarchy of these devices as illustrated in the **Formula 2** reported below:

Formula 2 (Hierarchical order of information) : COMMONSENSE KNOWLEDGE $\lessapprox$ (IMPLICIT SIGNALS $\lesssim$ TENSE $\lesssim$ VIEWPOINT ASPECT $\lesssim$ LEXICAL ASPECT $\lesssim$ TEMPORAL EXPRESSIONS $\lesssim$ EXPLICIT SIGNALS)

On the basis of this hierarchy we have developed the internal modules of the model and we have also identified the set of constraints under which the devices in **Formula 2** can represent necessary and sufficient information for the identification of a temporal relation. Moreover, we have advanced the proposal of tense temporal polysemy. This proposal state that, in adjacent sentences, according to the possible tense patterns and in absence of particular relations between the eventualities such as causal relations, there are tense sequences which seem to grammaticalize a particular temporal relation and those which, on the contrary, remains underspecified and allow to code every possible temporal relations. Strictly connected to this proposal is the identification of a cohesiveness hierarchy of tenses, i.e. tenses which are more prone to create "texture" (e.g. *trapassato I* and *II*, *imperfetto*, *presente*) and those which are not (e.g. *passato composto*, *passato semplice*).

The set of temporal relations which is used by the model is wider than the one we have presented in chapter 2. The introduction of coarse-grained temporal relations based on the notion of conceptual neighbors is a necessary strategy in order to be as much compliant as possible with the human ability to infer and identify temporal relations. Our experiments have shown that the identification of temporal relations is not the easy task that one can imagine. Vagueness, partial ordering and missing information are intrinsic to text/ discourse and the representations that we, as humans, construct when decoding a text/discourse are at best only approximate. However, we claim that coarse-grained knowledge should not be introduced in annotation schemes unless extremely necessary. We can still ask human annotators to state a unique and precise temporal relation between two eventualities. It will be in the post-processing phase of analysis of the annotated data that conceptual neighbors relations will be identified on the basis of the annotators' disagreements. After this operation is accomplished we will have a set of annotated data which can be reliably used to train algorithms and to evaluate them.

The distinction between coarse-grained and finely-grained knowledge does not apply only to temporal relations but also for the various devices that language have at disposal to code temporal relations. As we have illustrated in chapter 5 section 5.3, according to which entities are involved in a temporal relation different levels of granularity, in terms of informational structures, apply. In particular, we have claimed that:

- the values for the viewpoint aspect have been set to PERFECTIVE and IMPERFECTIVE. More specific values, like PROGRESSIVE or HABITUAL, can be identified and assigned only in presence of explicit elements in the text/discourse signalling them, like verbal periphrases or particular types of temporal expressions;

- lexical aspectual values are more varied. They range from precise values, i.e. the 5 values we have proposed in the temporal ontology in 2, section 2.3.1, to very coarse grained ones, i.e. bare distinction between the two ontological primitives of event and state, when this type of knowledge is the most salient for the computation of temporal relations between adjacent eventualities, in order to reduce the influence of commonosense knowledge, thus obtaining possible unique temporal values.

As for temporal expressions, we have showed that their contribution is strictly dependent on their number and role in the text/discourse. We have argued that temporal expressions can be considered as the most specific source of information for determining a temporal relation between eventualities only when they provide a *time-stamping* of the eventualities, that is only when they collocate in an unambiguous way the eventualities on the time line. Unfortunately, such a condition is very rare in real texts/discourses.

Temporal signals have been divided into two classes according to their semantic transparency. The results from the corpus study, presented in appendix A, are to our knowledge, the first comprehensive list of temporal signals and their associated meanings. As for the subclass of implicit signals we have concentrated on relations between eventualities and temporal expressions, since, on the one hand, they are the easiest constructions which can be automatically extracted from a corpus, and on the other hand, because these constructions are very common and represent instances of *time-stamping* of eventualities, i.e. explicit information which may facilitate the identification of temporal relations.

The second part of this work is more technical but strictly connected to the first, since both the theoretical statements and the modalization procedures are "put to work". We have presented a working prototype of a temporal expression tagger for Italian, compliant with the TimeML standard, and a procedure for the implementation of an event detector component.

As for the tagger of temporal expressions we claim that the most innovative features are the use of shallow parsed text as input and the presence of semantic relations between the temporal trigger words. The former element has an important contribution in reducing the number of rules to be created in order to identify temporal expressions, while the latter represents a strategy to improve the correctness of the tagger, improving recall and precision.

The event detector component has not been implemented yet, but we have identified a procedure to accomplish this task. The annotation experiments we have conducted have provided important data on the validity of connecting the component to a lexical resource, which is not used as a simple dictionary but offers information, namely semantic, which is essential to improve both the identification and the classification of eventualities. Of course, the limits of lexical resources are well known. In the perspective of improving the coverage of the event detector component, it is conceivable to create a hybrid system which implements stochastic methods of analysis to discover new items, which are missing in the resource.

Future Directions

Many are the points, which for lack of time and data, are left open. In the present section we will illustrate some open issues which we have encountered in this work and which provide interesting tracks of further research:

Event detection and event coreferentiality : one of the main issues we have faced in this project is represented by the realization of eventualities in text/discourses. In this work we have limited to enumerate the possibilities which language have at disposal to give rise to instances of eventualities. However, the big issue of how to automatically detect eventualities and which are the linguistic properties activated in this task need further research. A proposal we advance is that of elaborating a measure of eventhood based on a set of syntagmatic cues, which can then be used in a statistical analysis to assign the probability that a certain noun, in a certain linguistic co-text, may assume the eventive reading or not. Moreover, further research is needed to identify cases of coreferential eventualities and of semantic relations between eventualities. As a matter of fact, knowing that two eventualities are coreferential, i.e. denote the same happening, is extremely important since it reduces the number of temporal relations to be analyzed and may also facilitate the identification of discourse relations. Semantic relations between eventualities, namely those of parthood, are of utmost importance since they may be associated with inferred temporal relations.

Temporal relations and nominal eventualities : in the description of the functioning of the model we have claimed that to deal with temporal relations involving nominal eventualities the best solution is that of considering these eventualities as simultaneous with the main tensed eventualities occurring in the same discourse segment, by applying the Cronoscope mechanism. However, we need to investigate in a deeper way how it could be possible to establish the temporal relations between nominal eventualities and tensed ones. To do this we need data, and in particular annotated data. So the first effort is represented by the creation of a relative large annotated corpus with eventualities and temporal relations. In addition to this, it will be interesting to investigate the kinds verbal eventualities with which nominal events co-occur. In our corpus exploration we have noticed that in many cases nominal eventualities tend to be arguments of temporal measurement or temporal movement verbs, i.e. verbs which intrinsically offer either a measure of time or a temporal relation. This observation calls for a differentiated treatment of verb eventualities, distinguishing between the real events, which denote things which happen or obtain in the world, and those which measure time.

Implicit signals and eventualities : an important element which needs further investigation is represented by temporal relations between eventualities marked out by implicit signals, namely temporal prepositions. In these cases, we need to distinguish those cases in which the prepositions are pre-selected particles by the events and when they are real signals of temporal relations. However, a good starting point is represented by the analysis we have conducted for constructions of the kind "EVENTUALITY + IMPLICIT SIGNAL + TEMPORAL EXPRESSION". We claim that the values we have obtained for the implicit signals when followed by a temporal expression could be extended to eventualities as well. However, to prove the validity of this working hypothesis we need data for constructions of the kind “EVENTUALITY + TEMPORAL PREPOSITION + EVENTUALITY” which cannot be obtained automatically but only from an already annotated corpus.

Complex sentences : we have only partially analyzed the temporal relations between a main sentence and a subordinated one. We have claimed that for this type of discourse context the setting of the *A* textual anchor of the subordinated clause must always be *A relative to* Rpt_1, where Rpt_1 represent the tensed eventuality of the main clause. However, this analysis is not sufficient to state in a clear way how temporal relations are to be investigated in these contexts. Other elements may influence the identification of the temporal relation, such as the semantic type of the verb in the main clause and also the type of subordinated clause. For instance, it is conceivable to imagine that subordinate relative clauses may require a different and specific analysis with respect to the other types of subordinate clauses.

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Appendix A

The semantics of temporal signals

A.1 Introduction

The term "signals" is used in this works as a cover term for a relative homogeneous set of parts of speech which are used to express, either explicitly or implicitly, different types of relations between textual entities. We claim, following Schilder & Habel (2001), that the semantics of signals in general can be expressed by the formula "*Rel (X, Y)*", where *Rel* represents the associated relation(s) of the signal, and X and Y the textual entities connected together by the signal. Signals can be divided into two groups:

(a.) Semantically explicit: it is a set of signals whose meaning is self-evident and stable, i.e. the same unique;

(b.) Semantically implicit: it is a set of signals whose meaning is highly abstract and gets specialized according to the semantic properties of the elements which precede and follows the signal itself. The semantics of this set of signals needs abstraction and thus can be represented as $Rel(\lambda(X), \lambda(Y))$.

In this annex we concentrate on temporal signals, i.e. on those set of signals whose *Rel* value corresponds to a temporal relation(s). The possible realizations of temporal signals comprehends:

- (temporal) prepositions;
- (temporal) conjunctions;
- (temporal) adverbs and adverbial constructions.

Temporal signals, both explicit and implicit, can occur in three different types of constructions involving text/discourse temporal entities, namely:

- they can temporally relate two temporal expressions;
- they can temporally relate a temporal expression and an eventuality (or viceversa); and finally
- they can temporally relate two adjacent eventualities.

The aim of this annex is that of providing a list of temporal signals of Italian and their associated semantics. The data reported are to be interpreted as generalizations based on empirical evidences, they have not absolute value since exceptions may occur due to the particular meaning of an eventuality.

To accomplish this task, we have performed a corpus exploration on a 5 million word shallow parsed corpus of contemporary Italian, drawn from the PAROLE corpus, and automatically extracted those chunks containing elegible parts of speech which may assume the status of temporal signals. As far as conjunctions and adverbs are concerned we have manually checked their immediate context (a reduced window of the five preceding and following chunks). As for prepositions, in addition to the local context, i.e. the five chunk windows, we have extracted also the noun heads and matched them, by means of a database query with the ontological information from the SIMPLE Ontology, by associating the head noun of each prepositional chunk to its ontological type, and has been queried in order to extract all instances of Temporal PPs, by restricting the nouns headed by prepositions to the type "TIME" and then manually post-processed in order to eliminate all instances of false positive temporal expressions.

By means of this corpus exploration we have collected a list of temporal signals. For each of them, we have also stated their semantic transparency, i.e. whether they explicitly code a temporal relation or if, in order to identify their semantics, co-textual information, comprehending the type of temporal expression, viewpoint aspect, tense and lexical aspect, is necessary. The working hypothesis we have applied to state the semantic transparency of signals is based on their morphological form. Following previous works in the field of prepositions' semantics, we have hypothesized that polysyllabic signals should be semantically explicit while monosyllabic ones should be semantically implicit.

In order to identify the validity of the working hypothesis we have manually annotated the sentences from the 5 million corpus where polysyllabic signals occurred. The set of temporal relations used to determine their semantics were taken from the TimeML `TLINK` values[1], but we have excluded the inverse relations of the binary temporal relations of `INCLUDES`, `DURING`, `BEGINS` and `ENDS`.

A.2 Explicit Signals

For the subset of explicit signals we have taken into account the relation between EVENT - EVENT and, when present, EVENT - TEMPORAL EXPRESSION. In Table A.1 on the next page, we report the list of explicit signals we have identified and their corresponding meaning represented by the formula *Rel (X, Y)*, where *Rel* is replaced by the temporal relation. In order to be compliant with the TimeML specifications, we have also identified a minimum set of constraints, according to the fact that the temporal relation was either between two eventualities or between an eventuality and a temporal expression. The value *none* for the constraints means that the temporal relations may hold both between two eventualities and between an eventuality and a temporal expression.

The results have confirmed in part the validity of the working hypothesis and have shown that there is not a direct correlation between polysyllabic signals and semantic transparency, i.e. explicitness, of the meaning but a general tendency. In fact, we have identified polysyllabic temporal signals which need information from the sourrounding co-textual elements in order to be correctly interpreted, e.g. *quando* [when], *appena* [as soon as] and *entro* [by].

[1]See appendix C.

Table A.1: *Appendix A: Explicit signals and semantics.*

Explicit Signals	**Semantics**	**Constraint**
poi	AFTER (X, Y)	when X and Y are two eventualities
dopo (di — che)	AFTER (X, Y)	none
prima (di — che)	BEFORE (X, Y)	none
fino a (che — quando)	ENDS (X, Y)	none
durante	DURING (X, Y)	only when X or Y is a temporal expression
durante	SIMULTANEOUS (X, Y)	when X and Y are two eventualities
mentre	SIMULTANEOUS (X, Y)	when X and Y are two eventualities
finché	ENDS (X, Y)	when X and Y are two eventualities
fin da (quando)	BEGINS (X, Y)	none
intanto (che)	SIMULTANEOUS (X, Y)	when X and Y are two eventualities
nel frattempo	SIMULTANEOUS (X, Y)	when X and Y are two eventualities
poco dopo	IMMEDIATELY_AFTER (X, Y)	none
poco prima	IMMEDIATELY_BEFORE (X, Y)	none
in seguito	AFTER (X, Y)	when X and Y are two eventualities
subito dopo	IMMEDIATELY_AFTER (X, Y)	none
subito prima	IMMEDIATELY_BEFORE (X, Y)	none
quindi	AFTER (X, Y)	when X and Y are two eventualities
successivamente	AFTER (X, Y)	when X and Y are two eventualities
nel corso di	INCLUDES (X, Y)	none
contemporaneamente	SIMULTANEOUS (X, Y)	when X and Y are two eventualities
in contemporanea	SIMULTANEOUS (X, Y)	when X and Y are two eventualities

A.3 Implicit Signals

As far as the set of implicit signals is concerned we have concentrated on one type of constructions, namely the sequence "EVENTUALITY + SIGNAL + TEMPORAL EXPRESSIONS", where the signal is realized by a temporal preposition. As already stated, the meaning of the these signals can be inferred by taking into account the sourrounding co-textual information. Thus, we have identified a set of principled linguistic features which, on the one hand, have proven useful during the annotation phase to determine the meaning of this kind of signals, and on the other hand, it can be used to develop a machine learning algorithm to automatically determine the meaning of these signals and, consequently, automatically state the temporal relation between an eventuality and a temporal expression when introduced by a signal. The set of features identified is the following:

- part of speech of the eventuality, whether it is a verb or an eventive nominal;
- TimeML type of the temporal expression: `TIME`, `DATE`, `DURATION` or `SET`;
- presence of quantifiers, either general or numerical, in the temporal expression;
- ontological status of the temporal expressions, i.e. whether it is an instant or an interval;
- diatesis, tense, viewpoint aspect and actual lexical aspect, if the eventuality is realized by a verb;

It is important to point out that most of the type of implicit signals we have taken into account, i.e. temporal prepositions whose noun head is a temporal expression, are also used as discriminating cues of the lexical aspectual value of verbal eventuality. Thus, their contribution in the text/discourse is twofolded: (i.) cues for the activation of rules for determining the actual aspectual value of an eventuality, and (ii.) signals of a temporal relations. In this work, we have concentrated on the second element, though during the annotation phase their contribution to the identification of the lexical aspect feature was essential.

Since the meaning of these types of signals is highly underspecified and may vary according to the different possible settings of the features, we have manually annotated a set of 910 occurrences of the construction "EVENTUALITY + SIGNAL + TEMPORAL EXPRESSIONS", comprehending 90 eventualities realized by an eventive nominal, and 820 by a verb. In Table A.2 on the following page we report the set temporal propositions we have analyzed, their absolute frequency in the 5 million corpus and the relative frequency when they assume a temporal value, and, finally, the number of occurrences we have analyzed.

According to our analysis, neither of these temporal prepositions can be considered as coding a unique temporal relation. FAs it emerged from the data, it possible to identify a one-to-one correspondence with a specific temporal relation only with respect to a particular configuration of the set of the features, which takes in account both the preceding and following elements of the prepositions. The features represent the lambda abstraction operations required to obtained the prepositions' semantic. In the following sections, we will present the results obtained for each of the prepositions analyzed. The tense values have been set to: past, which includes *passato composto*, *passato semplice*, *trapassato I* and *trapassato II*; imperfect for the *imperfetto*; future, which includes *futuro semplice* and

Table A.2: *Appendix A: Implicit signals and their frequencies.*

Temporal Preposition	Absolute frequency	Frequency with temporal value	Occurrences analyzed
in	76457	5265	307
per	30200	1658	155
da	42498	2318	142
a	80673	3587	173
di	110721	3378	91
entro	637	637	28
tra-fra	7024	242	14

futuro composto; and present for *presente*. Binary temporal relations are to be assigned according to the time directionality of the relation, that is if the temporal relation is computed from the temporal expression to the eventuality or viceversa. The direct temporal relations, e.g. DURING or INCLUDES, are assigned when the directionality goes from the temporal expression towards the eventuality. In case of unique value, they are to be interpreted with the directionality going from the eventuality to the temporal expression, since the inverse relation will result as unacceptable.

A.3.1 IN

We have identified four possible meanings for the signal IN, namely DURING (or DURING_INV), AFTER, SIMULTANEOUS and INCLUDES (or IS_INCLUDED), which are distributed as follows:

- DURING — DURING_INV:
  - TENSE: every;
  - VIEWPOINT: perfective — imperfective
  - LEXICAL ASPECT: [-telic] — [state]
  - TIMEX TYPE: DATE — DURATION — TIME
  - TIMEX QUANTIFIED: No
  - TIMEX Ontological status: INTERVAL
- INCLUDES — IS_INCLUDED
  - TENSE: every;
  - VIEWPOINT: perfective
  - LEXICAL ASPECT: [+telic]
  - TIMEX TYPE: DATE — TIME
  - TIMEX QUANTIFIED: No
  - TIMEX Ontological status: INTERVAL
- SIMULTANEOUS

- TENSE: every;
- VIEWPOINT: perfective
- LEXICAL ASPECT: [+telic]
- TIMEX TYPE: TIME
- TIMEX QUANTIFIED: No
- TIMEX Ontological status: INSTANT

- AFTER
  - TENSE: every;
  - VIEWPOINT: perfective
  - LEXICAL ASPECT: [+telic]
  - TIMEX TYPE: DURATION
  - TIMEX QUANTIFIED: Yes
  - TIMEX Ontological status: INTERVAL

  - TENSE: every;
  - VIEWPOINT: perfective
  - LEXICAL ASPECT: [-telic]$_{incremetative}$
  - TIMEX TYPE: DURATION
  - TIMEX QUANTIFIED: Yes
  - TIMEX Ontological status: INTERVAL

A.3.2 PER

Two possible meanings have been identified for PER, namely DURING (or DURING_INV), and INCLUDES (or IS_INCLUDED). Similarly to IN, the direct temporal relations, e.g. DURING or INCLUDES, are assigned when the directionality goes from the temporal expression towards the eventuality.

- DURING — DURING_INV:
  - TENSE: every;
  - VIEWPOINT: perfective — imperfective
  - LEXICAL ASPECT: [-telic] — [state]
  - TIMEX TYPE: DATE — DURATION — TIME
  - TIMEX QUANTIFIED: No — Yes
  - TIMEX Ontological status: INTERVAL
- INCLUDES — IS_INCLUDED
  - TENSE: every;
  - VIEWPOINT: perfective
  - LEXICAL ASPECT: [-telic]$_{iterative\_reading}$
  - TIMEX TYPE: DATE — TIME — DURATION
  - TIMEX QUANTIFIED: No — Yes
  - TIMEX Ontological status: INTERVAL

A.3.3 A

This signal has two possible meanings according to the ontological status of the temporal expression, namely SIMULTANEOUS and INCLUDES (or IS_INCLUDED):

- SIMULTANEOUS
  - TENSE: every;
  - VIEWPOINT: perfective
  - LEXICAL ASPECT: [+/- telic] — [state]
  - TIMEX TYPE: TIME
  - TIMEX QUANTIFIED: No
  - TIMEX Ontological status: INSTANT
- INCLUDES — IS_INCLUDED
  - TENSE: every;
  - VIEWPOINT: perfective
  - LEXICAL ASPECT: [+/- telic] — [state]
  - TIMEX TYPE: TIME
  - TIMEX QUANTIFIED: No
  - TIMEX Ontological status: INTERVAL

Moreover, from the analysis of the data two other constructions have emerged, the first of the kind "A + TEMPORAL EXPRESSION + DA + EVENTUALITY" and the second when it occurs in conjunction with DA in constructions of the kind "EVENTUALITY + DA + TEMPORAL EXPRESSION + A + TEMPORAL EXPRESSION". Both types of constructions activate two different meanings, i.e. temporal relations, of the signal A. In particular, for constructions of the type "A + TEMPORAL EXPRESSION + DA + EVENTUALITY", we will have

- AFTER
  - TENSE: none;
  - VIEWPOINT: none
  - LEXICAL ASPECT: none
  - TIMEX TYPE: DURATION
  - TIMEX QUANTIFIED: No — Yes
  - TIMEX Ontological status: INTERVAL

On the contrary, when it is in conjunction with DA, i.e. "EVENTUALITY + DA + TEMPORAL EXPRESSION + A + TEMPORAL EXPRESSION", we will have:

- ENDS — IS_ENDED
  - TENSE: every;
  - VIEWPOINT: perfective — imperfective$_{habitual}$
  - LEXICAL ASPECT: [-telic] — [state$_{temporary}$]
  - TIMEX TYPE: DATE — TIME
  - TIMEX QUANTIFIED: No — Yes
  - TIMEX Ontological status: INSTANT — INTERVAL

A.3.4 DA

DA seems to qualify for a unique value, namely BEGIN (IS_BEGUN). Nevertheless, this value is strictly dependent on the features settings, mainly those for the eventuality. Thus, we will have:

- BEGIN— IS_BEGUN
  - TENSE: every;
  - VIEWPOINT: perfective — imperfective
  - LEXICAL ASPECT: [-telic] — [state$_{temporary}$]
  - TIMEX TYPE: DATE — TIME
  - TIMEX QUANTIFIED: No
  - TIMEX Ontological status: INTERVAL
- BEGIN— IS_BEGUN
  - TENSE: every;
  - VIEWPOINT: perfective — imperfective
  - LEXICAL ASPECT: [-telic] — [state$_{temporary}$]
  - TIMEX TYPE: DURATION
  - TIMEX QUANTIFIED: No — Yes
  - TIMEX Ontological status: INTERVAL
- No Temp. Relation
  - TENSE: past;
  - VIEWPOINT: perfect
  - LEXICAL ASPECT: [+telic]
  - TIMEX TYPE: DURATION
  - TIMEX QUANTIFIED: No — Yes
  - TIMEX Ontological status: INTERVAL
- No Temp. Relation
  - TENSE: past;
  - VIEWPOINT: perfect
  - LEXICAL ASPECT: [+telic]
  - TIMEX TYPE: DATE — TIME
  - TIMEX QUANTIFIED: No
  - TIMEX Ontological status: INTERVAL
- BEGIN— IS_BEGUN
  - TENSE: past;
  - VIEWPOINT: perfect

- LEXICAL ASPECT: [+telic$_{contingentstate}$]
- TIMEX TYPE: DATE — TIME — DURATION
- TIMEX QUANTIFIED: No — Yes
- TIMEX Ontological status: INTERVAL

In constructions with telic eventualities at the perfect viewpoint, there is no direct temporal relation between the moment of reference of the event , i.e. the *Rpt*, and the temporal expression since the temporal expression offers a measure of the temporal distance between the moment in which the event has taken place and the moment of utterance, thus we have assigned the value "No Temp. Relation". On the contrary, there is a temporal relation between the contingent states of these events and the temporal expressions, and an **inferred** temporal relations of EQUALS in case that the telic event is an accomplishment. In TimeML this value of the DA signal can be represented by means of the attribute `temporalDistance`.

When it is in conjunction with A, in constructions of the kind "EVENTUALITY + DA + TEMPORAL EXPRESSION + A + TEMPORAL EXPRESSION", we will have:

- BEGIN— IS_BEGUN
  - TENSE: every;
  - VIEWPOINT: perfective — imperfective$_{habitual}$
  - LEXICAL ASPECT: [-telic] — [state$_{temporary}$]
  - TIMEX TYPE: DATE — TIME
  - TIMEX QUANTIFIED: No — Yes
  - TIMEX Ontological status: INSTANT — INTERVAL

We claim that in constructions of the kind "A + TEMPORAL EXPRESSION + DA + EVENTUALITY", provided the fact that A is always followed by an interval, the eventuality introduced by DA represents the starting point of the interval, but no specific temporal relation can be identified between DA and the following eventuality.

A.3.5 DI

This signal has very few occurrences in type of construction we have analyzed and presents the highest variability of meaning with respect to all the others. The values identified are the following:

- INCLUDES — IS_INCLUDED
  - TENSE: past — imperfect — present;
  - VIEWPOINT: perfective — imperfective
  - LEXICAL ASPECT: [+/-telic]
  - TIMEX TYPE: DATE — DURATION
  - TIMEX QUANTIFIED: No
  - TIMEX Ontological status: INTERVAL
- DURING — DURING_INV

- TENSE: past — imperfect — present;
- VIEWPOINT: perfective — imperfective
- LEXICAL ASPECT: [state]
- TIMEX TYPE: DATE — DURATION
- TIMEX QUANTIFIED: No
- TIMEX Ontological status: INTERVAL

• BEGIN — IS_BEGUN

- TENSE: future;
- VIEWPOINT: perfective
- LEXICAL ASPECT: [state]
- TIMEX TYPE: TIME
- TIMEX QUANTIFIED: No
- TIMEX Ontological status: INTERVAL

A.3.6 TRA/FRA

Similarly to DA and A, these two signals have a very regular behavior. In most cases these signals appears in connection with the conjunction "*e*" [and] followed by a temporal expression. In these cases, there are two possible values which they can assume:

• BEGIN — IS_BEGUN

- TENSE: every;
- VIEWPOINT: perfective — imperfective
- LEXICAL ASPECT: [-telic] — [state]
- TIMEX TYPE: DATE — TIME
- TIMEX QUANTIFIED: No
- TIMEX Ontological status: INTERVAL — INSTANT

• INCLUDES— IS_INCLUDED

- TENSE: every;
- VIEWPOINT: perfective — imperfective
- LEXICAL ASPECT: [+telic]
- TIMEX TYPE: DATE — TIME
- TIMEX QUANTIFIED: No
- TIMEX Ontological status: INTERVAL — INSTANT

When they occur in isolation, on the basis of the data collected, they have a unique value, namely AFTER:

• AFTER

- TENSE: future;
- VIEWPOINT: perfective
- LEXICAL ASPECT: [+/-telic] — [state]
- TIMEX TYPE: DURATION
- TIMEX QUANTIFIED: Yes
- TIMEX Ontological status: INTERVAL

A.3.7 ENTRO

As for the temporal relations, i.e. meanings, of ENTRO, TimeML does not offer the correct values for this signal. Consider this sentence:

(A.1) E' possibile prenotare tale servizio **telefonando** all'ATL entro *domani*.
It is possible to reserve this service by calling the ATL by tomorrow.

In these case, when "*entro*" is followed by a temporal expression having the ontological status of an interval, it cannot be interpreted as a pure precedence relation but it is a precedence relation which may coincide with the ending point of the interval itself, i.e. before the end of the interval including its ending point. To represent this intrinsic ambiguity of the signal ENTRO when followed by an interval temporal expression we have adopted Freska (1992)'s coarse grained relation of YOUNGER and OLDER since they best represent its semantics. Thus, we have obtained:

- YOUNGER
  - TENSE: future;
  - VIEWPOINT: imperfective
  - LEXICAL ASPECT: [state]
  - TIMEX TYPE: DURATION — DATE — TIME
  - TIMEX QUANTIFIED: Yes — No
  - TIMEX Ontological status: INTERVAL — INSTANT
- OLDER
  - TENSE: every;
  - VIEWPOINT: perfective — imperfective
  - LEXICAL ASPECT: [+/- telic]
  - TIMEX TYPE: DATE — TIME — DURATION
  - TIMEX QUANTIFIED: No — Yes
  - TIMEX Ontological status: INTERVAL
- BEFORE
  - TENSE: every;
  - VIEWPOINT: perfective — imperfective
  - LEXICAL ASPECT: [+/- telic]
  - TIMEX TYPE: TIME
  - TIMEX QUANTIFIED: No
  - TIMEX Ontological status: INSTANT

A.3.8 Temporal Movement Events and Implicit Signals with Eventualities

Interesting data have emerged for the class of Temporal Movement Events i.e the subset of verbs or nominal events which express a temporal relation, e.g. *prevedere* [to schedule/to forsee], *anticipare* [to anticipate], *postporre* [to postpone], *ritardare* [to delay], *aggiornare* [to postpone/to update] and similar. In these cases we claim that the when followed by a temporal PP the preposition does not qualify as a signal but as a particle pre-selected by the verb. With this particular class of verbs the inferred temporal relation does not hold between the verbal (or nominal) event and the temporal expression but between its eventive argument and the temporal expression. In support to this claim, consider the following examples, extracted from the data set; in bold we have marked the eventive argument which has a temporal relation with the temporal expression:

(A.2) Il programma di riforestazione di questa area prevede nei *prossimi quattro anni* **la piantumazione** di altri alberi.

The reforestation program of this area forsees the planting of other trees in the next four years.

(A.3) Il primo **euroappuntamento** importante del 1998 e' fissato in *marzo*.

The first important eurometing is scheduled in March.

(A.4) Confermata **la giornata di campionato** dell'8 giugno che lui aveva chiesto di anticipare di *almeno ventiquattr' ore*.

It has been confirmed the major league turn of June 8th which he had asked to anticipate of 24 hours.

In addition to this, we have also considered those constructions involving polysyllabic temporal signals which have been classified as semantically implicit, namely *quando* [when] and *appena* [as soon as]. In these cases we are dealing with two eventualities. In Table A.3 we report their values and constraints.

Table A.3: *Appendix A: Implicit signals' semantics.*

Signal	**Tense Constraint**	**Viewpoint Aspect sub. clause**	**Viewpoint Aspect main clause**	**Temporal Relation**
quando	same tense	perfective	perfective	SIMULTANEOUS
quando	main clause at *Trapassato I*	perfective	perfective	AFTER
quando	same tense	imperfective	imperfective	SIMULTANEOUS
quando	same tense	habitual	habitual	AFTER
quando	different tenses	perfective	imperfective	INCLUDES
(non) appena	same tense	perfective	perfective	SIMULTANEOUS

A working hypothesis which needs further study and data is that of extending the values identified for the temporal prepositions to constructions of the kind "EVENTUALITY + IMPLICIT SIGNAL + EVENTUALITY". In these cases, we suggest that the features identified for the temporal expressions, in particular the ontological status, should be extended to the second eventuality, provided the fact that interval temporal expressions can be mapped to states and durative events and instants to non durative ones.

Appendix B

TETI Rules

In this annex we illustrate the set of rules implemented in the tagger of temporal expressions. Each rule is followed by some examples of the temporal expression(s) which is able to recognize and bracket. It is important to remember that the tagger applies every rule until it has not identified the one with the correct conditions (COND) (depth-first search). Only when the correct conditions has been identified, it creates the TIMEX3.

```
POTGOV_lemma equals lextrigger
  then ((GET GRAN) and (GET DEFAULT TYPE)
        then
        APPLY RULES

R1     COND
         (and (POTGOV_lemma equals DATE PATTERN)
         (not (POTGOV_lemma CHUNK-1 equals modiftrigger))
         (or (not(POTGOV_lemma CHUNK+1 equals lextrigger))
              (not (POTGOV_lemma CHUNK+1 equals modiftrigger)))
          )
              then
             CREATE TIMEX3_tag
             (and (BEGIN_AT POTGOV)
                     (END_AT POTGOV))
```

Examples:

- $29/06/2006_{DATEPATTERN}$;
- $25\text{-}05\text{-}94_{DATEPATTERN}$;
- $'94_{DATEPATTERN}$
- $1994_{DATEPATTERN}$
- il $1995_{DATEPATTERN}$

```
R2     COND
         (and (POTGOV_lemma equals TIME PATTERN)
         (not (POTGOV_lemma CHUNK-1 equals modiftrigger))
         (or (not(POTGOV_lemma CHUNK+1 equals lextrigger))
         (not (POTGOV_lemma CHUNK+1 equals modiftrigger)))
```

```
        )
              then
             CREATE TIMEX3_tag
             (and (BEGIN_AT POTGOV)
                     (END_AT POTGOV))
```

Examples:

- 11:30$_{TIMEPATTERN}$;
- 12.00$_{TIMEPATTERN}$;
- 11 e 30$_{TIMEPATTERN}$

```
R3    COND
       (and
             (or (POTGOV_CHUNK equals N_C)
             (POTGOV_CHUNK equals ADV_C)
             (POTGOV_CHUNK equals ADJ_C))
             (not (POTGOV_CHUNK has PREMODIF))
             (not (POTGOV_lemma CHUNK-1 equals modiftrigger))
             (or (not(POTGOV_lemma CHUNK+1 equals lextrigger))
             (not (POTGOV_lemma CHUNK+1 equals modiftrigger)))
        )
         then
        CREATE TIMEX3_tag
        (and(BEGIN_AT B_CHUNK)
                (END_AT E_CHUNK))
```

Examples:

- sabato$_{N_C}$;
- maggio$_{N_C}$;
- annuale$_{ADJ_C}$
- ieri$_{ADV_C}$
- la mattina$_{N_C}$

```
R6    COND
       (and
             (or (POTGOV_CHUNK equals P_C)
                  (POTGOV_CHUNK equals DI_C)
                  (POTGOV_lemma equals TIME PATTERN)
                  (POTGOV_lemma equals DATE PATTERN))
             (not (POTGOV_CHUNK has PREMODIF))
             (not (POTGOV_lemma CHUNK-1 equals modiftrigger))
             (not (POTGOV_lemma CHUNK+1 equals lextrigger))
             (not (POTGOV_lemma CHUNK+1 equals modiftrigger))
        )
         then
```

```
        CREATE TIMEX3_tag
        (and
              (or (BEGIN_AT DET)
                   (BEGIN_AT POTGOV))
                   (END_AT POTGOV))
     CREATE SIGNAL_tag)
    (and (BEGIN_AT PREP)
             (END_AT PREP))
```

Examples:

- da domani$_{P_C}$;
- da un anno$_{P_C}$;
- di ieri$_{DI_C}$
- a mezzanotte$_{P_C}$
- entro la mattina$_{P_C}$
- dal 1993$_{DATEPATTERN}$
- delle 13:00$_{DI_C}$
- nel '94$_{DATEPATTERN}$
- di agosto$_{DI_C}$

```
R7 COND
     (and
             (POTGOV_CHUNK equals N_C)
             (POTGOV_CHUNK has PREMODIF)
           (COND
                 ((PREMODIF_POTGOV_CHUNK equals modiftrigger)
                       then
                   (GET INFO_NORMALIZATION
                    GET TIMEML_MOD_ATTRIBUTE
                    GET TIMEML_BEGINPOINT_ATTRIBUTE
                    GET TIMEML_ENDPOINT_ATTRIBUTE
                    GET TR_RESPECT_TO ANCHOR))
                    T)
        (not (POTGOV_lemma CHUNK-1 equals modiftrigger))
       (not (POTGOV_lemma CHUNK+1 equals lextrigger))
       (not (POTGOV_lemma CHUNK+1 equals modiftrigger))
       )
         then
         CREATE TIMEX3_tag
        (and (BEGIN_AT B_CHUNK)
                 (END_AT E_CHUNK))
```

Examples

- tre notti$_{N_C}$;
- un bel lunedì$_{N_C}$;
- tutte le mattine$_{N_C}$
- 30 giugno$_{N_C}$
- il 30 giugno$_{N_C}$

```
R10 COND
       (and
             (or (POTGOV_CHUNK equals P_C)
                   (POTGOV_CHUNK equals DI_C))
             (POTGOV_CHUNK has PREMODIF)
             (COND
             ((PREMODIF_POTGOV_CHUNK equals modiftrigger)
                then
                     (GET INFO_NORMALIZATION
                     GET TIMEML_MOD_ATTRIBUTE
                     GET TIMEML_BEGINPOINT_ATTRIBUTE
                     GET TIMEML_ENDPOINT_ATTRIBUTE
                     GET TR_RESPECT_TO ANCHOR))
                     T)
          (not (POTGOV_lemma CHUNK-1 equals modiftrigger))
          (or (not (POTGOV_lemma CHUNK+1 equals lextrigger))
               (not (POTGOV_lemma CHUNK+1 equals modiftrigger)))
        )
        then
        CREATE TIMEX3_tag
        (and
        (or (BEGIN_AT DET)
             (BEGIN_AT POTGOV))
             (END_AT POTGOV))
      CREATE SIGNAL_tag
      (and (BEGIN_AT PREP)
               (END_AT PREP))
```

Examples

- da tre notti$_{P_C}$;
- di un bel lunedì$_{DI_C}$;
- entro quest'anno$_{P_C}$
- dal 30 giugno$_{P_C}$
- del 30 giugno$_{DI_C}$
- di tre giorni$_{DI_C}$

```
R17 COND
            (and
            (not (POTGOV_lemma CHUNK-1 equals modiftrigger))
            ((POTGOV_lemma CHUNK+1 equals modiftrigger)
                         then
                        (GET  TIMEML_MOD_ATTRIBUTE
                         GET TIMEML_BEGINPOINT_ATTRIBUTE
                         GET TIMEML_ENDPOINT_ATTRIBUTE
                         GET TR_RESPECT_TO_ ANCHOR ))
            (COND
             ((PREMODIF_POTGOV_CHUNK equals modiftrigger)
                then
                     (GET INFO_NORMALIZATION
                     GET TIMEML_MOD_ATTRIBUTE
                     GET TIMEML_BEGINPOINT_ATTRIBUTE
                     GET TIMEML_ENDPOINT_ATTRIBUTE
                     GET TR_RESPECT_TO ANCHOR))
                     T)
              (POTGOV_CHUNK equals N_C)
              (or (POTGOV_CHUNK+1 equals ADJ_C)
                    (POTGOV_CHUNK+1 equals ADV_C)
                    (POTGOV_CHUNK+1 equals P_C)
                    (POTGOV_CHUNK+1 equals DI_C))
              )
              then
              CREATE TIMEX3_tag
              (and
                     (BEGIN_AT B_CHUNK)
                     (END_AT POTGOV_CHUNK+1))
```

Examples

- tre giorni$_{N_C}$ fa$_{ADV_C}$
- la bella estate$_{N_C}$ scorsa$_{ADJ_C}$;
- il 3 aprile$_{N_C}$ prossimo$_{ADJ_C}$
- due giorni$_{N_C}$ al massimo$_{P_C}$
- tre giorni$_{N_C}$ di seguito$_{DI_C}$

```
R18 COND
       (and
       (not (POTGOV_lemma CHUNK-1 equals modiftrigger))
       ((POTGOV_lemma CHUNK+1 equals modiftrigger)
                           then
                        (GET INFO_NORMALIZATION
                         GET  TIMEML_MOD_ATTRIBUTE
                         GET TIMEML_BEGINPOINT_ATTRIBUTE
                         GET TIMEML_ENDPOINT_ATTRIBUTE
```

```
                    GET TR_RESPECT_TO_ ANCHOR ))
    (not (POTGOV_CHUNK has PREMODIF))
    (POTGOV_CHUNK equals N_C)
    (or (POTGOV_CHUNK+1 equals ADJ_C)
         (POTGOV_CHUNK+1 equals ADV_C))
    then
    CREATE TIMEX3_tag
    (and
           (BEGIN_AT B_CHUNK)
           (END_AT POTGOV_CHUNK+1))
```

Examples

- i giorni$_{N_C}$ passati$_{ADJ_C}$
- un anno$_{N_C}$ fa$_{ADV_C}$;
- l'anno$_{N_C}$ prossimo$_{ADJ_C}$

```
R21 COND
        (and
        (not (POTGOV_lemma CHUNK-1 equals modiftrigger))
        ((POTGOV_lemma CHUNK+1 equals lextrigger)
                           then
                        (GET GRAN
                         GET DEFAULT TYPE))
         (COND
         ((PREMODIF_POTGOV_CHUNK equals modiftrigger)
                     then
                     (GET INFO_NORMALIZATION
                     GET TIMEML_MOD_ATTRIBUTE
                     GET TIMEML_BEGINPOINT_ATTRIBUTE
                     GET TIMEML_ENDPOINT_ATTRIBUTE
                     GET TR_RESPECT_TO ANCHOR))
                     T)
        (or  (POTGOV_CHUNK+1 equals N_C)
              (POTGOV_CHUNK+1 equals ADV_C)
              (POTGOV_lemma CHUNK+1 equals DATE PATTERN))
       (not (POTGOV_CHUNK+1 has PREMODIF))
       (POTGOV_CHUNK equals N_C)
       (COND
                1((and (equals (SEM_RELATION POTGOV_CHUNK)
                              (has_as_part (LEXTRIG_CIBLE POTGOV_CHUNK+1))


                      (equals (DEFAULT_TYPE POTGOV_CHUNK)DATE))
                      (or (equals (DEFAULT_TYPE POTGOV_CHUNK+1) DATE))
                          (equals (DEFAULT TYPE POTGOV_CHUNK+1) TIME)))

                          then
                           CREATE TIMEX3
```

```
                    (and (BEGIN_AT B_POTGOV_CHUNK)
                         (END_AT E_POTGOV_CHUNK+1)))
                 2 (( and (CREATE TIMEX3
                    (and  (BEGIN_AT B_POTGOV_CHUNK)
                          (END_AT E_POTGOV_CHUNK))
                    (and  (BEGIN_AT B_POTGOV_CHUNK+1)
                            (END_AT E_POTGOV_CHUNK+1))
                   )))
```

Examples

- giovedì$_{N_C}$ sera$_{N_C}$
- ieri$_{ADV_C}$ sera$_{N_C}$
- (il semestre$_{N_C}$)$_{TIMEX3R3}$ (giugno$_{N_C}$)$_{TIMEX3R3}$ (- dicembre)
- (il periodo$_{N_C}$)$_{TIMEX3R3}$ ('92)$_{DATEPATTERNR1}$ (- '93)

```
R21_2RULE1 COND
                      (and
                      (not (POTGOV_lemma CHUNK-1 equals modiftrigger))
                      ((POTGOV_lemma CHUNK+1 equals lextrigger)
                           then
                           (GET GRAN
                             GET DEFAULT TYPE))
                     (COND
                     ((PREMODIF_POTGOV_CHUNK equals modiftrigger)
                               then
                               (GET INFO_NORMALIZATION
                                GET TIMEML_MOD_ATTRIBUTE
                                GET TIMEML_BEGINPOINT_ATTRIBUTE
                                GET TIMEML_ENDPOINT_ATTRIBUTE
                                GET TR_RESPECT_TO ANCHOR))
                                T)
                     (or (POTGOV_CHUNK+1 equals N_C)
                           (POTGOV_CHUNK+1 equals ADV_C)
                           (POTGOV_lemma CHUNK+1 equals DATE PATTERN))
                     (not (POTGOV_CHUNK+1 has PREMODIF))
                    (or (POTGOV_CHUNK equals P_C)
                          (POTGOV_CHUNK equals DI_C))
       (COND
                1((and (equals (SEM_RELATION POTGOV_CHUNK)
                              (has_as_part (LEXTRIG_CIBLE POTGOV_CHUNK+1))
                    (equals (DEFAULT_TYPE POTGOV_CHUNK)DATE))
                    (or (equals (DEFAULT_TYPE POTGOV_CHUNK+1) DATE))
                          (equals (DEFAULT TYPE POTGOV_CHUNK+1) TIME)))

                         then
                         CREATE TIMEX3
                         (and (BEGIN_AT B_POTGOV_CHUNK)
```

```
                                (END_AT E_POTGOV_CHUNK+1))
                       CREATE SIGNAL_tag
                       (and (BEGIN_AT PREP_POTGOV_CHUNK)
                               (END_AT PREP_POTGOV_CHUNK)))
                      2 ( CREATE TIMEX3
                          (and (BEGIN_AT B_POTGOV_CHUNK)
                                  (END_AT E_POTGOV_CHUNK))
                          (and (BEGIN_AT B_POTGOV_CHUNK+1)
                                   (END_AT E_POTGOV_CHUNK+1))
                         (CREATE SIGNAL_tag
                          (and (BEGIN_AT PREP_POTGOV_CHUNK)
                                  (END_AT PREP_POTGOV_CHUNK))))
```

Examples:

- di giovedì$_{DI_C}$ sera$_{N_C}$
- per domani$_{P_C}$ sera$_{N_C}$

```
R21_b COND
           (and
           (not (POTGOV_lemma CHUNK-1 equals modiftrigger))
           ((POTGOV_lemma CHUNK+1 equals lextrigger)
                            then
                            (GET GRAN
                            GET DEFAULT TYPE))
         (not (POTGOV_CHUNK has PREMODIF))
         (POTGOV_CHUNK equals N_C)
         (POTGOV_CHUNK+1 equals N_C)
         (and (POTGOV_CHUNK+1 has PREMODIF)
                 (PREMODIF_POTGOV_CHUNK+1 equals modiftrigger)
                        then
                        (GET INFO_NORMALIZATION
                         GET  TIMEML_MOD_ATTRIBUTE
                         GET TIMEML_BEGINPOINT_ATTRIBUTE
                         GET TIMEML_ENDPOINT_ATTRIBUTE
                         GET TR_RESPECT_TO_ ANCHOR )
           )
       (COND
               1((and (equals (SEM_RELATION POTGOV_CHUNK)
                              (is_a_part_of (LEXTRIG_CIBLE POTGOV_CHUNK+1))
                   (equals (DEFAULT_TYPE POTGOV_CHUNK)DATE))
                   (equals (DEFAULT_TYPE POTGOV_CHUNK+1) DATE))

                        then
                        CREATE TIMEX3
                        (and (BEGIN_AT B_POTGOV_CHUNK)
                                (END_AT E_POTGOV_CHUNK+1))
                      2 ( CREATE TIMEX3
                          (and (BEGIN_AT B_POTGOV_CHUNK)
```

```
                              (END_AT E_POTGOV_CHUNK))
                      (and (BEGIN_AT B_POTGOV_CHUNK+1)
                               (END_AT E_POTGOV_CHUNK+1)))
```

Examples

- martedì$_{N_C}$ cinque luglio$_{N_C}$
- 1 gennaio$_{N_C}$ 1993$_{DATEPATTERN}$

```
R23 COND
        (and
        (not (POTGOV_lemma CHUNK-1 equals modiftrigger))
         ((POTGOV_lemma CHUNK+1 equals lextrigger)
                              then
                             (GET GRAN
                             GET DEFAULT TYPE))
         (not (POTGOV_CHUNK has PREMODIF))
         (or (POTGOV_CHUNK equals P_C)
               (POTGOV_CHUNK equals DI_C))
         (POTGOV_CHUNK+1 equals N_C)
         (and (POTGOV_CHUNK+1 has PREMODIF)
                 (PREMODIF_POTGOV_CHUNK+1 equals modiftrigger)
                         then
                         (GET INFO_NORMALIZATION
                          GET  TIMEML_MOD_ATTRIBUTE
                          GET TIMEML_BEGINPOINT_ATTRIBUTE
                          GET TIMEML_ENDPOINT_ATTRIBUTE
                          GET TR_RESPECT_TO_ ANCHOR )
          )
       (COND
                1((and (equals (SEM_RELATION POTGOV_CHUNK)
                              (is_a_part_of (LEXTRIG_CIBLE POTGOV_CHUNK+1))
                    (equals (DEFAULT_TYPE POTGOV_CHUNK)DATE))
                    (equals (DEFAULT_TYPE POTGOV_CHUNK+1) DATE)))

                         then
                         CREATE TIMEX3
                         (and (BEGIN_AT B_POTGOV_CHUNK)
                                (END_AT E_POTGOV_CHUNK+1))
                        CREATE SIGNAL_tag
                        (and (BEGIN_AT PREP_POTGOV_CHUNK)
                               (END_AT PREP_POTGOV_CHUNK)))
                       2 ( CREATE TIMEX3
                           (and (BEGIN_AT B_POTGOV_CHUNK)
                                   (END_AT E_POTGOV_CHUNK))
                           (and (BEGIN_AT B_POTGOV_CHUNK+1)
                                    (END_AT E_POTGOV_CHUNK+1))
                          (CREATE SIGNAL_tag
                           (and (BEGIN_AT PREP_POTGOV_CHUNK)
```

```
                              (END_AT PREP_POTGOV_CHUNK))))
```

Examples

- in data$_{P_C}$ cinque luglio$_{N_C}$
- di martedì$_{DI_C}$ cinque luglio$_{N_C}$

```
R24_1 COND
           (and
            ((POTGOV_lemma CHUNK-1 equals modiftrigger)
                           then
                        (GET INFO_NORMALIZATION
                         GET  TIMEML_MOD_ATTRIBUTE
                         GET TIMEML_BEGINPOINT_ATTRIBUTE
                         GET TIMEML_ENDPOINT_ATTRIBUTE
                         GET TR_RESPECT_TO_ ANCHOR ))
           (not (POTGOV_CHUNK+1 equals modiftrigger))
           (not (POTGOV_CHUNK+1 equals lextrigger))
           (or (POTGOV_CHUNK-1 equals P_C)
                 (POTGOV_CHUNK-1 equals DI_C))
           (not (POTGOV_CHUNK-1 has PREMODIF))
           (or (POTGOV_CHUNK equals N_C)
                 (POTGOV_CHUNK equals P_C)
                 (POTGOV_CHUNK equals DI_C)
                 (POTGOV_lemma equals DATE PATTERN))
           (not (POTGOV_CHUNK has PREMODIF)))
            then
            CREATE TIMEX3_tag
            (and
                  (or (BEGIN_AT DET_POTGOV_CHUNK-1)
                        (BEGIN_AT POTGOV_CHUNK-1))
                        (END_AT E_CHUNK))
            CREATE SIGNAL_tag
            (and (BEGIN_AT PREP_POTGOV_CHUNK-1)
                     (END_AT PREP_POTGOV_CHUNK-1))
```

Examples

- a fine$_{P_C}$ giugno$_{N_C}$
- entro la fine$_{P_C}$ del 1994$_{DATEPATTERN}$
- al massimo$_{P_C}$ per domani$_{P_C}$
- dell'inizio$_{DI_C}$ settimana$_{N_C}$
- a metà$_{DI_C}$ settimana$_{N_C}$
- all'inizio$_{P_C}$ dell'anno$_{DI_C}$
- da appena$_{P_C}$ un anno$_{N_C}$

- all'inizio$_{P_C}$ del 1950$_{DATEPATTERN}$
- a fine$_{P_C}$ '92$_{DATEPATTERN}$

```
R24_2 COND
           (and
            ((POTGOV_lemma CHUNK-1 equals modiftrigger)
                           then
                        (GET INFO_NORMALIZATION
                         GET  TIMEML_MOD_ATTRIBUTE
                         GET TIMEML_BEGINPOINT_ATTRIBUTE
                         GET TIMEML_ENDPOINT_ATTRIBUTE
                         GET TR_RESPECT_TO_ ANCHOR ))
           (not (POTGOV_CHUNK+1 equals modiftrigger))
           (not (POTGOV_CHUNK+1 equals lextrigger))
           (or (POTGOV_CHUNK-1 equals P_C)
                 (POTGOV_CHUNK-1 equals DI_C))
           (not (POTGOV_CHUNK-1 has PREMODIF))
           (or  (POTGOV_CHUNK equals N_C)
                 (POTGOV_CHUNK equals DI_C))
          (COND
          ((PREMODIF_POTGOV_CHUNK equals modiftrigger)
                then
                     (GET INFO_NORMALIZATION
                     GET TIMEML_MOD_ATTRIBUTE
                     GET TIMEML_BEGINPOINT_ATTRIBUTE
                     GET TIMEML_ENDPOINT_ATTRIBUTE
                     GET TR_RESPECT_TO ANCHOR))
                     T)
            then
            CREATE TIMEX3_tag
            (and
                  (or (BEGIN_AT DET_POTGOV_CHUNK-1)
                        (BEGIN_AT POTGOV_CHUNK-1))
                        (END_AT E_CHUNK))
            CREATE SIGNAL_tag
            (and (BEGIN_AT PREP_POTGOV_CHUNK-1)
                     (END_AT PREP_POTGOV_CHUNK-1))
```

- alla fine$_{P_C}$ del primo semestre$_{DI_C}$
- entro la fine$_{P_C}$ di quest'anno$_{DI_C}$
- dall'inizio$_{P_C}$ del caldo autunno$_{DI_C}$
- da appena$_{P_C}$ due giorni$_{N_C}$
- da meno$_{P_C}$ di due giorni$_{DI_C}$

```
R24_3 COND
           (and
```

```
 ((POTGOV_lemma CHUNK-1 equals modiftrigger)
               then
            (GET INFO_NORMALIZATION
             GET  TIMEML_MOD_ATTRIBUTE
             GET TIMEML_BEGINPOINT_ATTRIBUTE
             GET TIMEML_ENDPOINT_ATTRIBUTE
             GET TR_RESPECT_TO_ ANCHOR ))
(not (POTGOV_CHUNK+1 equals modiftrigger))
(not (POTGOV_CHUNK+1 equals lextrigger))
(POTGOV_CHUNK-1 equals N_C)
(not (POTGOV_CHUNK-1 has PREMODIF))
(or (POTGOV_CHUNK equals DI_C)
      (POTGOV_lemma equals DATE PATTERN))
(not (POTGOV_CHUNK has PREMODIF))
 then
 CREATE TIMEX3_tag
 (and
       (or (BEGIN_AT DET_POTGOV_CHUNK-1)
             (BEGIN_AT POTGOV_CHUNK-1))
             (END_AT E_CHUNK))
```

- la fine$_{N_C}$ dell'anno$_{DI_C}$
- l'inizio$_{N_C}$ del 1995$_{DATEPATTERN}$

```
R24_4 COND
           (and
            ((POTGOV_lemma CHUNK-1 equals modiftrigger)
                          then
                       (GET INFO_NORMALIZATION
                        GET  TIMEML_MOD_ATTRIBUTE
                        GET TIMEML_BEGINPOINT_ATTRIBUTE
                        GET TIMEML_ENDPOINT_ATTRIBUTE
                        GET TR_RESPECT_TO_ ANCHOR ))
           (not (POTGOV_CHUNK+1 equals modiftrigger))
           (not (POTGOV_CHUNK+1 equals lextrigger))
           (POTGOV_CHUNK-1 equals N_C)
           (not (POTGOV_CHUNK-1 has PREMODIF))
           (or (POTGOV_CHUNK equals DI_C)
                 (POTGOV_lemma equals DATE PATTERN))
          (COND
          ((PREMODIF_POTGOV_CHUNK equals modiftrigger)
                then
                     (GET INFO_NORMALIZATION
                     GET TIMEML_MOD_ATTRIBUTE
                     GET TIMEML_BEGINPOINT_ATTRIBUTE
                     GET TIMEML_ENDPOINT_ATTRIBUTE
                     GET TR_RESPECT_TO ANCHOR))
                     T)
            then
```

```
          CREATE TIMEX3_tag
          (and
                (or (BEGIN_AT DET_POTGOV_CHUNK-1)
                      (BEGIN_AT POTGOV_CHUNK-1))
                      (END_AT E_CHUNK))
```

- la fine$_{N_C}$ dello scorso anno$_{DI_C}$
- l'inizio$_{N_C}$ del caldo 1995$_{DATEPATTERN}$
- la metà$_{N_C}$ del secondo trimestre$_{DI_C}$

```
R24_5 COND
           (and
            ((POTGOV_lemma CHUNK-1 equals modiftrigger)
                            then
                         (GET INFO_NORMALIZATION
                          GET  TIMEML_MOD_ATTRIBUTE
                          GET TIMEML_BEGINPOINT_ATTRIBUTE
                          GET TIMEML_ENDPOINT_ATTRIBUTE
                          GET TR_RESPECT_TO_ ANCHOR ))
           (not (POTGOV_CHUNK+1 equals modiftrigger))
           (not (POTGOV_CHUNK+1 equals lextrigger))
           (POTGOV_CHUNK-1 equals ADV_C)
           (COND
            ((PREMODIF_POTGOV_CHUNK-1 equals modiftrigger)
                            then
                         (GET INFO_NORMALIZATION
                          GET  TIMEML_MOD_ATTRIBUTE
                          GET TIMEML_BEGINPOINT_ATTRIBUTE
                          GET TIMEML_ENDPOINT_ATTRIBUTE
                          GET TR_RESPECT_TO_ ANCHOR ))
                    T)
           (or (POTGOV_CHUNK equals N_C)
                (POTGOV_CHUNK equals DI_C))
           (COND
            ((PREMODIF_POTGOV_CHUNK equals modiftrigger)
                            then
                         (GET INFO_NORMALIZATION
                          GET  TIMEML_MOD_ATTRIBUTE
                          GET TIMEML_BEGINPOINT_ATTRIBUTE
                          GET TIMEML_ENDPOINT_ATTRIBUTE
                          GET TR_RESPECT_TO_ ANCHOR ))
                    T)
            then
            CREATE TIMEX3_tag
            (and (BEGIN_AT POTGOV_CHUNK-1))
                    (END_AT E_CHUNK))
```

Examples:

- almeno_{ADV_C} un anno_{N_C}
- quasi_{ADV_C} ogni anno_{N_C}
- meno_{ADV_C} di un giorno_{DI_C}
- non più_{ADV_C} di un anno_{DI_C}
- almeno_{ADV_C} due anno_{N_C}
- quasi_{ADV_C} tutti gli anno_{N_C}
- appena_{ADV_C} due giorni_{N_C}
- meno_{ADV_C} di due anni_{DI_C}
- non meno_{ADV_C} di due giorni_{DI_C}
- non più_{ADV_C} di due mesi_{DI_C}

```
R29 COND
       (and
       ((POTGOV_lemma CHUNK-1 equals modiftrigger)
                           then
                          (GET INFO_NORMALIZATION
                          GET  TIMEML_MOD_ATTRIBUTE
                          GET TIMEML_BEGINPOINT_ATTRIBUTE
                          GET TIMEML_ENDPOINT_ATTRIBUTE
                          GET TR_RESPECT_TO_ ANCHOR ))
         (or (POTGOV_CHUNK-1 equals P_C)
               (POTGOV_CHUNK-1 equals DI_C))
          (COND
          ((PREMODIF_POTGOV_CHUNK-1 equals modiftrigger)
                           then
                         (GET INFO_NORMALIZATION
                          GET  TIMEML_MOD_ATTRIBUTE
                          GET TIMEML_BEGINPOINT_ATTRIBUTE
                          GET TIMEML_ENDPOINT_ATTRIBUTE
                          GET TR_RESPECT_TO_ ANCHOR ))
                    T)
      ((POTGOV_lemma CHUNK+1 equals lextrigger)
                      then
                     (GET GRAN
                     GET DEFAULT TYPE))
      (or (POTGOV_CHUNK+1 equals DI_C)
            (POTGOV_lemma CHUNK+1 equals DATE PATTERN))
      (not (POTGOV_CHUNK+1 has PREMODIF)
      (POTGOV_CHUNK equals DI_C)
      (COND
      ((PREMODIF_POTGOV_CHUNK equals modiftrigger)
                         then
                        (GET INFO_NORMALIZATION
```

```
                  GET  TIMEML_MOD_ATTRIBUTE
                  GET TIMEML_BEGINPOINT_ATTRIBUTE
                  GET TIMEML_ENDPOINT_ATTRIBUTE
                  GET TR_RESPECT_TO_ANCHOR ))
                  T))
then
CREATE TIMEX3_tag
(and (BEGIN_AT POTGOV_CHUNK-1)
  (END_AT POTGOV_CHUNK+1))
CREATE SIGNAL_tag
(and (BEGIN_AT PREP_POTGOV_CHUNK-1))
         (END_AT PREP_POTGOV_CHUNK-1))
```

Examples:

- alla fine$_{P_C}$ del caldo mese$_{DI_C}$ di ottobre$_{DI_C}$
- alla fine$_{P_C}$ dello scorso mese$_{DI_C}$ di ottobre$_{DI_C}$
- alla fine$_{P_C}$ del primo semestre$_{DI_C}$ del 1990$_{DATEPATTERN}$
- alla fine$_{P_C}$ dei primi anni$_{DI_C}$ '50$_{DATEPATTERN}$
- nella prima metà$_{P_C}$ del caldo mese$_{DI_C}$ di ottobre$_{DI_C}$
- nella prima parte$_{P_C}$ dello scorso mese$_{DI_C}$ di ottobre$_{DI_C}$
- nella prima metà$_{P_C}$ del secondo semestre$_{DI_C}$ del 1994$_{DATEPATTERN}$
- nella prima metà$_{P_C}$ del mese$_{DI_C}$ di ottobre$_{DI_C}$
- nella prima parte$_{P_C}$ degli anni$_{DI_C}$ '50$_{DATEPATTERN}$
- nella prima metà$_{P_C}$ dell'anno $_{DI\_C}$ 1994$_{DATEPATTERN}$
- a metà$_{P_C}$ del mese$_{DI_C}$ di ottobre$_{DI_C}$
- alla fine$_{P_C}$ degli anni$_{DI_C}$ '50$_{DATEPATTERN}$

```
R35 COND
        (and
        (not (POTGOV_lemma CHUNK-1 equals modiftrigger))
        ((POTGOV_lemma CHUNK+1 equals lextrigger)
                 then
                 (GET GRAN
                  GET DEFAULT TYPE))
         (or (POTGOV_CHUNK+1 equals DI_C)
               (POTGOV_lemma CHUNK+1 equals DATE PATTERN)
               (POTGOV_lemma CHUNK+1 equals TIMEPATTERN))
        (or (POTGOV_CHUNK equals P_C)
              (POTGOV_CHUNK equals DI_C))
        (COND
        ((PREMODIF_POTGOV_CHUNK equals modiftrigger)
                        then
```

```
                    ((GET INFO_NORMALIZATION
                    GET  TIMEML_MOD_ATTRIBUTE
                    GET TIMEML_BEGINPOINT_ATTRIBUTE
                    GET TIMEML_ENDPOINT_ATTRIBUTE
                    GET TR_RESPECT_TO_ ANCHOR))
                      T)
  )
  (COND
  ((PREMODIF_POTGOV_CHUNK+1 equals modiftrigger)
                 then
                 ((GET INFO_NORMALIZATION
                  GET  TIMEML_MOD_ATTRIBUTE
                  GET TIMEML_BEGINPOINT_ATTRIBUTE
                  GET TIMEML_ENDPOINT_ATTRIBUTE
                  GET TR_RESPECT_TO_ ANCHOR))
                 T)
   )
   then
   CREATE TIMEX3_tag
     (and  (or (BEGIN_AT PREMODIF_POTGOV_CHUNK)
               (BEGIN_AT DET_POTGOV_CHUNK))
               (END_AT POTGOV_CHUNK+1))
    CREATE SIGNAL_tag
    (and (BEGIN_AT PREP_POTGOV_CHUNK)
            (END_AT PREP_POTGOV_CHUNK))
```

Examples:

- in data$_{P_C}$ 24/05/1996$_{DATEPATTERN}$
- dei primi mesi$_{DI_C}$ dell'anno$_{DI_C}$
- del mese$_{DI_C}$ di agosto$_{DI_C}$
- al mese$_{P_C}$ di agosto$_{DI_C}$
- entro il caldo mese$_{P_C}$ di agosto$_{DI_C}$
- dei primi mesi$_{DI_C}$ di quest'anno$_{DI_C}$
- entro l'autunno$_{P_C}$ del 1994$_{DATEPATTERN}$
- alle ore$_{P_C}$ 15:00$_{TIMEPATTERN}$
- nello stesso periodo$_{P_C}$ dell'anno$_{DATEPATTERN}$

```
R40 COND
       (and
       (not (POTGOV_lemma CHUNK-1 equals modiftrigger))
       ((POTGOV_lemma CHUNK+1 equals modiftrigger)
                then
                (GET INFO_NORMALIZATION
                GET  TIMEML_MOD_ATTRIBUTE
```

```
            GET TIMEML_BEGINPOINT_ATTRIBUTE
            GET TIMEML_ENDPOINT_ATTRIBUTE
            GET TR_RESPECT_TO_ ANCHOR ))
   (or (POTGOV_CHUNK+1 equals ADJ_C)
        (POTGOV_CHUNK+1 equals ADV_C)
        (POTGOV_CHUNK+1 equals P_C))
   (or (POTGOV_CHUNK equals DI_C)
         (POTGOV_CHUNK equals P_C)
    (COND
   ((PREMODIF_POTGOV_CHUNK equals modiftrigger)
                    then
                     ((GET INFO_NORMALIZATION
                     GET  TIMEML_MOD_ATTRIBUTE
                     GET TIMEML_BEGINPOINT_ATTRIBUTE
                     GET TIMEML_ENDPOINT_ATTRIBUTE
                     GET TR_RESPECT_TO_ ANCHOR))
                       T)
     )
           then
          CREATE TIMEX3_tag
          (and
                (or (BEGIN_AT PREMODIF_POTGOV_CHUNK)
                      (BEGIN_AT POTGOV_CHUNK))
                  (END_AT POTGOV_CHUNK+1))
         CREATE SIGNAL_tag
         (and (BEGIN_AT PREP_POTGOV_CHUNK)
                 (END_AT PREP_POTGOV_CHUNK))
```

Examples:

- dell'anno$_{DI_C}$ precedente$_{ADJ_C}$
- dall'anno$_{P_C}$ scorso$_{ADJ_C}$
- per domani$_{P_C}$ al massimo$_{P_C}$
- nelle due settimane$_{P_C}$ scorse$_{ADJ_C}$
- di due giorni$_{DI_C}$ fa$_{ADV_C}$

```
R42 COND
       (and
       ((POTGOV_lemma CHUNK-1 equals modiftrigger)
                              then
                        (GET INFO_NORMALIZATION
                        GET  TIMEML_MOD_ATTRIBUTE
                        GET TIMEML_BEGINPOINT_ATTRIBUTE
                        GET TIMEML_ENDPOINT_ATTRIBUTE
                        GET TR_RESPECT_TO_ ANCHOR ))
      (or (POTGOV_CHUNK-1 equals P_C)
           (POTGOV_CHUNK-1 equals DI_C))
```

```
      (not (POTGOV_lemma CHUNK+1 equals lextrigger))
      (not (POTGOV_lemma CHUNK+1 equals modiftrigger))
      (POTGOV_CHUNK equals N_C)
      ((PREMODIF_POTGOV_CHUNK equals modiftrigger)
                            then
                        (GET INFO_NORMALIZATION
                         GET  TIMEML_MOD_ATTRIBUTE
                         GET TIMEML_BEGINPOINT_ATTRIBUTE
                         GET TIMEML_ENDPOINT_ATTRIBUTE
                         GET TR_RESPECT_TO_ ANCHOR )))
         then
         CREATE TIMEX3_tag
           (and
                 (or (BEGIN_AT PREMODIF_POTGOV_CHUNK-1)
                      (BEGIN_AT POTGOV_CHUNK-1))
           (END_AT POTGOV_CHUNK))
        CREATE SIGNAL_tag
          (and (BEGIN_AT PREP_POTGOV_CHUNK-1)
              (END_AT PREP_POTGOV_CHUNK-1))
```

Examples:

- della prima$_{DI_C}$ mezz'ora$_{N_C}$
- nei primi$_{P_C}$ trenta minuti$_{N_C}$
- negli ultimi$_{P_C}$ tre giorni$_{N_C}$
- al massimo$_{P_C}$ due giorni$_{N_C}$

```
R42_2 COND
       (and
       ((POTGOV_lemma CHUNK-1 equals modiftrigger)
                              then
                         (GET INFO_NORMALIZATION
                         GET  TIMEML_MOD_ATTRIBUTE
                         GET TIMEML_BEGINPOINT_ATTRIBUTE
                         GET TIMEML_ENDPOINT_ATTRIBUTE
                         GET TR_RESPECT_TO_ ANCHOR ))
      (or (POTGOV_CHUNK-1 equals P_C)
           (POTGOV_CHUNK-1 equals DI_C))
      (POTGOV_lemma CHUNK+1 equals lextrigger)
      (POTGOV_CHUNK+1 equals DI_C)
      (POTGOV_CHUNK equals N_C)
      ((PREMODIF_POTGOV_CHUNK equals modiftrigger)
                            then
                        (GET INFO_NORMALIZATION
                         GET  TIMEML_MOD_ATTRIBUTE
                         GET TIMEML_BEGINPOINT_ATTRIBUTE
                         GET TIMEML_ENDPOINT_ATTRIBUTE
                         GET TR_RESPECT_TO_ ANCHOR )))
```

```
   then
  CREATE TIMEX3_tag
     (and (BEGIN_AT POTGOV_CHUNK-1)
              (END_AT POTGOV_CHUNK+1))
  CREATE SIGNAL_tag
    (and (BEGIN_AT PREP_POTGOV_CHUNK-1)
         (END_AT PREP_POTGOV_CHUNK-1))
```

Examples:

- nelle ultime$_{P_C}$ tre ore$_{N_C}$ del pomeriggio$_{DI_C}$
- delle ultime$_{DI_C}$ cinque ore$_{N_C}$ del giorno$_{DI_C}$

```
R43 COND
       (and
      ((POTGOV_lemma CHUNK-1 equals modiftrigger)
                          then
                          (GET INFO_NORMALIZATION
                          GET  TIMEML_MOD_ATTRIBUTE
                          GET TIMEML_BEGINPOINT_ATTRIBUTE
                          GET TIMEML_ENDPOINT_ATTRIBUTE
                          GET TR_RESPECT_TO_ ANCHOR ))
        (or (POTGOV_CHUNK-1 equals N_C)
              (POTGOV_CHUNK-1 equals ADJ_C))
      (not (POTGOV_lemma CHUNK+1 equals lextrigger))
      (not (POTGOV_lemma CHUNK+1 equals modiftrigger))
      (or (POTGOV_CHUNK equals N_C)
            (POTGOV_lemma CHUNK equals DATE PATTERN))
      ((PREMODIF_POTGOV_CHUNK equals modiftrigger)
                             then
                         (GET INFO_NORMALIZATION
                          GET  TIMEML_MOD_ATTRIBUTE
                          GET TIMEML_BEGINPOINT_ATTRIBUTE
                          GET TIMEML_ENDPOINT_ATTRIBUTE
                          GET TR_RESPECT_TO_ ANCHOR )))
       then
       CREATE TIMEX3_tag
       (and (or (BEGIN_AT POTGOV_CHUNK-1)
                (BEGIN_AT DET_POTGOV_CHUNK-1))
               (END_AT POTGOV_CHUNK))
```

Examples:

- la prima$_{N_C}$ mezz'ora$_{N_C}$
- gli ultimi$_{N_C}$ due anni$_{N_C}$
- il passato$_{N_C}$ semestre$_{N_C}$
- lo scorso$_{ADJ_C}$ 15 maggio$_{N_C}$

- le ultime$_{N_C}$ tre ore$_{N_C}$

```
R44 COND
       (and
       ((POTGOV_lemma CHUNK-1 equals modiftrigger))
                      then
                      (GET INFO_NORMALIZATION
                      GET  TIMEML_MOD_ATTRIBUTE
                      GET TIMEML_BEGINPOINT_ATTRIBUTE
                      GET TIMEML_ENDPOINT_ATTRIBUTE
                      GET TR_RESPECT_TO_ ANCHOR ))
        (or (POTGOV_CHUNK-1 equals P_C)
              (POTGOV_CHUNK-1 equals DI_C))
        ((POTGOV_lemma CHUNK+1 equals modiftrigger)
                            then
                       (GET INFO_NORMALIZATION
                        GET  TIMEML_MOD_ATTRIBUTE
                        GET TIMEML_BEGINPOINT_ATTRIBUTE
                        GET TIMEML_ENDPOINT_ATTRIBUTE
                        GET TR_RESPECT_TO_ ANCHOR ))
        (COND
        ((PREMODIF_POTGOV_CHUNK+1 equals modiftrigger)
                      then
                      (GET INFO_NORMALIZATION
                       GET  TIMEML_MOD_ATTRIBUTE
                       GET TIMEML_BEGINPOINT_ATTRIBUTE
                       GET TIMEML_ENDPOINT_ATTRIBUTE
                       GET TR_RESPECT_TO_ ANCHOR ))
                       T)
          )
          (POTGOV_CHUNK+1 equals ADJ_C)
          (or (POTGOV_CHUNK equals DI_C)
                (POTGOV_CHUNK equals N_C))
          (COND
          ((PREMODIF_POTGOV_CHUNK equals modiftrigger)
                       then
                       (GET INFO_NORMALIZATION
                        GET  TIMEML_MOD_ATTRIBUTE
                        GET TIMEML_BEGINPOINT_ATTRIBUTE
                        GET TIMEML_ENDPOINT_ATTRIBUTE
                        GET TR_RESPECT_TO_ ANCHOR ))
                  T)
             )
             then
             CREATE TIMEX3_tag
             (and  (or (BEGIN_AT PREMODIF_POTGOV_CHUNK-1)
                          (BEGIN_AT DET_POTGOV_CHUNK-1))
                          (END_AT POTGOV_CHUNK+1))
             CREATE SIGNAL_tag
             (and (BEGIN_AT PREP_POTGOV_CHUNK-1)
```

```
                    (END_AT PREP_POTGOV_CHUNK-1))
```

Examples:

(B.1) alla fine$_{P_C}$ dell'anno$_{DI_C}$ scorso$_{ADJ_C}$

(B.2) nella prima metà$_{P_C}$ della settimana$_{DI_C}$ passata$_{ADJ_C}$

(B.3) della prima metà$_{DI_C}$ dell'anno$_{DI_C}$ passato$_{ADJ_C}$

(B.4) nel corrispondente$_{P_C}$ periodo$_{N_C}$ passato$_{ADJ_C}$

(B.5) nella prima metà$_{P_C}$ dell'anno$_{Di_C}$ fiscale$_{ADJ_C}$

(B.6) per il corrispondente$_{P_C}$ periodo$_{N_C}$ scorso$_{ADJ_C}$

```
R44_1 COND
       (and
       ((POTGOV_lemma CHUNK-1 equals modiftrigger))
                       then
                       (GET INFO_NORMALIZATION
                       GET  TIMEML_MOD_ATTRIBUTE
                       GET TIMEML_BEGINPOINT_ATTRIBUTE
                       GET TIMEML_ENDPOINT_ATTRIBUTE
                       GET TR_RESPECT_TO_ ANCHOR ))
        (or (POTGOV_CHUNK-1 equals P_C)
              (POTGOV_CHUNK-1 equals DI_C))
        ((POTGOV_lemma CHUNK+1 equals lextrigger)
                             then
                        (GET INFO_NORMALIZATION
                         GET  TIMEML_MOD_ATTRIBUTE
                         GET TIMEML_BEGINPOINT_ATTRIBUTE
                         GET TIMEML_ENDPOINT_ATTRIBUTE
                         GET TR_RESPECT_TO_ ANCHOR ))
        (COND
        ((PREMODIF_POTGOV_CHUNK+1 equals modiftrigger)
                       then
                       (GET INFO_NORMALIZATION
                        GET  TIMEML_MOD_ATTRIBUTE
                        GET TIMEML_BEGINPOINT_ATTRIBUTE
                        GET TIMEML_ENDPOINT_ATTRIBUTE
                        GET TR_RESPECT_TO_ ANCHOR ))
                        T)
          )
          (or (POTGOV_CHUNK+1 equals DI_C)
               (POTGOV_lemma CHUNK+1 equals DATE PATTERN)
                (POTGOV_CHUNK equals N_C))
          (not  (POTGOV_CHUNK has PREMODIFIER)
          then
          CREATE TIMEX3_tag
          (and  (or (BEGIN_AT PREMODIF_POTGOV_CHUNK-1)
                        (BEGIN_AT DET_POTGOV_CHUNK-1))
```

```
                    (END_AT POTGOV_CHUNK+1))
    CREATE SIGNAL_tag
   (and (BEGIN_AT PREP_POTGOV_CHUNK-1)
           (END_AT PREP_POTGOV_CHUNK-1))
```

Examples:

- nel corrispondente$_{P_C}$ periodo$_{N_C}$ dell'anno$_{DI_C}$
- del corrispondente$_{DI_C}$ periodo$_{N_C}$ '93$_{DATEPATTERN}$

```
R45 COND
       (and
       ((POTGOV_lemma CHUNK-1 equals modiftrigger))
                        then
                       (GET INFO_NORMALIZATION
                         GET  TIMEML_MOD_ATTRIBUTE
                         GET TIMEML_BEGINPOINT_ATTRIBUTE
                         GET TIMEML_ENDPOINT_ATTRIBUTE
                         GET TR_RESPECT_TO_ ANCHOR ))
        (COND
        ((PREMODIF_POTGOV_CHUNK-1 equals modiftrigger)
                        then
                        (GET INFO_NORMALIZATION
                         GET  TIMEML_MOD_ATTRIBUTE
                        GET TIMEML_BEGINPOINT_ATTRIBUTE
                        GET TIMEML_ENDPOINT_ATTRIBUTE
                        GET TR_RESPECT_TO_ ANCHOR ))
                        T)
         )
        (POTGOV_CHUNK-1 equals N_C)
        (not (POTGOV_lemma CHUNK+1 equals modiftrigger)
        (not (POTGOV_lemma CHUNK+1 equals lextrigger)
        (COND
        ((POTGOV CHUNK+1 equals ADJ_C))
          T)
        (or (POTGOV_CHUNK equals DI_C)
             (POTGOV_CHUNK equals DATE PATTERN))
        (not (POTGOV_CHUNK has PREMODIF)
       then
       CREATE TIMEX3_tag
           (and  (or (BEGIN_AT PREMODIF_POTGOV_CHUNK-1)
                     (BEGIN_AT DET_POTGOV_CHUNK-1))
                     (or (END_AT POTGOV_CHUNK)
                          (END_AT POTGOV_CHUNK+1))
          )
```

Examples:

- la prima parte$_{N_C}$ dell' 80$_{DATEPATTERN}$
- la prima parte$_{N_C}$ dell'anno$_{DI_C}$

- la parte$_{N_C}$ dell'anno$_{DI_C}$ interessata$_{ADJ}$

```
R46 COND
       (and
       ((POTGOV_lemma CHUNK-1 equals modiftrigger))
                           then
                           (GET INFO_NORMALIZATION
                           GET  TIMEML_MOD_ATTRIBUTE
                           GET TIMEML_BEGINPOINT_ATTRIBUTE
                           GET TIMEML_ENDPOINT_ATTRIBUTE
                           GET TR_RESPECT_TO_ ANCHOR ))
        (COND
        ((PREMODIF_POTGOV_CHUNK-1 equals modiftrigger)
                        then
                        (GET INFO_NORMALIZATION
                         GET  TIMEML_MOD_ATTRIBUTE
                        GET TIMEML_BEGINPOINT_ATTRIBUTE
                        GET TIMEML_ENDPOINT_ATTRIBUTE
                        GET TR_RESPECT_TO_ ANCHOR ))
                        T)
         )
        (or (POTGOV_CHUNK-1 equals N_C)
             (POTGOV_CHUNK-1 equals ADV_C))
        (or (POTGOV_CHUNK equals N_C)
             (POTGOV_CHUNK equals DI_C))
        (COND
        ((PREMODIF_POTGOV_CHUNK equals modiftrigger)
                        then
                        (GET INFO_NORMALIZATION
                         GET  TIMEML_MOD_ATTRIBUTE
                        GET TIMEML_BEGINPOINT_ATTRIBUTE
                        GET TIMEML_ENDPOINT_ATTRIBUTE
                        GET TR_RESPECT_TO_ ANCHOR ))
                        T)
         )
       ((POTGOV_lemma CHUNK+1 equals modiftrigger))
                      then
                     (GET INFO_NORMALIZATION
                     GET  TIMEML_MOD_ATTRIBUTE
                     GET TIMEML_BEGINPOINT_ATTRIBUTE
                     GET TIMEML_ENDPOINT_ATTRIBUTE
                     GET TR_RESPECT_TO_ ANCHOR ))
    (or (POTGOV_CHUNK+1 equals ADJ_C)
         (POTGOV_CHUNK+1 equals ADV_C)
    then
    CREATE TIMEX3_tag
       (and (BEGIN_AT DET_POTGOV_CHUNK-1)
            (END_AT POTGOV_CHUNK+1)
```

Examples:

- la prima parte$_{N_C}$ dell'anno$_{DI_C}$ scorso$_{ADJ_C}$
- il corrispondente$_{N_C}$ periodo$_{N_C}$ passato$_{ADJ_C}$
- non meno$_{ADV_C}$ di due anni$_{DI_C}$ fa$_{ADV_C}$

```
R46_1 COND
          (and
          ((POTGOV_lemma CHUNK-1 equals modiftrigger))
                           then
                           (GET INFO_NORMALIZATION
                           GET  TIMEML_MOD_ATTRIBUTE
                           GET TIMEML_BEGINPOINT_ATTRIBUTE
                           GET TIMEML_ENDPOINT_ATTRIBUTE
                           GET TR_RESPECT_TO_ ANCHOR ))
         (COND
         ((PREMODIF_POTGOV_CHUNK-1 equals modiftrigger)
                        then
                        (GET INFO_NORMALIZATION
                         GET  TIMEML_MOD_ATTRIBUTE
                        GET TIMEML_BEGINPOINT_ATTRIBUTE
                        GET TIMEML_ENDPOINT_ATTRIBUTE
                        GET TR_RESPECT_TO_ ANCHOR ))
                        T)
          )
         (POTGOV_CHUNK-1 equals N_C)
         (POTGOV_CHUNK equals N_C)
         (COND
         ((PREMODIF_POTGOV_CHUNK equals modiftrigger)
                         then
                        (GET INFO_NORMALIZATION
                         GET  TIMEML_MOD_ATTRIBUTE
                         GET TIMEML_BEGINPOINT_ATTRIBUTE
                         GET TIMEML_ENDPOINT_ATTRIBUTE
                         GET TR_RESPECT_TO_ ANCHOR ))
                        T)
          )
         ((POTGOV_lemma CHUNK+1 equals lextrigger))
         (or (POTGOV_CHUNK+1 equals DI_C)
              (POTGOV_lemma CHUNK+1 equals DATE PATTERN)
      then
     CREATE TIMEX3_tag
     (and (BEGIN_AT DET_POTGOV_CHUNK-1)
             (END_AT POTGOV_CHUNK+1)
```

Examples:

- il corrispondente$_{N_C}$ periodo$_{N_C}$ dell'anno$_{DI_C}$
- il corrispondente$_{N_C}$ periodo$_{N_C}$ '93$_{DATEPATTERN}$
- le ultime$_{N_C}$ tre ore$_{N_C}$ del pomeriggio$_{DI_C}$

```
R46_b1 COND
          (and
          ((POTGOV_lemma CHUNK-1 equals modiftrigger))
                           then
                           (GET INFO_NORMALIZATION
                           GET  TIMEML_MOD_ATTRIBUTE
                           GET TIMEML_BEGINPOINT_ATTRIBUTE
                           GET TIMEML_ENDPOINT_ATTRIBUTE
                           GET TR_RESPECT_TO_ ANCHOR ))
         (COND
         ((PREMODIF_POTGOV_CHUNK-1 equals modiftrigger)
                        then
                        (GET INFO_NORMALIZATION
                         GET  TIMEML_MOD_ATTRIBUTE
                        GET TIMEML_BEGINPOINT_ATTRIBUTE
                        GET TIMEML_ENDPOINT_ATTRIBUTE
                        GET TR_RESPECT_TO_ ANCHOR ))
                        T)
          )
         (or (POTGOV_CHUNK-1 equals P_C)
               (POTGOV_CHUNK-1 equals DI_C))
         (or (POTGOV_CHUNK equals DI_C)
               (POTGOV_CHUNK equals DATE PATTERN)
         (not (POTGOV_lemma CHUNK+1 equals lextrigger))
         (not (POTGOV_lemma CHUNK+1 equals modfitrigger))
      then
     CREATE TIMEX3_tag
     (and (BEGIN_AT PREMODIF_POTGOV_CHUNK-1)
             (END_AT POTGOV_CHUNK)
    CREATE SIGNAL_tag
         (and (BEGIN_AT PREP_POTGOV_CHUNK-1)
                 (END_AT PREP_POTGOV_CHUNK-1))
```

Examples:

- della seconda parte$_{DI_C}$ dell'anno$_{DI_C}$
- nella seconda metà$_{P_C}$ del 1989$_{DATEPATTERN}$
- nella prima metà$_{P_C}$ di questo caldo agosto$_{DI_C}$

```
R51 COND
       (and
       (not (POTGOV_lemma CHUNK-1 equals modiftrigger))
       (POTGOV_CHUNK equals N_C)
       (COND
       ((PREMODIF_POTGOV_CHUNK equals modiftrigger)
                        then
                       (GET INFO_NORMALIZATION
                       GET  TIMEML_MOD_ATTRIBUTE
                       GET TIMEML_BEGINPOINT_ATTRIBUTE
```

```
                  GET TIMEML_ENDPOINT_ATTRIBUTE
                  GET TR_RESPECT_TO_ ANCHOR ))
                  T)
    ((POTGOV_lemma CHUNK+1 equals lextrigger)
             then
            (GET GRAN
            GET DEFAULT TYPE))
    (or (POTGOV_CHUNK+1 equals DI_C)
         (POTGOV_lemma CHUNK+1 equals DATE PATTERN))
    (COND
    ((PREMODIF_POTGOV_CHUNK+1 equals modiftrigger)
                  then
                  (GET INFO_NORMALIZATION
                  GET  TIMEML_MOD_ATTRIBUTE
                  GET TIMEML_BEGINPOINT_ATTRIBUTE
                  GET TIMEML_ENDPOINT_ATTRIBUTE
                  GET TR_RESPECT_TO_ ANCHOR ))
                   T)
   then
   CREATE TIMEX3_tag
   (and (or (BEGIN_AT DET_POTGOV_CHUNK)
                (BEGIN_AT POTGOV_CHUNK))
            (END_AT POTGOV_CHUNK+1))
```

Examples:

- il mese$_{N_C}$ di agosto$_{DI_C}$
- il caldo mese$_{N_C}$ di agosto$_{DI_C}$
- agosto$_{N_C}$ '98$_{DATEPATTERN}$
- il primo semestre$_{N_C}$ dello scorso anno$_{DI_C}$
- l'equininozio$_{N_C}$ di primavera$_{DI_C}$
- il settembre$_{N_C}$ del '92$_{DATEPATTERN}$
- la sera$_{N_C}$ di giovedì$_{DI_C}$

```
R34 COND
    (and
    (POTGOV_CHUNK-1 equals END_TIMXE3_tag)
    (POTGOV_CHUNK-1 equals modiftrigger)
    (or (POTGOV_lemma_CHUNK equals DATE PATTERN)
         (POTGOV_CHUNK equals di_C))
        (COND
           ((PREMODIF_POTGOV_CHUNK equals modiftrigger)
                   then
                   (GET INFO_NORMALIZATION
                    GET  TIMEML_MOD_ATTRIBUTE
                    GET TIMEML_BEGINPOINT_ATTRIBUTE
```

```
                    GET TIMEML_ENDPOINT_ATTRIBUTE
                    GET TR_RESPECT_TO_ ANCHOR ))
                    T)
     (not (POTGOV_lemma CHUNK+1 equals lextrigger))
     (not (POTGOV_lemma CHUNK+1 equals modiftrigger))
    then
    CREATE TIMEX3_tag
    ( and (ADD TO TIMEX3_tag (POTGOV_CHUNK)
             END NEW_TIMEX3_tag_AT POTGOV_CHUNK))
```

Examples:

- (il primo semestre$_{N_C}$ fiscale$_{ADJ_C}$)$_{TIMEX3}$ 2006$_{DATEPATTERN}$
- (nel primo semestre$_{ADJ_C}$ fiscale$_{ADJ_C}$)$_{TIMEX3}$ dell'anno$_{DI_C}$
- (nei primi$_{P_C}$ tre mesi$_{N_C}$ del primo semestre$_{DI_C}$ fiscale$_{ADJ_C}$)$_{TIMEX3}$ dello scorso anno $_{DI\_C}$

```
R38_2 COND
       (and
       (POTGOV_CHUNK-1 equals END_TIMXE3_tag)
       (POTGOV_CHUNK-1 equals modiftrigger)
       (POTGOV_CHUNK equals di_C))
       ((POTGOV_lemma CHUNK+1 equals modiftrigger))
                       then
                       (GET INFO_NORMALIZATION
                       GET  TIMEML_MOD_ATTRIBUTE
                       GET TIMEML_BEGINPOINT_ATTRIBUTE
                       GET TIMEML_ENDPOINT_ATTRIBUTE
                       GET TR_RESPECT_TO_ ANCHOR ))
                        T)
        (POTGOV_CHUNK+1 equals ADJ_C))
        then
       CREATE TIMEX3_tag
       ( and (ADD TO TIMEX3_tag (POTGOV_CHUNK)
                END NEW_TIMEX3_tag_AT POTGOV_CHUNK+1))
```

Examples:

- (nel primo semestre$_{ADJ_C}$ fiscale$_{ADJ_C}$]$_{TIMEX3}$ dell'anno$_{DI_C}$ scorso$_{ADJ_C}$
- (nei primi$_{P_C}$ tre mesi$_{N_C}$ del primo semestre$_{DI_C}$ fiscale$_{ADJ_C}$)$_{TIMEX3}$ dell'anno$_{DI_C}$ scorso$_{ADJ_C}$

```
R38_3 COND
       (and
       (POTGOV_CHUNK-1 equals END_TIMEX3_tag)
       (POTGOV_CHUNK-1 equals lextrigger)
       (POTGOV_CHUNK equals DATE PATTERN)
       (not (POTGOV_lemma CHUNK+1 equals modiftrigger))
       (not (POTGOV_lemma CHUNK+1 equals lextrigger))
```

```
COND
 (
 (GET POTGOV_CHUNK_SemRelation equals to has_as_part )
 (and (granularity_POTGOV_CHUNK has_as_part granularity_POTGOV_CHUNK-1)
          (POTGOV_CHUNK DEFAULT TYPE equals DATE)
          (POTGOV_CHUNK+1 DEFAULT TYPE equals DATE)
   )
 then
CREATE TIMEX3_tag
( and (ADD TO TIMEX3_tag (POTGOV_CHUNK)
         END NEW_TIMEX3_tag_AT POTGOV_CHUNK+1))
```

Examples:

- (del mese$_{DI_C}$ di agosto$_{DI_C}$)$_{TIMEX3}$ del '96$_{DATEPATTERN}$
- (l'intero mese$_{N_C}$ di novembre$_{DI_C}$)$_{TIMEX3}$ '95$_{DATEPATTERN}$

Appendix C

It-TimeML: TimeML annotation guidelines for Italian

C.1 Introduction

This document[1] describes the annotation guidelines for marking up Italian texts with the TimeML (Pustejovsky et al., 2003c) and ISO-TimeML specifications. It presents the results of discussions and elaborations developed at the ILC-CNR in Pisa and during the ISO TC 37 SC4 meetings[2].

The document is structured as follows: the next section, section C.2, will present a brief overview of the purpose of this annotation scheme and will describe the TimeML tags (XML markables) and their attributes. It will also provide a BNF description of each tag and some explanatory examples. Notice that for clarity's sake the examples will focus only on the tag (or attribute) under discussion and they will present an English translation. In section C.4 instructions on how to annotate each markable will be presented. Finally, section C.6 will provide some examples of completely annotated texts. In section C.7 the first release of the Italian TimeML DTD is presented. Finally, section C.8 illustrates some general instructions to annotate texts in a reliable way.

In the rest of the document the markup language will be referred as It-TimeML. All examples of the concrete use of the annotation language will be reported by applying in-line annotation to ease the reading of the document. Notice that ISO-TimeML implements stand-off annotation, which is considered a standard and is slightly more expressive than in-line annotation.

C.2 It-TimeML markable tags and attributes

C.2.1 Overview

TimeML and It-TimeML are markup languages for the annotation of temporal entities in texts. The identification of these expressions is a critical component for any robust

[1]This work has been financed by CNR grants as part of the project "Modello per analisi e estrazione di eventi e espressioni temporali in testi italiani di ambito generale sfruttando le risorse linguistiche ItalWordNet e PAROLE/SIMPLE/CLIPS e realizzazione di un sistema di annotazione in accordo con gli standard internazionali", bando n. 126.048. BS 01/06, prot. n. 11/06, under the scientific tutoring of Prof.ssa Irina Prodanof.

[2]The meetings took place at Brandeis University (U.S.A.), at Tiburg University (The Netherlands) and at AFNOR (France) between 2006 and 2007.

NLP system, like Information Retrieval or language understanding systems, and recently it has been the topic of lots of research both in computational Linguistics and Artificial Intelligence. The access by content to the information in texts is still an open issue, although some tasks, like named entity recognition and automatic semantic role labelling have provided good improvements. However, there is still a limited ability for marking up texts for real semantic content. One of the field of information which can provide significant steps forward to access by content is represented by temporal information. Time is a pervasive element of human life through which we perceive, inference and reason about the outside world and what (or might) happen in it.

Temporal entities are represented by **events**, **temporal expressions** and the **relations** which are created among these entities. Events represent what happen in the outside world and, thus, are intimately connected to time, which is often realized by temporal expressions, i.e. expressions which provide us with information on **when** something took, is taking or will take place. Without a robust capacity to comprehend the relations between events and times the real aboutness of a document could be missed.

As it often happens in natural language, most information is not explicitly stated, and this is the case of most temporal information. The aim of TimeML and ISO-TimeML, of which It-TimeML is part, is that of annotating all expressions which code temporal information and their relationships, which range from strictly temporal (e.g. "*before*", "*includes*"...), to subordinating (e.g. "*factive*", "*modal*"...), to aspectual or phasal (e.g. "initiates", "finishes"...). With respect to other existing annotation schemes for temporal annotation, TimeML presents a unifying approach to event-temporal identification, in particular with respect to four big issues:

- event identification and its anchoring in time;
- temporal ordering of events, distinguishing lexical properties from discourse properties;
- reasoning with underspecified temporal expressions;
- reasoning about the persistence of an event.

It-TimeML represents one of the first adaptations and applications of TimeML and ISO-TimeML to a language different from English.

C.2.2 The tag <EVENT>

In TimeML and ISO-TimeML, "event" is used as a cover term to identify "something that can be said to obtain or hold true, to happen or to occur" (ISO (2008): 1). In literature this notion is often referred to as eventuality (Bach, 1986). It includes all types of actions (punctuals or duratives) and states as well. It is not to be confused with the ontological notion of event as something which occurs at a certain point in time (e.g. *The meeting is at 2 o'clock*) or which lasts for a certain interval of time (e.g. *John has eaten an apple*). Syntactically, the linguistic elements which may realize an event are the following:

(a) Verbs (finite or non-finite form) e.g.:

   - *I pompieri* ***hanno isolato*** *la sala.*
   - *Fim-Cisl e Uilm-Uil* ***hanno annunciato*** *oggi una conferenza stampa.*
   - *La città mostra i segni della battaglia: cassonetti* ***incendiati*** *o* ***rivoltati****.*

(b) Adjectives e.g.:

- *La coppia, **residente** a Milano, stava trascorrendo un periodo di vacanza in Sicilia.*

(c) Predicative sections e.g. :

- *Al Sayed è il nuovo **presidente** della Fermenta.*

(d) Prepositional phrases, e.g.:

- *Una giovane turista **in vacanza** nel villaggio "Katibubbo" è morta.*
- *Un centinaio di giovani è tuttora **agli arresti**.*

(e) Nouns, which can realize eventualities in three different ways (Gross & Kiefer, 1995):

- deverbal nouns, obtained through a nominalization process from verbs; e.g.: ***fuga**, **arrivo**, **corsa**, **bevuta**, **accordo**...*
- nouns which are not derived from a verb and have an eventive meaning in their lexical properties; e.g.: ***guerra**, **uragano**, **assemblea**, **cerimonia**...*
- nouns which normally denote objects but which are assigned an eventive reading either through the process of type-coercion, or through the processes of logical metonymy and coercion induced by temporal prepositions (Pustejovsky, 1995); (the co-textual elements which give rise to the type-coercion phenomenon are underlined) e.g.:
  - *Ho <u>interrotto</u> **il libro**.*
  - *Vengo a casa <u>dopo</u> **la pizza**.*
  - ***La scuola** <u>è durata tutta la mattina</u>.*

The `EVENT` tag is also used to annotate states, but only a subsets of states are annotated, that is transient states or those which explicitly participate in a temporal relation. Thus, for instance in "*Marco **è alto***" no annotation will be performed, since the state of being tall is not transient nor participates explicitly to a temporal relations. On the other hand, "*Marco è **uno studente***" and "*Il prezzo del petrolio oggi è di **60$** al barile*" are to be considered as possible markables. See section C.4 for details.

C.2.2.1 BNF description of the `EVENT` tag

```
attributes ::= id anchor pred class type tense aspect pos polarity
               mood [modality]
id ::= e<integer>
anchor ::= IDREF
{IDREF ::= (token<integer>)*}
{default, if absent, is an empty string}
pred ::= CDATA
class ::= REPORTING | PERCEPTION | ASPECTUAL | I_ACTION |
            I_STATE | OCCURRENCE
pos ::=  ADJECTIVE | NOUN | VERB | PREPOSITION | OTHER
tense ::= FUTURE | PAST | PRESENT | IMPERFECT | NONE
```

```
aspect ::= PROGRESSIVE | PERFECTIVE | IMPERFECTIVE | NONE
vform ::= INFINITIVE | GERUNDIVE | PARTICIPLE | NONE
          {default, if absent, is NONE}
polarity ::= NEG | POS {default, if absent, is POS}
mood ::= SUBJUNCTIVE | CONDITIONAL | NONE
{default, if absent, is NONE}
modality ::= CDATA
comment ::= CDATA
```

C.2.2.2 Attributes of EVENT

A. id **(Event ID)**: obligatory attribute. It assigns a unique ID number to every event instance. It is automatically assigned by the annotation tool every time the EVENT tag is assigned to a string.

B. anchor **(Anchor)**: obligatory attribute. It is used in stand-off annotation to link each tag to the primary data; e.g.:

(C.1) *La Procura di Marsala* ***ha aperto*** *un'inchiesta.*

...<word id="w4" token="Marsala"/> <word id="w2" token="ha"/>
<word id="w3" token="aperto"/>...
<EVENT id="e1" anchor="w4"/>

C. pred **(Predicate)**: obligatory attribute. It explicits the predicative/semantic content of each event; e.g.

(C.2) *La Procura di Marsala* ***ha aperto*** *un'inchiesta.*

ha <EVENT id="e1" pred="APRIRE">aperto</EVENT>

D. class **(Class)**: obligatory attribute. Each event is classified in one of the following classes. These are not the traditional classes for event classification, they are lexical category classes. Their identification is performed by combining semantic and syntactic criteria. It is important to point out that the examples show verbs which belong to a given type, but a certain variability among types has to be taken into account, i.e. the same occurrence of the event in question in a different context not necessarily expresses the same type. The definition of the classes are taken from the ISO-TimeML document draft.

- REPORTING: "Reporting events describe the action of a person or an organization declaring something, narrating an event, informing about an event, etc" (ISO (2008): 48); e.g.: *dire, spiegare, raccontare, affermare, notizia, commento...*;

  (C.3) *Punongbayan ha*<EVENT ...class="REPORTING">*detto*</EVENT> *che dal vulcano fuoriuscivano gas con temperature fino a 1.800 gradi.*

  (C.4) <EVENT ...class="REPORTING">*Citando*</EVENT> *l'esempio di....*

- PERCEPTION: "Events involving the physical perception of another event" (ISO (2008): *ibid.*); e.g.: *vedere, guardare, osservare, ascoltare, sentire,...*

  (C.5) *Dei testimoni hanno dichiarato alla polizia di aver* <EVENT ...class="PERCEPTION"*visto*</EVENT> *delle persone fuggire.*

- `ASPECTUAL`: these events code information on a particular phase or aspect in the description of an event. They are a grammatical device which code a kind of temporal information and focus on different facets of the event history. They may signal one of the following aspects:

  (a.) Initiation: *iniziare*, *incominciare*. . . .

  (b.) Reinitiation: *rincominciare*. . . .

  (c.) Termination: *smettere*, *terminare*, *cessare*, *interrompere*.

  (d.) Culmination: *finire*, *completare*. . .

  (e.) Continuation: *continuare*, *andare avanti*. . . .

  Some examples:

  (C.6) `<EVENT ...class="ASPECTUAL">`*iniziando*`</EVENT>` *il consueto lancio di pietre.*

  (C.7) *una trattativa già* `<EVENT ...class="ASPECTUAL">`*conclusa*`</EVENT>`*per l'acquisizione.*

- `I_ACTION`: "`I_ACTION` stands for intensional action. `I_ACTION`s describe an action or situation which introduces another event as its argument, **which must be in the text explicitly**. Explicit performative predicates [...] are also included in this class" (ISO (2008): 49). It is important to point out the difference between "intensional" and "intentional" or purposeful. `I_ACTION`s include but are broader than actions with intended consequences. Note that nouns, in particular nominalizations, can be classified as `I_ACTIONS` as well. In the examples, `I_ACTION`s are in bold and their event arguments, underlined; e.g.:

  (a.) **cercare, provare, tentare**. . .

  (C.8) *Compagnie coma la Microsft stanno* `<EVENT ...class="I_ACTION"`*cercando*`</EVENT>` *di <u>monopolizzare</u>.*

  (b.) **investigare, indagare, ricercare, progettare**. . .

  (C.9) *Una nuova task force ha inizato a* `<EVENT ...class="I_ACTION">`*indagare*`</EVENT>` *sull'<u>uccisione</u> di 14 donne.*

  (C.10) *è ormai in fase avanzata il* `<EVENT ...class="I_ACTION">`*progetto*`</EVENT>` *di <u>ricorrere</u> al mercato.*

  (c.) **ritardare, postporre, ostacolare**. . .

  (C.11) *IsraeIe chiederà agli Stai Uniti di* `<EVENT ...class="I_ACTION">`*ritardare*`</EVENT>` *l'<u>attacco</u> contro l'Iraq.*

  (d.) **evitare, impedire, prevenire, cancellare, disdire**. . .

  (C.12) *La* `<EVENT ...class="I_ACTION">`*cancellazione*`</EVENT>` *<u>dei voli</u> dell'Alitalia ha creato disagi.*

  (C.13) *La Questura di Livorno ha* `<EVENT ...class="I_ACTION">`*impedito*`</EVENT>` *lo <u>svolgimento</u> della manifestazione di Forza Nuova indetta per il 10 Febbraio.*

  (e.) **chiedere, ordinare, persuadere, comandare, richiedere, autorizzare**

  (C.14) *Le autorità hanno* `<EVENT ...class="I_ACTION">`*richiesto*`</EVENT>` *la massima <u>collaborazione</u> da parte dei mezzi di informazione.*

  (f.) **promettere, offrire, assicurare, proporre, accordarsi**

  (g.) **nominare, eleggere, dichiarare, proclamare**

- I_STATE: "They are similar to the events in the previous class. I_STATEs also select for another event as their argument, but contrary to I_ACTIONs, they denote stative situations" (ISO (2008): *ibid.*). The I_STATE is in bold, whereas the embedded argument is underlined. Again, nouns can be classified as I_STATEs.; e.g.:

  (a.) **credere, pensare, immaginare, essere sicuro, sospettare**...

  (C.15) <EVENT ...class="I_STATE">*Crediamo*</EVENT> *che le sue parole non abbiano distratto il pubblico da quello che è accaduto.*

  (b.) **sembrare, desiderare, bramare, auspicare**...

  (C.16) *Il governo italiano ha* <EVENT ...class="I_STATE">*auspicato*</EVENT> *un'intesa in tempi rapidi.*

  (c.) **sperare, aspirare, decidere**...

  (C.17) <EVENT ...class="I_STATE">Sperano</EVENT> *che i residenti rientreranno nelle loro case una volta cessato l'allarme.*

  (d.) **temere, odiare, essere preoccupato, aver paura, spaventarsi**...

  (C.18) <EVENT ...class="I_STATE">*Temevano*</EVENT> *per la loro incolumità.*

  (e.) **aver bisogno, necessitare**...

  (f.) **dovere, potere, volere, sapere, essere in grado di, riuscire**

  (C.19) *I soldati* <EVENT ...class="I_STATE">*devono*</EVENT> *essere ritirati dall'Iraq.*

- OCCURRENCE: This class includes all other types of events describing situations that happen or occur in the world.

  (C.20) *Il patrimonio dell'Assofondi è* <EVENT ...class="OCCURRENCE">*cresciuto*</EVENT>.

  (C.21) *I ministri dei 150 Paesi se ne* <EVENT ...class="OCCURRENCE">*tornano*</EVENT> *in patria.*

  (C.22) <EVENT ...class="OCCURRENCE">*L' uragano*</EVENT>*, definito di " prima grandezza " , è in grado di provocare danni per miliardi di dollari.*

- STATE: "States describe **circumstances** in which something obtains or holds true" (ISO (2008): 50). As already stated in section C.2.2 only a subset of states is annotated in particular:

  (a.) "States that are identifiably changed over the course of the document being marked up" (ISO (2008): *ibid.*).

  (C.23) *Numerosi punk sono tutt'ora* <EVENT ...class="STATE">*agli arresti*</EVENT>.

  (C.24) *auto e cabine telefoniche* <EVENT ...class="STATE">*distrutte*</EVENT> .

  (b.) "States that are directly related to a temporal expression." (ISO (2008): *ibid.*). This includes all states that are linked to a TIMEX3 tag (see section C.2.3) by means of a TLINK (see section C.3.1). In the examples, the associated temporal expression is underlined.

  (C.25) *Silvio Berlusconi è stato il* <EVENT ...class="STATE">*Presidente del Consiglio*</EVENT> *negli ultimi 5 anni.*

  To clarify this condition notice the difference between the two sentences below: in C.26 the sortal noun "*proprietario*" must not be marked as a STATE because it is not temporally relevant, while in C.27 the presence of the temporal expression "*attuale*" gives rise to a temporal relation with the noun, and thus it must be marked.

(C.26) *Silvio Berlusconi è il proprietario di Mediaset.*

(C.27) *Silvio Berlusconi è l'attuale* `<EVENT ...class="STATE">`*proprietario*`</EVENT>` *di Mediaset.*

(c.) "States that are introduced by an I_ACTION, an I_STATE, or a REPORTING event" (ISO (2008): *ibid.*).

(C.28) *Una partecipazione* <EVENT ...class="I_ACTION">*garantita*</EVENT> *dalla* <EVENT ...class="STATE">*presenza*</EVENT> *dei nostri ministri.*

(C.29) *Ha* <EVENT ...class="REPORTING">dichiarato</EVENT> *che è* <EVENT ...class="STATE">*un bugiardo*</EVENT>.

(d.) "Predicative states the validity of which is dependent on the document creation time" (ISO (2008): *ibid.*). In some cases, according to the general context of the document, the absence of an explicit relation with a temporal expression does not prevent the annotation of states. In such cases, the state is perceived as still valid with respect to the document creation time (DCT), i.e. the state still holds at the point in time when it was asserted.

(C.30) *Più di 2.000 soldati italiani sono* <EVENT ...class="STATE">*in Afghanistan*</EVENT>[3].

(C.31) *In totale, sono* <EVENT ...class="STATE">*più di 4 milioni*</EVENT> *gli stranieri regolari in Italia*[4].

(C.32) *Le quote di circolazione sono salite dai* <EVENT ...class="STATE">*3,6 miliardi*</EVENT> *ai 3,7 di oggi*[5].

Note that this condition does not apply to sortal nouns, like "*presidente*", "*proprietario*" and similar, to which condition (b.) applies. Finally, the class of STATE does not contain any instance of I_STATEs.

E. pos (Part of Speech): obligatory attribute. It signals the distinction of the different grammatical categories which may realize an event. Its values are VERB, for events realized by verbs or VPs, ADJECTIVE, for events realized by adjectives, NOUN, for events realized by nouns, PREPOSITION, for events realized by prepositional phrases, and, OTHER, for all other realizations of events which do not fit into one of the previous categories.

(C.33) *I pompieri hanno* <EVENT ...pos="VERB">*isolato*</EVENT> *la sala.*

(C.34) <EVENT ...pos="NOUN">*La caduta*</EVENT> *della base aerea di Ubdina* <EVENT ...pos="VERB">*allontana*</EVENT> *il fronte di 120 km.*

(C.35) *La coppia,* <EVENT ...pos="ADJECTIVE">*residente*</EVENT> *a Milano,* <EVENT ...pos="VERB">*stava trascorrendo*</EVENT> *un periodo di vacanza in Sicilia.*

(C.36) *Una giovane turista* <EVENT ...pos="PREPOSITION">*in vacanza*</EVENT> *nel villaggio "Katibubbo"* <EVENT ...pos="VERB">*è morta*</EVENT>.

E. tense (Tense): obligatory attribute. It captures standard distinctions in the grammatical category of verbal tense. It can have values PRESENT, PAST, FUTURE, IMPERFECT,

[3] And they are still there ("*in Afghanistan*" at the moment of writing the article.

[4] And they are still "*più di 4 milioni*" at the moment of writing

[5] And they were "*3,6 miliardi*" at the moment of writing

or NONE. The values assigned to this attribute mirror the highly-surface based character of TimeML and ISO-TimeML. The values presented are based on classical tense distinctions in Italian. It is important to stress the fact that on the level of general temporal reference there are no major differences between Italian and English and also among other Indo-European languages. In Table C.1, correspondences between the classical grammatical tense classification system and the TimeML values are presented:

Table C.1: *Tense classification and corresponding TimeML values.*

Classical Grammatical Tense Classification	It-TimeML values
Presente Semplice	PRESENT
Passato Composto	PAST
Imperfetto	IMPERFECT
Passato Semplice	PAST
Trapassato	PAST
Piucchepperfetto (or Trapassato Prossimo)	PAST
Futuro Semplice	FUTURE
Futuro Composto	FUTURE

Section C.4.1.3 on page 278 will present rules for annotation of the attribute `tense` with detailed examples.

F. `aspect` **(Aspect)**: obligatory attribute. It captures standard distinctions in the grammatical category of semantic aspect. It can have values `PROGRESSIVE, PERFECTIVE, IMPERFECTIVE`, or `NONE`. With respect to English, Italian has not a clear-cut morphological distinction to code semantic aspect. It is recognized and determined more on a sort of pragmatic level. Note that due to language specific issues and in the perspective of an automatic annotation process we do not propose to use fine-grained values like *aorist*, *perfect*, *continuous* or *habitual* but general cover term like `PERFECTIVE` and `IMPERFECTIVE`. The `PROGRESSIVE` value, which is a specification of the IMPERFECTIVE aspect, is restricted to explicit cases realized in Italian by an aspectual periphrasis (e.g. "*sto giocando*"). Section C.4.1.3 on page 278 will present rules for the annotation of the attribute `aspect` with detailed examples.

G. `polarity` **(Polarity)**: obligatory attribute. It captures the grammatical category that distinguishes affirmative and negative statements. Its values are `POS` in affirmative sentences and `NEG` in negative ones.

H. `mood` **(Mood)**: obligatory attribute. It captures the contrastive grammatical expressions of different modalities about the event realization. It can have the following values:

- `NONE`: it is used as the default value; indicative is considered the default.

  (C.37) *Le forze dell'ordine hanno* `<EVENT ...mood="NONE">`*schierato*`</EVENT>` *in campo 3.000 agenti.*

- `COND`: it signals the conditional mood which in Italian is realized by the morphological inflection on the verb. It is used to speak of an event whose realization is dependent on a certain condition, or to signal the future-in-the-past.

  (C.38) `<EVENT ...mood="COND">`*Mangerei*`</EVENT>` *del pesce.*

- `SUBJUNCTIVE`: it has several uses in independent clauses and is required for certain types of dependent clauses.

  (C.39) `<EVENT mood="NONE">`*Voglio*`</EVENT>` *che tu te ne* `<EVENT ...mood="SUBJUNCTIVE">`*vada*`</EVENT>`.

I. `vForm` **(Verb form)**: obligatory attribute. It captures the distinctions between finite and non-finite verb forms. Its values are `NONE`, `INIFINITIVE`, `PARTICIPLE` and `GERUNDIVE`. The value for all finite verb forms is `NONE`.

(C.40) *l'ultima area del comprensorio romano Torre Spaccata che ancora* `<EVENT ...vForm="NONE">`*mancava*`</EVENT>` *per* `<EVENT ...vForm="INFINITIVE">`*unificare*`</EVENT>` *la proprietà.*

(C.41) `<EVENT ...vForm="PARTICIPLE">`*Certificato*`</EVENT>` *il bilancio della società.*

(C.42) *I Fumagalli, infatti, hanno* `<EVENT ...vForm="NONE">`*incaricato*`</EVENT>` *lo studio di un agente di cambio milanese.*

(C.43) *hanno* `<EVENT ...vForm="NONE">`*attaccato*`</EVENT>` la Flm nazionale e regionale `<EVENT ...vForm="GERUNDIVE">`*accusando*`</EVENT>`*le di averli* `<EVENT ...vForm="INFINITIVE">`*esclusi*`</EVENT>`.

J. `modality` **(Modality)**: optional attribute. It is used to convey the different degrees of modality nature of an event, mainly epistemic and deontic. Its values are represented by the modal verb itself.

(C.44) *I profughi* `<EVENT ...modality="DOVERE">`*devono*`</EVENT>` `<EVENT>`*abbandonare*`</EVENT>` *le loro case.*

C.2.3 The tag `<TIMEX3>`

What is normally referred to with the label *temporal expressions* (i.e. timexes) in the NLP community is only a small and closed subset of words which have temporal reference or meaning, in particular, as it is stated in the annotation guidelines of TIDES (2001) "the flagging of temporal expressions is restricted to those temporal expressions which contained a reserved time word, called **lexical trigger**" (Ferro et al. (2001): 2). This means that many other words (e.g. *scuola*, *presidenza*, *incubazione* ...) which can assume a temporal meaning are excluded. The specifics of the TimeML tagset for annotating temporal expressions differ in details from both the `TIMEX` tag in STAG and the `TIMEX2` tag in TIDES, though some common points are kept.
The `<TIMEX3>` tag, thus, marks up any temporal expression referring to:

(a.) Day times (*mezzogiorno, 3, la sera, la mattina ...*);

(b.) Dates of different granularity: days (*ieri, 8 Gennaio 1980, venerdì scorso, sabato ...*), weeks (*la prossima settimana, la seconda settimana del mese ...*), months (*tra due mesi, il mese prossimo, l' Agosto del 1980 ...*), seasons or business quarters (*la scorsa primavera, lo scorso semestre, il primo trimestre, il bimestre ...*), years (*1980, l'anno scorso, ...*), centuries, ...

(c.) Durations (*due mesi, cinque ore, nei prossimi anni, il periodo ...*).

(d.) Sets (*una volta al mese, ogni martedì ...*).

Table C.2: *Temporal expression triggers and corresponding POS.*

Timex Lexical Triggers	POS
agosto, alba, anniversario, domenica, estate, giornata, serata, futuro, lustro, stagione…	Nouns
Natale, Pasqua, Capodanno, Ferragosto	Proper Nouns
25/07/2007, 1980, 13:11…	Calendar/Time Patterns
annuale, primaverile, estivo, recente, mensile…	Adjectives
annualmente, oggi, ora, allora, adesso, finora, ieri, tutt'ora…	Adverbs
primo, secondo, 1, 31, 28…	Numbers

The linguistic realizations of temporal expressions present a reduced set of variations with respect to the eventualities and are, in a certain way, more regular. In Table C.2 we report on the possible linguistic realizations of temporal expressions together with some examples.

Additional properties of timexes related to their meaning are:

- **Granularity** level: the value of a timex may be more or less precise. An expression like "*lo scorso fine settimana*" can refer to the entire week-end or a specific day in the week-end. The timeline format used to normalize the values of timexes, i.e. to assign them a standard value corresponding to point (or interval) on a calendar/clock or to an unanchored duration, is based on the Gregorian calendar, and derived from the ISO 8601 standard for time values. The format is of the general form *YYYY-MM-[WW]DDhh:mm:ss*.This means that the granularity of an expression can have the values *Year*, *Month*, *Week*, *Day*, *Hour*, *Minute* and *Second* including also *Millennium*, *Century* and *Decades*.
- **Fuzziness**: many timexes have fuzzy boundaries in their intended values with respect to when the denoted time period starts and ends, e.g.; *ora*, *circa tre anni*, *nei primi anni sessanta* …
- **Ambiguity**: like many other expressions, timexes can be ambiguous, e.g. the expression "*il prossimo mese*" if uttered on July 25th, 2007, can mean August 2007, or exactly one month after the moment of utterance, i.e. August 25th. Disambiguating a timex means figuring out which of the possible values is the intended one.

C.2.3.1 BNF description of the `EVENT` tag

```
attributes ::= id anchor type [functionInDocument][beginPoint]
           [endPoint] [quant][freq][temporalFunction]
           (value|valueFromFunction) [mod][anchorTimeID]
id ::= ID
{ID ::= TimeID
TimeID ::= t<integer>}
anchor ::= IDREF
{anchor ::=(token<integer>)
type ::= DATE | TIME | DURATION | SET
```

```
beginPoint ::= IDREF
{beginPoint ::= TimeID}
endPoint ::= IDREF
{endPoint ::= TimeID}
quant ::= CDATA
freq ::= CDATA
functionInDocument ::= CREATION_TIME | EXPIRATION_TIME |
                     MODIFICATION_TIME | PUBLICATION_TIME |
                     RELEASE_TIME | RECEPTION_TIME |  NONE
                 {default, if absent, is 'NONE'}
temporalFunction ::= true | false {default, if absent, is 'false'}
{temporalFunction ::= boolean}
value ::= CDATA
{value ::= duration | dateTime | time | date | gYearMonth |
             gYear | gMonthDay | gDay | gMonth}
valueFromFunction ::= IDREF
{valueFromFunction ::= TemporalFunctionID
TemporalFunctionID ::= tf<integer>}
mod ::= BEFORE | AFTER | ON_OR_BEFORE | ON_OR_AFTER |
             LESS_THAN | MORE_THAN | EQUAL_OR_LESS |
             EQUAL_OR_MORE | START | MID | END | APPROX
anchorTimeID ::= IDREF
{anchorTimeID ::= TimeID}
```

C.2.3.2 Attributes for TIMEX3

A. id (Temporal Expression ID): obligatory attribute. It assigns a unique ID number to each timex instance. It is automatically assigned by the annotation tool whenever the TIMEX3 tag is assigned to a string.

B. anchor (Anchor): obligatory attribute. It is used in stand-off annotation to link each tag to the primary data, see point B C.2.2.2 on page 259.

C. type (Type): obligatory attribute. It specifies the type of the timex. Its values are DATE, TIME, DURATION and SET.

- DATE: this type applies to all temporal expressions which describe a calendar time.

  (C.45) *1,6 milioni di sterline di utile nel* <TIMEX3 ...type="DATE">*1985*</TIMEX3>.

  (C.46) *Ha sostanzialmente contestato l'accordo raggiunto* <TIMEX3 ...type="DATE">*venerdì scorso*</TIMEX3>.

- TIME: the temporal expression refers to a time of the day, even if in a very indefinite way. Clock times are classified as TIME as well.

  (C.47) *L' ultima ondata di violenza si è scatenata* <TIMEX3 ...type="TIME">*sabato notte*</TIMEX3>.

  (C.48) *L'assemblea è iniziata alle* <TIMEX3 ...type="TIME">*15.00*</TIMEX3>.

- DURATION: the expression describes a duration, i.e. a period of time not pointing to any specif area in the time axis. This value is assigned only to explicit durations.

(C.49) *La trattativa dura ormai da* <TIMEX3 ...type="DURATION">*oltre un mese*</TIMEX3>.

(C.50) *Un incremento del 105 per cento in* <TIMEX3 ...type="DURATION">*10 mesi*</TIMEX3>.

As a rule, if any specific calendar information is supplied in the temporal expression, then the type of the TIMEX3 must be either DATE or TIME. For instance, an expression like "1985" cannot be marked as a DURATION, even if the context may suggest that an event holds throughout that year. Temporal expressions like the former "must always be of type DATE, since they refer to a particular area in the temporal axis –even though that area spans over a period of time" (ISO (2008): 57).

- SET: The expression describes a set of times.

  (C.51) *Meno di un milione di tonnellate* <TIMEX3 ...type="SET">*all'anno*</TIMEX3>.

  (C.52) *un raduno che dal 1982 si tiene* <TIMEX3 ...type="SET">*quasi tutti gli anni*</TIMEX3>.

D. value (Value): obligatory attribute. It expresses the temporal value of the temporal expressions, i.e. it assigns to the temporal expression a normalized value corresponding to a calendar date, a clock time or special formats for durations based on the ISO 8601 standard and its extensions in TIDES. The format of this attribute value is determined by the type attribute. Details and examples will be provided in section C.4.2.

E. mod (Modifier): optional attribute. This attribute is inherited directly from the TIMEX2 MOD attribute. It is used to signal the presence of a modifier which changes/influences the interpretation of the value attribute. In general, mod captures the meaning of some quantifier modifiers (e.g. *circa*, *oltre*...) and lexicalized aspectual markers (*inizio*, *fine*, *tardo*...). Its values are BEFORE, AFTER, ON_OR_AFTER, LESS_THAN, MORE_THAN, EQUAL_OR_LESS, EQUAL_OR_MORE, START, MID, END, and APPROX. Details and a table with correspondences between linguistic tokens and values will be provided in section C.4.2.

F. temporalFunction (Temporal Function): obligatory attribute. Its values are true and false. "It expresses whether the value of the temporal expression needs to be determined via evaluation of a temporal function. Temporal functions will be applied as a postprocess." (ISO (2008): 59). Details on how to assign the values and examples in section C.4.2.

G. anchorTimeID (Temporal anchor time ID): optional attribute. It introduces the id value of the temporal expression to which the TIMEX3-marked expression is linked in order to compute its value. To illustrate how this attribute works, consider the following example:

(C.53) *<TIMEX3>Ieri</TIMEX3> circa mille giovani hanno lasciato la città.*

"*Ieri*" requires the application of a temporal function: to know the calendar date corresponding to "*Ieri*" we need to identify its temporal anchor, that is another temporal expression which helps us to recover all the necessary information to identify its Year, Month and Day. Imagine this anchor is the time at which the document has been created (i.e. 26/11/2008), whose id is t0, then we will obtain this representation:

(C.54) <TIMEX3 ...anchorTimeID="t0">*Ieri*</TIMEX3> *circa mille giovani hanno lasciato la città.*

H. `valueFromFunction` **(Value from Function)**: optional attribute. It is not relevant for manual annotation. Human annotators should ignore it.

I. `functionInDocument` **(Function in document)**: optional attributes. It indicates what is the function of a temporal expression in the document and its function as a temporal anchor for other temporal expressions. Its values are:

(a.) `CREATION_TIME`: the time the text is created;

(b.) `MODIFICATION_TIME`: the time the text is modified;

(c.) `PUBLICATION_TIME`: the time the text is published;

(d.) `RELEASE_TIME`: the time it may be released (if not immediately);

(e.) `RECEPTION_TIME`: the time it is received by a reader;

(f.) `EXPIRATION_TIME`: the time that the text expires (if any)

(g.) `NONE`: the default value; a general time without a particular reference to document 's life.

J. `beginPoint` **(Beginning point) and** `endPoint` **(Ending point)**: optional attributes. These attributes are used to strengthen the annotation of durations. They are used when a duration is (or can be) anchored to one or two temporal expressions which signal(s) its beginning and/or ending point(s). In some ways these attributes are similar to `anchorTimeID`.

K. `quant` **(Quantifier) and** `freq` **(Frequency)**: optional attributes. These attributes are (generally) used in conjunction with temporal expressions classified with type `SET`. `quant` is a literal from the text; it corresponds to general quantifiers like "*ogni*", "*tutto*" .... `freq` is expressed by a integer and a time granularity (e.g. D = Day, Y = Year, M = Month, X = not specified ...) and it expresses the frequency with which the event linked to the temporal expression occurs.

(C.55) `<TIMEX3 ...type="SET" freq="1X">`*una volta a settimana*`</TIMEX3>`.

(C.56) `<TIMEX3 ...type="SET" quant="OGNI">`*ogni tre settimane*`</TIMEX3>`.

C.2.4 The tag `<SIGNAL>`

This tag is used to mark up all those textual elements which make explicit a relation between two entities. Entities' relations may be of three kinds:

(a.) relations between two temporal expressions (timex - timex);

(b.) relations between a temporal expression and an event (timex - event); and

(c.) relations between two events (event - event)

The range of linguistic expressions which are to be marked as events is restricted to:

- Temporal prepositions: *prima*, *durante*, all simple and complex prepositions followed by a temporal expression...;
- Temporal conjunctions: *prima, quando, mentre* ...;
- Temporal adverbs: *intanto, nel frattempo,* ...
- Special characters: "-" and "/", in temporal expressions denoting ranges (e.g. *26 - 28 Settembre 2006*);
- Prepositions and conjunctions signalling a subordinating relation (see section C.3.3): *per*, *affinché*, *se*....

C.2.4.1 BNF description of the SIGNAL tag

```
attributes ::= id anchor
id ::= ID
{ID ::= s<integer>}
anchor ::= IDREF
{anchor ::= (token<integer>)*}
```

C.2.4.2 Attribute for SIGNAL

A. ID **(Signal ID)**: obligatory attribute. It assigns a unique ID number to each signal instance.

C.3 The link tags: <TLINK>, <ALINK> and <SLINK>

These tags are not markables. They are used to signal three different kinds of relations which may exists between the annotated entities.

C.3.1 TLINK

The TLINK tag represents the temporal relationship holding between two events, two temporal expressions, or between an event and a temporal expression, and indicates how they are temporally related. Possible temporal relations are:

(a.) **Simultaneous**: the two events are judged as simultaneous if they happen at the same time, or if an event is perceived as happening at a moment (point or interval) in time:

(C.57) <EVENT>*Fumo*</EVENT> *instancabilmente quando* <EVENT>*scrivo*</EVENT>.

(b.) **Before**: an event (or temporal expression) is before an other:

(C.58) *Circa mille giovani hanno* <EVENT>*lasciato*</EVENT> *la città. Un grande magazzino di generi alimentari a buon mercato è stato* <EVENT>*saccheggiato*</EVENT>.

(c.) **After**: the inverse of the preceding relation;

(d.) **Immediately before**: one immediately before the other:

(C.59) *Nell'*<EVENT>*impatto*</EVENT> *tutti i passeggeri a bordo* <EVENT>*sono morti*</EVENT>.

(e.) **Immediately after**: the inverse of the preceding relation;

(f.) **During**: one entity holds during the other; it it applicable to those events which persist through a duration:

(C.60) *Marco* <EVENT>*insegna*</EVENT> *per* <TIMEX3>*un'ora*<TIMEX3> il *lunedì.*

(g.) **Includes**: one entity includes the other[6]:

(C.61) *Marco è* <EVENT>*arrivato*</EVENT> *a Boston* <TIMEX3>*lunedì*</TIMEX3>.

(h.) **Being included**: the inverse of the preceding relation;

(i.) **Beginning**: one entity being the beginning of the other:

[6]It corresponds to Allen (1984)'s `during` relation.

(C.62) *Si* <EVENT>*cerca*</EVENT> *un accordo da* <TIMEX3>*ieri*</TMEX3>.

(j.) **Begun by**: the inverse of the preceding relation;

(k.) **Ending**: one entity being the ending of another:

(C.63) *Marco è stato* <EVENT>*in palestra*</EVENT> *fino alle* <TIMEX3>*7*</TIMEX3>.

(l.) **Ended by**: the inverse of the preceding relation;

TLINKs are also used to in the following situations:

- **To signal event identity**: the same event can be referred more than once in the document. These cases, which corresponds to istances of anaphoric, i.e. coreferential, relations are marked by using the TLINK e.g.:

  (C.64) *Marco ha* <EVENT>*guidato*$_1$</EVENT> *fino a Boston ieri. Durante* <EVENT>*la guida*$_1$</EVENT> *ha mangiato una ciambella.*

  As the indexes shows the events " *(ha) guidato*" and "*guida*" express the same event, the latter being coreferential with the former.

- **Causative constructions**: two cases of causative constructions can be identified:

  (i.) EVENT causare EVENT

  (C.65) <EVENT>*La pioggia*</EVENT> *ha* <EVENT>*causato*</EVENT> <EVENT>*delle alluvioni*</EVENT>.

  (ii.) HUMAN — ENTITY causare EVENT

  (C.66) *Marco ha* <EVENT>*causato*</EVENT> <EVENT>*l'incendio*</EVENT>.

  TLINK should be used only in cases like (i.). Cases like (ii.) are not to be tagged with TLINK. Details for the annotation of cases like (i.) will be provided in section C.5.1.

- **Light verb constructions (*costruzioni a verbo supporto*)**: the relation between the light verb and the nominal is marked with a TLINK. Details and examples in section C.5.1.

- **Set/Subset relationship**: in some cases, between two events may exist a (semantic) relation of set/subset. An example is:

  (C.67) *La polizia sta indagando su* <EVENT>*14 casi di omicidio*</EVENT>*. In* <EVENT>*6 di questi*<EVENT> *i sospetti sono stati arrestati.*

  The second EVENT tag is a subset of the first one and the two events will be related via a TLINK.

C.3.1.1 BNF description of TLINK

```
attributes ::= [id] [origin] (eventID | timeID) [signalID]
               (relatedToEvent | relatedToTime) relType
id ::= ID
{id ::= LinkID
LinkID ::= l<integer>}
origin ::= CDATA
eventID ::= IDREF
{eventID ::= EventID}
timeID ::= IDREF
{timeID ::= TimeID}
```

```
signalID ::= IDREF
{signalID ::= SignalID}
relatedToEvent ::= IDREF
{relatedToEvent ::= EventID}
relatedToTime ::= IDREF
{relatedToTime ::= TimeID}
relType ::= BEFORE | AFTER | INCLUDES | IS_INCLUDED
            | DURING | DURING_INV | SIMULTANEOUS
            | IAFTER | IBEFORE | IDENTITY | BEGINS
            | ENDS | BEGUN_BY | ENDED_BY
temporalDistance ::= IDREF
{temporalDistance ::=TimeID}
```

C.3.1.2 Attributes of TLINK

A. ID **(Temporal Link ID)**: obligatory attribute. It assigns a unique ID number to each temporal link.

B. eventID **(Event ID) or** timeID **(temporal expression ID)**: obligatory attributes. These attributes signal, respectively, the ID of the event **or** of the temporal expression from which the temporal relation is created.

C. signalID **(Signal ID)**: optional attribute. It represents the ID of the SIGNAL which signals the existence of a temporal relation between two entities.

D. relatedToEvent **(Related to the event) or** relatedToTime **(Related to the temporal expression)**: obligatory attributes. They represent the ID of the target event **or** of temporal expression which is related to either the event instance, with eventID, or to the time expression, with timeID.

E. relType **(Relation type)**: obligatory attribute. This is the core attribute of this link, it explicits the temporal relations between the entities involved. Its values are: BEFORE, AFTER, INCLUDES, IS_INCLUDED, DURING, DURING_INV, SIMULTANEOUS, IAFTER, IBEFORE, IDENTITY, BEGINS, ENDS, BEGUN_BY, ENDED_BY. There will be only **one relation** assigned per TLINK. Details on their annotation and examples will be presented in section C.5.1.

F. temporalDistance **(Temporal Distance)**: optional attribute. It signals the temporal distance, typically a duration, between two events when it is expressed in the document. Details and examples in section C.5.1.

C.3.2 ALINK

An ALINK, or aspectual link, represents relations between aspectual or phasal events (EVENT class="ASPECTUAL") and their event arguments. There are different types of aspectual relations according to the semantics of the phasal/aspectual event (see also section C.2.2.2 point **D.**):

(a.) **Initiation**:

(C.68) *Il Parlamento* `<EVENT ...class="ASPECTUAL">`*incomincerà*`</EVENT>` `<TIMEX3>`*il 3 aprile prossimo*`</TIMEX3>` *un* `<EVENT ...class="OCCURRENCE">`*dibattito*`</EVENT>`.

(b.) **Culmination**:

(C.69) *La Germania federale ha* `<EVENT ...class="ASPECTUAL">`*concluso*`</EVENT>` *un* `<EVENT ...class="OCCURRENCE">`*accordo*`</EVENT>` *con gli Stati Uniti.*

(c.) **Termination**:

(C.70) *Marco* `<EVENT ...class="ASPECTUAL">`*ha smesso*`</EVENT>` *di* `<EVENT ...class="ASPECTUAL">`*fumare*¡/EVENT¿.

(d.) **Continuation**:

(C.71) `<EVENT ...class="OCCURRENCE">`*La trattativa*`</EVENT>` `<EVENT ...class="ASPECTUAL">`*dura*`</EVENT>` *ormai* `<SIGNAL sid="s1">`da`</SIGNAL>` `<TIMEX3>`oltre un mese`</TIMEX3>`.

C.3.2.1 BNF description of ALINK

```
attributes ::= [id] [origin] eventID [signalID]
               relatedToEvent relType
id ::= ID
{ID ::= LinkID
LinkID ::= l<integer>}
origin ::= CDATA
eventID ::= ID
{ID ::= EventID}
signalID ::= IDREF
{signalID ::= SignalID}
relatedToEvent ::= IDREF
{relatedToEvent ::= EventID}
relType ::= INITIATES | CULMINATES | TERMINATES
               | CONTINUES | REINITIATES
```

C.3.2.2 Attributes of ALINK

A. `id` **(Aspectual Link ID)**: obligatory attribute. It assigns a unique ID number to each aspectual link.

B. `signalID`: optional attribute. It represents the ID of the SIGNAL which signals the aspectual relation between the two events.

C. `relatedToEvent` **(Related to event)**: obligatory attribute. It represents the ID of the event argument which is related to the aspectual event.

D. `relType` **(Relation type)**: obligatory attribute. This is the core attribute of this link, it explicits the type of aspectual relation between the events involved. Its values are: INITIATES, CULMINATES, TERMINATES, CONTINUES, REINITIATES. There will be only **one relation** assigned per ALINK. Details on their annotation and examples will be presented in section C.5.2.

C.3.3 SLINK

An SLINK, or subordination link, is used to explicit particular types of subordinating relations between two events for contexts introducing relations between two events. With respect to the other two link tags, SLINK are not unique, i.e. an event may be slink-ed to more than one event.
SLINKs can be of two types:

- **Lexically-based**: "they are triggered by an event of class I_ACTION, I_STATE, PERCEPTION, or REPORTING, which are events that generally take a clausal complement or an NP headed by an event-denoting nominal. The SLINK is established between those events and the one denoted by the complement" (ISO (2008): 67). For each event belonging to the above classes an SLINK with its event argument must be created.
- **Structurally-based**:
  - (i.) **Purpose clauses**: they correspond to the Italian subordinated clause *finale*. The SLINK is created between the event in the main clause and the event in the subordinated clause *finale*.
  - (ii.) **Conditional constructions**: in conditional constructions an SLINK is always created between the main clause and the consequent clause, or *se*-clause.

  Subordinating relations between events are varied. For the purpose of the annotation scheme 6 of them have been considered as most relevant. Notice that from these relations can be inferred additional (i.e. implicit) temporal links. Possible relations are:

  (a.) **Intensionality**: It refers to the set of all possible things a word or phrase could describe. Intensional subordinating links are created by events which introduce a reference to a possible world:

  (C.72) <EVENT>*Spero*</EVENT> *che tu* <EVENT>*venga*<EVENT>.

  The first event ("*spero*") gives rise to a subordination link with the second event ("*venga*"), expressing a reference to a possible world where the participant of the event is able to come. Notice that in Italian intensional relations are marked (normally) by the use of the subjunctive and conditional moods in the subordinate clause. Some instances of intensional relations are coded by the lexical meaning of the event in the main sentence (e.g. "*La polizia ha* ***provato*** *ad* <u>*arrestare*</u> *il ladro*"). Intensional relations hold also between a modal verb and its argument event.

  (b.) **Factive**: this relations signals the presupposition or entailment about the veridicity of the event argument or of the event expressed in a subordinated clause:

  (C.73) <EVENT>*Mi spiace*</EVENT> *che tu non* <EVENT>*venga*</EVENT>.

  The first event ("*mi spiace*") entails the truthfulness of the second event, i.e. the fact that the participant does not come.

  (d.) **Counter-factive**: the inverse of the preceding relation, i.e. the event presupposes the non-veridicity of the second event:

  (C.74) *La polizia ha* <EVENT>*impedito*</EVENT> *una* <EVENT>*manifestazione*</EVENT>.

  The first event ("*(ha) impedito*") presupposes the fact that the second event ("*(la) manifestazione*") has not taken place.

(e.) **Evidential**: an evidential relation indicates the nature (or the source) of evidence for a given statement. Evidentiality marks the source of information in a statement[7]. In Italian, evidentiality is not a grammatical category (unlike as it is in lots non Indo-european languages, such as Quechua), and it is thus signalled by the use of adverbials ("*a quanto si dice*") or verbs, namely *verba dicendi* or perception verbs.

(C.75) *Fim-Cisl e Uilm-Uil hanno* `<EVENT>`*annunciato*`</EVENT>` per oggi una `<EVENT>`*conferenza*`</EVENT>` stampa.

(f.) **Negative evidential**: it is the same as the preceding relation, but the polarity of the evidential statement is negative (non affirmative)

(C.76) *Il governo croato* `<EVENT>`*nega*`</EVENT>` *che siano stati* `<EVENT>`*espulsi*`</EVENT>`.

C.3.3.1 BNF description of SLINK

```
attributes ::= [id] [origin] eventID
               [signalID] subordinatedEvent relType
id ::= ID
{id ::= LinkID
LinkID ::= l<integer>}
origin ::= CDATA
eventID ::= IDREF
{eventID ::= EventID}
subordinatedEvent ::= IDREF
{subordinatedEvent ::= EventID}
signalID ::= IDREF
{signalID ::= SignalID}
relType ::= INTENSIONAL | EVIDENTIAL | NEG_EVIDENTIAL |
              FACTIVE | COUNTER_FACTIVE | CONDITIONAL
```

C.3.3.2 Attributes of SLINK

A. `eventID` **(Event ID)**: obligatory attribute. It conveys the ID of the source from which the slink relations starts.

B. `subordinatedEvent` **(Subordinated event**: obligatory attribute. It expresses the ID of the subordinated event, i.e. the target of the slink relation.

C. `signalID`: optional attribute. It conveys the ID of the signal which explicitly expresses the subordinating relation between the events.

D. `relType` **(Relation Type)**: obligatory attribute. It expresses the type of subordinating relation between the two events. Its values are: INTENSIONAL, EVIDENTIAL, NEG_EVIDENTIAL, FACTIVE, COUNTER_FACTIVE, CONDITIONAL. Details and examples will be provided in section C.5.3.

[7]Evidentiality is different from epistemic modality, which marks the speaker's degree of confidence in the propositional content of his/her statement.

C.4 How to annotate the markable tags: EVENT, TIMEX3 and SIGNAL

In the following sections we will provide detailed instructions and examples to annotate the markables tags for It-TimeML.

C.4.1 <EVENT> tag span and attributes' value

It-TimeML, as TimeML and ISO-TimeML, implements a highly surface oriented annotation. As for events, their annotation is based on the notion of *minimal chunk*, because higher constituents may contain more than one event expression. This means that only the head of the event denoting chunk will be marked up with the tag. Auxiliaries, clitics which are not part of the verb form, polarity markers, particles, modifiers, copula elements, complements and specifiers will be disregarded. In the following examples the event-denoting chunk is marked with the EVENT tag, while the event phrase is underlined:

(C.77) *I pompieri hanno* <EVENT>*isolato*</EVENT> *la sala*.

(C.78) <EVENT>*Accusando*</EVENT>*li di* <EVENT>*omicidio*</EVENT>.

(C.79) *La* <EVENT>*riunione*</EVENT> *sta per* <EVENT>*chiudersi*</EVENT>.

(C.80) *Il PIL Italiano non è* <EVENT>*cresciuto*</EVENT> *nell'ultimo trimestre*.

(C.81) *La* <EVENT>*caduta*</EVENT> *della base aerea di Ubdina* <EVENT>*allontana*</EVENT> *il fronte di 120 km*.

(C.82) *Al Sayed è il nuovo* <EVENT>*presidente*</EVENT> *della Fermenta*.

(C.83) *La coppia*, <EVENT>*residente*</EVENT> *a Milano*, *stava* <EVENT>*trascorrendo*</EVENT> *un periodo di vacanza in Sicilia*.

As far as prepositional phrases are concerned, if the prepositional chunk represents an expression denoting an event, then the preposition must be included into the tag. Otherwise, only the noun head of the embedded NP must be annotated if it is an event denoting expression.

(C.84) *Le strade mostrano ancora i segni della* <EVENT>*battaglia*</EVENT>.

(C.85) *Un centinaio di giovani è tuttora* <EVENT>*agli arresti*</EVENT>.

Most event tags will span over only one word, i.e. the minimal chunk, in particular if they are realized by verbs, nouns and adjectives. However, an important issue emerges with the nature of the textual extent of event denoting expressions realized by idioms, verbal collocations, metaphorical uses, light verb constructions, causative constructions and complex NPs of the kind "NP + PP". The following cases are contemplated:

(a.) Cases when a single EVENT tag is created. They comprise all occurrences of idiomatic expressions, metaphors and metaphoric uses, light verb constructions of the form "verb + non-deverbal noun", constructions with "*FARE + indefinite article + non-deverbal noun*", and causative constructions with "*FARE/DARE/METTERE + abstract noun*"[8]:

(C.86) *I punk hanno* <EVENT>*messo a ferro e fuoco*</EVENT> *la città*.

(C.87) *Tocca a Baker* <EVENT>*tirare le somme*</EVENT> *su questo incontro*.

[8]The examples do not present a complete annotation for all the events which may be in the sentences.

(C.88) *Tutte le questioni principali sono* <EVENT>*rimaste sul tappeto*</EVENT>.

(C.89) *La ragazza è morta mentre* <EVENT>*faceva una doccia*</EVENT>.

(C.90) *Daubre ha deciso di* <EVENT>*tenere sulla corda*</EVENT> *il sindacato.*

(C.91) *Mi* <EVENT>*fa paura*</EVENT>.

(b.) Cases when two different EVENT tags are created. Such cases involve light verb constructions of the form "verb + deverbal noun", constructions with "*FARE + indefinite article + deverbal noun*", constructions where "FARE" is used to substitute entire VPs (instances of "*fare*" as "*verbo vicario*"), causative constructions, all event-denoting constructions whose meaning is compositional. In these cases the two tags will be linked by means of a TLINK relation (see section C.5.1 and will receive the same event class value:

(C.92) *I guardiani hanno fatto scattare l'allarme.*

```
<EVENT ... pos="VERB" class="OCCURRENCE">fatto</EVENT>
<EVENT ... pos="VERB" class="OCCURRENCE">scattare</EVENT>
```

(C.93) *Gli Usa hanno fatto sapere che non sono disponibili.*

```
hanno
<EVENT ... pos="VERB" class="OCCURRENCE">fatto</EVENT>
<EVENT ... pos="VERB" class="OCCURRENCE">sapere</EVENT>
```

(C.94) *L'assemblea ha preso visione del bilancio consolidato.*

```
ha
<EVENT ... pos="VERB" class="OCCURRENCE">preso</EVENT>
<EVENT ... pos="NOUN" class="OCCURRENCE">visione</EVENT>
```

(C.95) *Marco ha fatto una passeggiata.*

```
ha
<EVENT ... pos="VERB" class="OCCURRENCE">fatto</EVENT>
una
<EVENT ... pos="NOUN" class="OCCURRENCE">
passeggiata
</EVENT>
```

C.4.1.1 Annotation of modal verbs

Modal verbs in Romance languages are very different from the English ones. In Italian, modal verbs are to be considered similar to other lexical verbs in that it is possible to assign them values for tense and aspect. Consequently, each instance of Italian modal verbs ("*dovere*", "*potere*", "*volere*", "*sapere*") will be annotated with the tag <EVENT>. In addition to this, all modal verbs will be **always** assigned to the class I_STATE. When annotating a modal verb the attribute modality must be filled in:

(C.96) *L'assemblea deve prendere una decisione.*

```
<EVENT ... class="I_STATE" tense="PRESENT"
aspect="IMPERFECTIVE" modality="DOVERE">deve</EVENT>
<EVENT ... tense="PRESENT" aspect="IMPERFECTIVE"
vForm="INFINITIVE" class="OCCURRENCE">prendere</EVENT>
una
<EVENT ... tense="NONE" aspect="NONE"
class="OCCURRENCE">decisione</EVENT>
```

(C.97) *Non ho potuto chiamare l'ufficio cambi.*

```
<EVENT ... class="I_STATE" tense="PAST"
aspect="PERFECTIVE" modality="POTERE">potuto</EVENT>
<EVENT ... tense="PRESENT" aspect="PERFECTIVE"
vForm="INFINITIVE" class="OCCURRENCE">chiamare</EVENT>
```

C.4.1.2 Annotation of verbal periphrases

In Italian it is possible to identify different instances of verbal periphrases. We accept here the proposal of Bertinetto (1991) to identify a hierarchy of verbal periphrases:

(a.) aspectual periphrases which code progressive or habitual aspect:

(C.98) *sta mangiando.*

(C.99) *è solito riposare.*

(b.) modal periphrases which code modality not realized by proper modal verbs:

(C.100) *essere in grado di + INFINITIVE.*

(C.101) *c'è da + INFINITIVE.*

(C.102) *andare + INIFINITIVE (va fatto).*

(C.103) *avere da + INFINITIVE.*

(c.) phasal (aspectual) periphrases which code information on a particular phase (or aspect) in the description of a particular event, corresponding to those verbs classified as `ASPECTUAL` events (see point D section C.2.2.2 `class`: ASPECTUAL)

Following Bertinetto (1991), we claim that only in the last two cases, i.e. modal periphrases and phasal (aspectual) periphrases, both elements involved should be annotated with a separate `EVENT` tag, while in the case of the aspectual periphrasis only the non finite verb form is to be tagged. The value of the attribute `modality` for modal periphrases is not represented by the periphrasis itself but by the corresponding modal verb, namely "*dovere*" or "*potere*". Finally, it is important to point out that phasal periphrases always give rise to an `ALINK`, whose value is dependent on the meaning of the phasal/aspectual verb, while modal periphrases always give rise to an `SLINK`, whose value is `INTENSIONAL` :

(C.104) *La borsa stava perdendo l'1,1% in prima mattinata.* (Progressive periphrasis)

```
<EVENT class="I_ACTION">perdendo</EVENT>
```

(C.105) *A oggi siamo in grado di dire che l'accordo non è stato raggiunto.* (Modal periphrasis)

```
<EVENT class="I_STATE"
modality="POTERE">siamo in grado</EVENT>
di
<EVENT class="REPORTING">dire</EVENT>
```

(C.106) *C'è da dire che questo trattamento non è soddisfacente.* (Modal periphrasis)

```
<EVENT class="I_STATE" modality="DOVERE">c'è</EVENT>
da
<EVENT class="REPORTING">dire</EVENT>
```

(C.107) *Il magistrato ha iniziato a condurre le indagini sulla mortedi Calipari.*(Phasal/Aspectual periphrasis)

```
<EVENT class="ASPECTUAL">iniziato</EVENT>
a
<EVENT class="I_ACTION">condurre</EVENT>
```

C.4.1.3 Annotation of tense and aspect

In this section we present the values and rules for annotating `tense` and `aspect` in Italian. Assignment of more than one value for `aspect` is due to the fact that the same tense can have more than one aspectual value according to co-textual and con-textual factors.

(a.) Events realized by finite verb forms:

* tense= "PRESENT"
  - *gioca* aspect= IMPERFECTIVE — PERFECTIVE — NONE
  - *sta giocando* aspect= PROGRESSIVE
  - *ha l'abitudine di giocare* aspect= IMPERFECTIVE
  - *ha mangiato* aspect= IMPERFECTIVE
  - *(che) mangi* aspect= IMPERFECTIVE — NONE
  - *mangerebbe* aspect= NONE
* tense= "PAST"
  - *giocò* aspect= PERFECTIVE
  - *ha giocato* aspect= PERFECTIVE — IMPERFECTIVE
  - *ebbe l'abitudine di giocare* aspect= PERFECTIVE
  - *fu mangiato* aspect= PERFECTIVE
  - *è stato mangiato* aspect= PERFECTIVE
  - *(che) abbia mangiato* aspect= PERFECTIVE
  - *aveva giocato* aspect= PERFECTIVE — IMPERFECTIVE
  - *ebbe giocato* aspect= PERFECTIVE
  - *era stata mangiata* aspect= PERFECTIVE
  - *(che) avesse mangiato* aspect= PERFECTIVE
  - *avrebbe mangiato* aspect= PERFECTIVE
* tense= "IMPERFECT"
  - *giocava* aspect= IMPERFECTIVE — PERFECTIVE
  - *stava giocando* aspect= PROGRESSIVE
  - *aveva l'abitudine di giocare* aspect= IMPERFECTIVE
  - *era mangiata* aspect= IMPERFECTIVE
  - *(che) mangiasse* aspect= NONE
* tense= "FUTURE"
  - *giocherà* aspect= IMPERFECTIVE — PERFECTIVE
  - *avrà giocato* aspect= PERFECTIVE — IMPERFECTIVE
  - *sarà mangiata* aspect= IMPERFECTIVE

(b.) Events realized by non-finite verb forms:

* tense= "PRESENT" vform="INFINITIVE"

- *giocare* aspect= PERFECTIVE — IMPERFECTIVE — NONE

∗ tense="PAST" vform="INFINITIVE"

-*aver giocato* aspect= PERFECTIVE

∗ tense= "PAST" vform="PASTPART"

- *giocato* aspect="PERFECTIVE"

∗ tense= "PRESENT" vform="PRESPART"

- *giocante* aspect= NONE

∗ tense= "PRESENT" vform="GERUNDIVE"

- *giocando aspect* = IMPERFECTIVE — PERFECTIVE — NONE

∗ tense= "PRESENT" vform="GERUNDIVE"

- *avendo giocato* aspect= PERFECTIVE

(c.) Modal verbs:

∗ tense= "PRESENT — IMPERFECT" aspect= "IMPERFECTIVE"

- *devo [andare a casa]*
- *dovevo [andare a casa]*

∗ tense= "PAST" aspect= "PERFECTIVE"

- *è dovuto [andare a casa]*
- *dovette [andare a casa]*
- *era dovuto [andare a casa]*

(d.) Events realized by adjectives or nouns:

∗ tense= "NONE"

∗ aspect= "NONE"

- *La coppia, residente a Milano, era in vacanza.*
- *I lavoratori chiedono nuove trattative.*

(e.) Events realized by adjectives or nouns in predicative clauses. Events are in bold face, whereas the copular verb, from which temporal and aspectual information can be recovered, is underlined.

∗ tense= "PRESENT — IMPERFECT — PAST — FUTURE"

∗ aspect= "PERFECTIVE — IMPERFECTIVE — NONE"

- *Questo è un* ***accordo*** *per altri negoziati.*
  (PRESENT - NONE)
- *La coppia è* ***residente*** *a Milano.*
  (PRESENT- IMPERFECTIVE)
- *Questo era un* ***tentativo*** *per un accordo.*
  (IMPERFECT - NONE)
- *La coppia era* ***residente*** *a Milano.*
  (IMPERFECT - PERFECTIVE)
- *Questo è stato un* ***accordo*** *per altri negoziati.*
  (PAST - NONE)
- *Questo fu un* ***tentativo*** *di accordo.*
  (PAST - NONE)
- *La coppia è stata* ***residente*** *a Milano.*
  (PAST - PERFECTIVE — IMPERFECTIVE)

- *La coppia* fu ***residente*** *a Milano.*
  (PAST - PERFECTIVE)
- *Questo* era stato *l'**accordo** per i negoziati.*
  (PAST - NONE)
- *La coppia* era stata ***residente*** *a Milano.*
  (PAST - PERFECTIVE — IMPERFECTIVE)
- *Al Sayed* sarà *il nuovo **padrone** della Fermenta.*
  (FUTURE - NONE —)
- *Questo* sarà stato *un **tentativo** di aprire nuovi negoziati.*
  (FUTURE - NONE)
- *La coppia* sarà ***residente*** *a Milano.*
  (FUTURE - IMPERFECTIVE).

Non-finite verb forms do not have autonomous temporal reference. For clarity's sake we keep the `PRESENT` value for simple forms and `PAST` for the compound ones. In addition to this, the aspectual values of simple forms are based on complex semantic and pragmatic factors. As Bertinetto (2001) points out, aspectual values of simple infinitives introduced by verbs are influenced by:

- lexical semantics of the main (finite) verb;
- the semantic aspect of the main verb;
- the lexical aspect, or *Aktionsaart*, both of the main verb and of the infinitive form
- pragmatic factors.

Simple (or present) infinitives introduced by modals have `PERFECTIVE` aspect because modals force a prospective/futurate reading of the infinitive; if modals have an epistemic reading (like in "*devono essere le 10*"), the infinitives have `IMPERFECTIVE` aspect, because modals force a simultaneous/present reading.

Similarly to present (*simple*) infinitive, present (*simple*) gerunds in Italian receive aspectual values according to contextual interpretation. In epistemic reading modals have `IMPERFECTIVE` aspect.

`ASPECTUAL` events assume `PERFECTIVE` or `IMPERFECTIVE` values for aspect on the basis of their semantics:

(C.108) *Ho finito di leggere il libro.*

```
<EVENT class="ASPECTUAL" tense="PAST"
aspect="PERFECTIVE">finito</EVENT>
di
<EVENT class="OCCURRENCE" vForm="INFINITIVE"
tense="PRESENT" aspect="PERFECTIVE">leggere</EVENT>
```

(C.109) Ho iniziato a leggere il libro.

```
<EVENT class="ASPECTUAL" tense="PAST"
aspect="IMPERFECTIVE">iniziato</EVENT>
a
<EVENT class="OCCURRENCE" vForm="INFINITIVE"
tense="PRESENT" aspect="IMPERFECTIVE">leggere</EVENT>
```

In the example with "*(ha) finito*" the event of reading is concluded, and thus it requires value `PERFECTIVE`, which in the example with "*(ha) iniziato*" the event reading has begun but no ending point is perceived by or indicated to the reader, and thus it requires value `IMPERFECTIVE`.

For events realized by prepositional phrases, the values for tense and aspect are the same as for those for adjectives and nouns, both if they occur alone or as a predicative complement of a copular phrase.

C.4.1.4 What NOT to tag

There are situations in which entities which may be eligible to be annotated as events should not be tagged:

(a.) When they express states that are not temporally relevant; that is, states that either are not directly related to a temporal expression, or are not identifiably changed over the course of the text being marked up (see section C.2.2.2 point D. `class`, value `STATE`).

(b.) When the event reading of a logically polysemous noun is not exploited in the verb predication, or, when the verb arguments do not require an eventive noun. The identification of an eventive reading of a noun, and thus its annotation, is licenced by a combination of these elements:

- the semantic types of a verb argument. Every verb has a set of valency features which corresponds both to the number of its arguments and also to their semantic types. For instance, the class of `ASPECTUAL` events, when realized by verbs, take as one of its arguments (either in the direct object position or in the subject position, according to the construction) an event. However, in natural language, it is quite common to find nouns which do not have an eventive reading in isolation but acquire it when they are arguments of these kinds of verbs:

  (C.110) *Marco ha iniziato a leggere un libro.*

  ```
  <EVENT class="ASPECTUAL" tense="PAST"
  aspect="IMPERFECTIVE">iniziato</EVENT>
  a
  <EVENT class="OCCURRENCE" vForm="INFINITIVE"
  tense="PRESENT" aspect="IMPERFECTIVE">leggere</EVENT>
  ```

  (C.111) *Marco ha iniziato il libro.*

  ```
  <EVENT class="ASPECTUAL" tense="PAST"
  aspect="IMPERFECTIVE">iniziato</EVENT>
  il
  <EVENT class="OCCURRENCE" tense="NONE"
   aspect="NONE">libro</EVENT>
  ```

- the semantic type (or types) of the noun itself. Following the G.L. approach (Pustejovsky, 1995) to lexical semantics, we claim that every noun realizes one or more semantic types, corresponding to lexical ontological classes. For instance, the noun "*mela*" realizes the semantic type `Food` (or the more general, `Physical_object`), the noun "*caduta*" realizes the semantic type `Event`, while the noun "*libro*" realizes two semantic types `Physical_object` and `Information`[9] at the same time, i.e. they are inherently polysemous. This latter type of nouns

[9]Nouns like "*libro*" are classified as *dot objects* in G.L. Theory.

realizes its semantics type according to the verb arguments' selection. To clarify, consider these examples with the noun "*assemblea*" which, in isolation, is associated with two semantic types: (`Human_group` ⊗ `Event`):

(C.112) *L'assemblea ha deliberato il bilancio '92.*

deliberare selects *assemblea* = `Human_group`

(C.113) *L'assemblea è stata rinviata.*

rinviare selects *assemblea* = `Event`

Only the instance in the example C.113, the noun "*assemblea*" must be tagged with `EVENT`.
Being aware of the possible semantic types associated with each noun and the verb arguments' selection is essential to identify event instances.

C.4.2 <TIMEX3>: tag span and attributes value

The `TIMEX3` tag relies on and is as much compliant as possible with the TIDES `TIMEX2` annotation. The Italian adaptation of this annotation scheme is presented in Lavelli et al. (2005b).
The identification of the markable expressions are those reported in Table C.2 on page 265.

C.4.2.1 Tag span

The surface-oriented approach to the tagging of expressions in ISO-TimeML implies that temporal expression annotation is based on the constituent structure and the time unit classification presented in Table C.3.

Table C.3: *Time units classification.*

t<**day**	**day**≤t≤ **month**	**month**≤t≤ **year**	*t* >**year**
alba	*domani*	*estate*	*lustro*
mezzogiorno	*fine settimana*	*semestre*	*secolo*
notte	*giornata*	*anno*	*biennio*
hh:mm:ss	*domani*	*1984*	
minuto	*il primo di dicembre*	*Febbraio*	
	martedì		

The span of the tag must correspond to one of the following categories:

- **Noun Phrase**: *lunedì, mese, la scorsa estate...*
- **Adjectival Phrase** *annuale, estivo, mensile, quotidiano...*
- **Adverbial Phrase** *oggi, ieri, finora...*
- **Time/Date Patterns**: *31-12-2006, 14.30, 24/08 ...*

All prepositions, including contracted prepositions, and subordinating conjunctions introducing a temporal expression are not to be considered part of the timex tag. This is due to the fact that relevant temporal prepositions, and other signals of temporal relations, are marked with the `SIGNAL` tag:

(C.114) *nel pomeriggio.*

```
nel
<TIMEX3>pomeriggio</TIMEX3>
```

(C.115) *per l'autunno.*

```
per
<TIMEX3>l'autunno</TIMEX3>
```

Exceptions are represented by the prepositions "*circa*", "*intorno a*" and "*verso*" which must be included into the extent of the tag because they have a role in the normalization of the timex:

(C.116) *per circa un mese.*

```
per
<TIMEX3>circa un mese<TIMEX3>
```

(C.117) *verso le 10 di sera.*

```
<TIMEX3>verso le 10 di sera<TIMEX3>
```

Further exceptions are represented by multiwords like *per ora*, *dopo domani*, *fin'ora*, *di recente* and similar where the whole expression is considered as a single unit and so the preposition is included into the tag:

(C.118) *per ora.*

```
<TIMEX3>per ora<TIMEX3>
```

(C.119) *dopo domani.*

```
<TIMEX3>dopo domani<TIMEX3>
```

(C.120) *fin'ora.*

```
<TIMEX3>fin'ora<TIMEX3>
```

All pre- and post-modifiers of a temporal expression must be included into the tag, with the exception of postmodifiers denoting an event:

(C.121) *durante lo scorso trimestre.*

```
durante
<TIMEX3>lo scorso trimestre</TIMEX3>
```

(C.122) *il mese scorso.*

```
{<TIMEX3>il mese scorso</TIMEX3>}}
```

(C.123) *nel secondo semestre.*

```
nel
<TIMEX3>secondo semestre</TIMEX3>
```

(C.124) *tre giorni fa.*

```
<TIMEX3>tre giorni fa</TIMEX3>
```

(C.125) *il giorno della partenza.*

```
<TIMEX3>il giorno</TIMEX3>
della partenza
```

(C.126) *appena tre giorni fa.*

```
<TIMEX3>appena tre giorni fa</TIMEX3>
```

The word "*dopo*" must be included into the tag span only when it has the function of adjective, otherwise it is to be excluded:

(C.127) *dopo tre giorni.*

```
dopo
<TIMEX3>tre giorni</TIMEX3>
```

(C.128) *tre giorni dopo.*

```
<TIMEX3>tre giorni dopo</TIMEX3>
```

Appositives are considered as post-modifiers, and thus are included into the tag span. However, if the appositives contains a lexical trigger for timexes we have two separate expressions:

(C.129) *gli anni '60, gli anni del libero amore.*

```
<TIMEX3>gli anni '60</TIMEX3>
<TIMEX3>gli anni del libero amore</TIMEX3>
```

Conjoined temporal expressions are to be marked in two separate tags, but if the temporal expression corresponds to a clock time it must be marked into a unique tag:

(C.130) *nel 2005 e nel 2006.*

```
nel
<TIMEX3>2005</TIMEX3>
e nel
<TIMEX3>2006</TIMEX3>
```

(C.131) *alle 13 e 56.*

```
alle
<TIMEX3>13 e 56</TIMEX3>
```

We accept the extensions proposed in Lavelli et al. (2005b) to be marked into a single `TIMEX3` tag:

(C.132) *ore e ore.*

```
<TIMEX3>ore e ore</TIMEX3>
```

(C.133) *di giorno in giorno.*

```
di
<TIMEX3>giorno in giorno</TIMEX3>
```

(C.134) *giorno dopo giorno.*

```
<TIMEX3>giorno dopo giorno</TIMEX3>
```

(C.135) *24 ore su 24.*

```
<TIMEX3>24 ore su 24</TIMEX3>
```

According to the type of relation which exists between two consecutive temporal expressions, different rules apply for the tag span. In these cases:

- the temporal expressions will be marked up in a single tag if:
  - (i.) the two expressions belong to the same temporal unit, as illustrated in Table C.3 on page 282, or if they are hierarchically related:
    (C.136) *venerdì sera.*
    `<TIMEX3>venerdì sera</TIMEX3>`
    (C.137) *venerdì ore 11.*
    `<TIMEX3>venerdì ore 11</TIMEX3>`
    (C.138) *martedì 26 giugno*
    `<TIMEX3>martedì 26 giugno</TIMEX3>`
    (C.139) *giugno 1969.*
    `<TIMEX3>giugno 1969</TIMEX3>`
  - (ii.) the second temporal expression is introduced by the prepositions *di* or *del* and it represents a definite time specification:
    (C.140) *la mattina del 20 giugno.*
    `<TIMEX3>la mattina del 20 giugno</TIMEX3>`
    (C.141) *ottobre del 1963*
    `<TIMEX3>ottobre del 1963</TIMEX3>`
    (C.142) *alle 11 di ieri mattina*
    `alle`
    `<TIMEX3>11 di ieri mattina</TIMEX3>`
- Two tags must be created:
  - (i.) when two temporal expressions are in an anchoring relation:
    (C.143) *due settimane da oggi*
    `<TIMEX3>due settimane</TIMEX3>`
    `da`
    `<TIMEX3>oggi</TIMEX3>`
    (C.144) tre giorni prima di ieri
    `<TIMEX3>tre giorni</TIMEX3>`
    `prima di`
    `<TIMEX3>ieri</TIMEX3>`
  - (ii.) in all other cases:
    (C.145) *venerdì sera alle 20.00.*
    `<TIMEX3>venerdì sera</TIMEX3>`
    `alle`
    `<TIMEX3>20.00</TIMEX3>`
    (C.146) *ieri alle 11.00.*
    `<TIMEX3>ieri</TIMEX3>`
    `alle`
    `<TIMEX3>11.00<TIMEX3>`

It is important to stress the difference between temporal expressions of the form *NP+ PP*, where the head of the PP is realized by the prepositions "*di*" or "*del*", and those cases where the head of the PP is realized by other prepositions, like "*a*" or its contracted variants. In the former case the expressions are viewed as belonging to the same syntactic constituent, while in the latter the temporal expression realized by the PP can attach either to the NP constituent or to a higher syntactic constituent like the IP or the VP.

C.4.2.2 What NOT to tag

Among non markable time expressions, together with those expressions which can have a temporal meaning but are not considered trigger words, we include (all non markable elements are in bold):

- Frequency expressions, when no time period is given:

  (C.147) *L' Italia è diventata campione del mondo per **quattro volte**.*

  (C.148) *I gestori si sono mostrati **spesso** inclini alla cautela.*

- Sequencing and ordering expressions:

  (C.149) *Le perizie erano state **inizialmente** predisposte dal presidente.*

- Manner adverbs:

  *La vendita sarà annunciata a Roma e a Londra **contemporaneamente**.**Subito** soccorsa dai medici presenti nel villaggio.*

- Non-quantifiable durations:

  (C.150) *Un investimento da liquidare **a breve termine**.*

  (C.151) *Attendevano **da tempo** lo sblocco delle certificazioni.*

- Proper names that contain or comprise a time expression but denote named entities or similar:

  (C.152) **Settembre Nero**.

  (C.153) *Domani aprirà la mostra "**Il secolo** breve".*

  (C.154) *"**1984**" è un libro di George Orwell.*

C.4.2.3 Annotation of `value`: expressing the meaning of temporal expressions

The `value` attribute expresses the meaning of a temporal expression. Its annotation is strictly dependant to the `type` value assigned to the temporal expressions. As a general rule, all temporal expressions should be given the following ISO format for dates (already presented in section C.2.3 on page 264): `YYYY-MM-[WW]-DDThh:mm:ss`, that is Year, Month, Week (optional), Day, Hour, Minute and Second. However, natural language temporal expressions cannot always be reconducted to such forms, so some extensions have been introduced.

A. `DATE`: they must always be reconducted to the format `YYYY-MM-[WW]-DD`:

(C.155) *venerdì due dicembre 2008.*

```
<TIMEX3 type="DATE" value="2008-12-02">
venerdì due dicembre 2008
</TIMEX3>
```

07/08/1995

```
<TIMEX3 type="DATE" value="1995-08-07">
07/08/1995
</TIMEX3>
```

The annotator will introduce as much information as is available both in the time expression and from the context. In case the text would include some reference to the specific date in which the time is anchored the annotator has to resolve it and assign the most specific value. Assuming that all the temporal expressions in the following examples have as anchor this date "*venerdì 28 Novembre 2008*", we will obtain:

(C.156) *il 3 aprile prossimo.*

```
<TIMEX3 type="DATE" value="2009-04-03">
il 3 aprile prossimo
</TIMEX3>
```

(C.157) *lo scorso 15 maggio*

```
<TIMEX3 type="DATE" value="2008-05-15">
lo scorso 15 maggio
</TIMEX3>
```

(C.158) *ieri*

```
<TIMEX3 type="DATE" value="2008-11-26">
ieri
</TIMEX3>
```

(C.159) *il 25/12*

```
<TIMEX3 type="DATE" value="2008-12-25">
il 25/12
</TIMEX3>
```

Weeks are assigned the position of Months in the date format and their value corresponds to the week number in the calendar of the corresponding year:

(C.160) *questa settimana* (referring to the week from 24-30 November 2008)

```
<TIMEX3 type="DATE" value="2008-W49">
questa settimana
</TIMEX3>
```

If some information cannot be recovered from the context, then the missing information must be signalled using the placeholders `X`

(C.161) *il 1980*

```
<TIMEX3 type="DATE" value="1980-XX-XX">
il 1980
</TIMEX3>
```

(C.162) *ad agosto*

```
ad
<TIMEX3 type="DATE" value="XXXX-08-XX">
agosto
</TIMEX3>
```

Table C.4: *Special* `DATE` *markables and value.*

Temporal Expression	`value`	**Annotation sample**
al momento, in questi giorni, tuttora, per ora, il/nel presente, a oggi, adesso	PRESENT_REF	`value="PRESENT_REF"`
recentemente, in/il passato, tempo fa, giorni fa	PAST_REF	`value="PAST_REF"`
il/al futuro, in futuro, il domani (generic reference), tra qualche mese/giorno/anno	FUTURE_REF	`value="FUTURE_REF"`
autunno, autunnale	FA	`value="XXXX-FA"`
primavera, primaverile	SP	`value="XXXX-SP"`
estate, estivo	SU	`value="XXXX-SU"`
inverno, invernale	WI	`value="XXXX-WI"`
fine settimana, week-end	WE	`value="XXXX-XX-WE"`
semestre	H	`value="XXXX-H1"`
trimestre	Q	`value="XXXX-Q1"`
quadrimestre	Qu	`value="XXXX-Qu1"`
bimestre	B	`value="XXXX-B1"`

Following the extensions proposed in TIDES, in Table C.4, we present some markable expressions which are classified as `DATE` but whose values cannot be reconducted to the standard ISO representation.

Notice that the symbols for "*semestre*", "*trimestre*", "*quadrimestre*" and "*bimestre*" always co-occur with ordinal numbers from 1 up to a maximum of 6, and corresponds to the cardinal modifiers "*primo*", "*secondo*" etc.. Thus, "*il terzo trimestre*" will receive `value=XXXX-Q3`, "il secondo semestre" will have `value="XXXX-H2"` and so on for the others. These four temporal expressions are assigned value `DATE` if and only if they co-occur with the cardinal modifiers because they denote a fixed set of months, e.g. "*il terzo trimestre*" corresponds to the months of "luglio - agosto - settembre". If they do not co-occur with these modifiers, and from the context it is impossible to identify the fixed set of months they refer to, then they are to be marked as `DURATION`, and, consequently, have a different value (see point C below).

B. `TIME`: all temporal expressions which correspond to the value `TIME` will begin with a 'T' (Time). The value are assigned on a 24 hour base (e.g. 4 p.m. = 16:00):

(C.163) le 16.00.

```
<TIMEX3 type="TIME" value="T16:00">
le 16.00
</TIMEX3>
```

In case the text would include some reference to a specific date in which the time is anchored, then the date must be contained in the value attribute:

(C.164) *ieri alle 16.00*

```
<TIMEX3 type="DATE" value="2008-11-27">
ieri
</TIMEX3>
alle
<TIMEX3 type="TIME" value="2008-11-27T16:00">
16.00
</TIMEX3>
```

As for DATE, TIME presents some extensions as well. In Table C.5, we present some markable expressions which are classified as TIME but whose values cannot be reconducted to the standard ISO representation, namely Thh:mm:ss:

Table C.5: *Special TIME markables and value.*

Temporal Expression	value	**Annotation sample**
mattina	MO	value="XXXX-XX-XXTMO"
mezzogiorno, mezzodì	MI	value="XXXX-XX-XXTMI"
pomeriggio	AF	value="XXXX-XX-XXTAF"
sera, serata	EV	value="XXXX-XX-XXTEV"
notte, nottata	NI	value="XXXX-XX-XXTNI"
giorno (day time or working hours)	DT	value="XXXX-XX-XXTDT"

C. DURATION: these temporal expressions denote intervals of time. All durations' value begins with a 'P' (Period of time). If the interval denoted by the duration can be determined by reasoning due to the presence of beginning and ending point, or if it is explicitly stated in the expression, then it is represented by an ordinal number; otherwise the placeholder X must be employed. In case of inferred durations non-text consuming TIMEX3 tags must be created to expressed the duration. The granularity value (Year, Month, ...) of the duration must always be expressed :

(C.165) *4 mesi*

```
<TIMEX3 type="DURATION" value="P4M">
4 mesi
</TIMEX>
```

(C.166) *per 45 minuti.*

```
per
<TIMEX3 type="DURATION" value="P45TM">
45 minuti
</TIMEX3>
```

(C.167) alcuni anni fa

```
<TIMEX3 type="DURATION" value="PXY">
alcuni anni fa
</TIMEX3>
```

(C.168) *Marco (oggi) è stato in palestra dalle 2 alle 5.*

```
dalle
<TIMEX3 id="t1" type="TIME" value="2008-11-28T14.00">
```

```
2
</TIMEX3>
alle
<TIMEX3 id="t2" type="TIME" value="2008-11-28T17.00">
5
</TIMEX3>
<TIMEX3 id="t3" type="DURATION"
 value="P3TH" beginPoint="t1" endPoint="t2"/>
```

D. `SET`: To fully annotate sets, the `TIMEX3` must also include either the `quant` or `freq` attributes, if not both. The following examples present the annotation of `TIMEX3 SET` for the `value` attribute (for the annotation of `quant` and `freq` see section C.2.3 point H):

(C.169) *una volta a settimana.*

```
<TIMEX3 type="SET" value="P1W" >
una volta a settimana
</TIMEX3>.
```

(C.170) *ogni tre giorni.*

```
<TIMEX3 type="SET" value="P3D">
ogni tre giorni
</TIMEX3>
```

(C.171) *ogni ottobre.*

```
<TIMEX3 type="SET" value="XXXX-10">
ogni ottobre
</TIMEX3>
```

(C.172) *3 giorni a settimana.*

```
<TIMEX3 type="SET" value="P1W" freq="3d">
3 giorni a settimana
</TIMEX3>
```

C.4.2.4 Annotation of `mod`

The `mod` attribute signals the presence of modifiers which code a vague quantification over the temporal expressions. They are marked with the attribute `mod` and as illustrated before they are part of the `TIMEX3` tag. In the Table C.6 we will present the linguistic expressions which fit into the attribute `mod` and their corresponding values:

(C.173) *mancano meno di due giorni alla consegna.*

```
<TIMEX3 type="DURATION" value="P2D" mod="LESS\_THAN">
meno di 2 giorni
</TIMEX3>.
```

(C.174) *ha svolto il suo mandato meno di un decennio fa e oggi si è ritirato a vita privata.*

```
<TIMEX3 type="DATE" value="1998" mod="AFTER">
meno di un decennio fa
</TIMEX3>
```

Table C.6: *Modifier expressions and values.*

Modifier	Value of `mod`
più di	BEFORE
meno di	AFTER
non meno di	ON_OR_BEFORE
non più di	ON_OR_AFTER
meno di appena	LESS_THAN
più di oltre	MORE_THAN
non più di al massimo	EQUAL_OR_LESS
almeno	EQUAL_OR_MORE
l'inizio di/del i primi di l'alba di/del	START
metà	MID
la fine di/del tardo ultimi	END
circa verso intorno a un paio di una decina di (and similar)	APPROX

(C.175) *una decina di anni fa.*

```
<TIMEX3 type="DURATION" value="P10Y"
mod="APPROX">
una decina di anni fa
</TIMEX3>
```

(C.176) *a metà pomeriggio.*

```
a
<TIMEX3 type="DATE" value="2008-11-28TAF"
mod="MID">
metà pomeriggio
</TIMEX3>
```

C.4.2.5 Annotation of `temporalFunction`

"The value for this attribute will be positive (`true`) for those cases that do not contain all the information necessary to fill the higher-order (left-hand) positions in the `value` attribute . This will apply even if `value` can be completely filled, given additional information provided by the context" (ISO (2008): 59):

(C.177) *le 11 di mattina* (missing the particular day but recoverable from the context.)

```
<TIMEX3 temporalFunction="true"
value="2008-11-28T11:00">
le 11 di mattina
</TIMEX3>
```

(C.178) *last week* (missing the month and year.)

```
<TMEX3 temporalFunction="true" value="2008-W47>
```

"On the other hand, for cases in which the higher-order position of `value` are filled from the information provided by the tagged temporal expression, `temporalFunction` should be assigned a negative value" (ISO (2008): 60):

(C.179) *le 11 di mattina del 23 Maggio*

```
<TIMEX3 temporalFunction="false" value="2008-05-23T11:00">
le 11 di mattina del 23 Maggio
</TIMEX3>
```

Only "[d]urations whose length is underspecified will receive `true` as the value of `temporalFunction`" (ISO (2008): *ibid.*):

(C.180) *nei mesi scorsi*

```
nei
<TIMEX3 type="DURATION" value="PXM" temporalFunction="true">
mesi scorsi
</TIMEX3>
```

(C.181) *per 2 mesi*

```
per
<TIMEX3 id="t1" type="DURATION"
value="P2M" temporalFunction="false">
2 mesi
</TIMEX3>
```

C.4.3 <SIGNAL>: tag span

As it appears from the description of the `SIGNAL` markable, the span of this tag corresponds to the extent of the signals in analysis:

(C.182) *nei mesi scorsi*

```
<SIGNAL id="s1">
nei
</SIGNAL>
mesi scorsi
```

C.5 Annotation of link tags

The annotation of the link tags is quite straightforward and it follows from their description in section C.3.1. However, some issues need examples and some instructions.

C.5.1 <TLINK>

TLINK is responsible for making explicit all kinds of temporal relations which may exist between the markables EVENT and TIMEX3.

As already stated, there may be three kinds of temporal relations:

(a.) between two temporal expressions:

(C.183) *Lunedì alle 20:00*

```
<TIMEX3 id="t1" temporalFunction="false"
type="DATE" value="XXXX-XX-XX">
Lunedì
</TIMEX3>
</SIGNAL id="s1">
alle
</SIGNAL>
<TIMEX3 id="t2" temporalFunction="false"
type="TIME" value="XXXX-XX-XXT20:00">
20:00
</TIMEX3>

<TLINK timeID="t2" relatedToTime="t1" signalID="s1"
relType="IS_INCLUDED"/>
```

- between two events:

(C.184) *Telefonate di insulti poi l' annuncio di una bomba*[10]

```
<EVENT id="e1" pred="TELEFONATA" class="OCCURRENCE"
pos="NOUN" tense="NONE" aspect="NONE">
Telefonate
</EVENT>
di insulti
</SIGNAL id="s1">
poi
</SIGNAL>
<EVENT id="e2" pred="ANNUNCIO" class="REPORTING"
pos="NOUN" tense="NONE" aspect="NONE">
l'annuncio
</TIMEX3>
di
<EVENT id="e3" pred="BOMBA" class="OCCURRENCE" pos="NOUN">

<TLINK eventID="e1" relatedToEvent="e1" signalID="s1"
relType="AFTER">
```

- between an event and a temporal expression:

(C.185) *Otto minuti dopo, l'esplosione.*

```
<TIMEX3 id="t1" temporalFunction="true" type="DURATION"
```

[10]Here the noun "bomba" must be tagged as an event instance due to coercion of the event "annuncio" which, being a nominalization, inherits the argument structure of its corresponding verb, which require an eventuality as its object argument.

```
value="P8TM">
Otto minuti dopo
</TIMEX3>
,
<EVENT id="e1" pred="ESPLOSIONE" class="OCCURRENCE"
pos="NOUN" tense="NONE" aspect="NONE">
l'esplosione
</EVENT>

<TLINK eventID="e1" relatedToTime="t1" relType="AFTER">
```

One issue which we have not pointed out in the previous sections is the fact that TimeML and ISO-TimeML allow the creation of empty markable tags. We have already seen how this can be done with the `TIMEX3` tag. Here, we want to explain the situations in which empty `EVENT` tags can be created, since these kinds of tags have a role for annotating `TLINK`s.
In most cases, the annotation of the single event instance present in the document is necessary and sufficient to perform all type of link relations. However, an additional `EVENT` tag must be created in some cases. These additional `EVENT` tags are empty (i.e. non-text consuming) and are a duplicate of the source `EVENT` tag. Their creation is motivated by the fact that sometimes a single event instance in the document expresses the occurrence of two separated event instances, which may have each a `TLINK` with another markable expression:

(C.186) *Marco ha insegnato lunedì e martedì*

As the example above shows, the event "*(ha) insegnato*" corresponds to two different instances, one which occurred "*lunedì*" and the other "*martedì*". To point out the fact that there are two instances of the same event, which have each a relation with a temporal expression, an empty event tag must be created. This procedure must always be kept present when annotating `TLINK`s.

C.5.1.1 Assigning the value to the attribute `relType`

The attribute `relType` is responsible for expressing the temporal relation which exists between two markable expressions. Among the 14 possible values, six of them are binary - one being the inverse of the other - namely: `BEFORE` and `AFTER`, `INCLUDES` and `IS_INCLUDED`, `BEGIN` and `BEGUN_BY`, `END` and `ENDED_BY`, `DURING` and `DURING_INV`, `END` and `ENDED_BY`, The decision of which value to assign, depends on the annotator perspective of the directionality of the temporal relation:

(C.187) ***Rilevata*** *la presenza di gas in uno dei tubi trasparenti che compongono l'opera, i guardiani* ***hanno fatto scattare*** *uno speciale piano d'emergenza.*

The temporal relation between the two events in bold character, can be assigned value `BEFORE`, if the directionality is from the event "*rilevata*" towards the event "*hanno fatto scattare*"; or `AFTER` if the directionality is the other way round, i.e. from "*hanno fatto scattare*" towards "*rilevata*".

We present some examples and instructions for those attributes' values which need clarifications. For clarity's sake, in the following examples we will present only the annotation of the relevant entities involved in the temporal relations:

A. `SIMULTANEOUS`: it is assigned to two markables either when they are perceived as happening at the same time, or when they temporally overlap, or when they occur close enough that it is not possible to further distinguish their times. It is not possible to have a `SIMULTANEOUS` relations between a `DURATION` and an `EVENT`. This value is to be assigned also to the event arguments of perceptions verbs (when required and/or present):

(C.188) *Quando Wong Kwan ha speso 16 milioni di dollari per comprare la casa, pensò che fosse un buon affare.*

```
<EVENT id="e1" pos="VERB" class="OCCURRENCE" tense="PAST"
aspect="PERFECTIVE" polarity="POS" mood="NONE">
speso
</EVENT>
...
<EVENT id="e4"  pos="VERB" class="I\_STATE" tense="PAST"
aspect="PERFECTIVE" polarity="POS" mood="NONE">
pensò
</EVENT>

<TLINK eventID="e1" relatedToEvent="e4"
relType="SIMULTANEOUS"/>
```

(C.189) *Ho sentito una serie di esplosioni, poi il silenzio.*

```
<EVENT id="e1"  pos="VERB" class="PERCEPTION" tense="PAST"
aspect="PERFECTIVE" polarity="POS" mood="NONE">
sentito
</EVENT>
...
<EVENT id="e2" pos="NOUN" class="OCCURRENCE" tense="NONE"
aspect="NONE" polarity="POS">
esplosioni
</EVENT>

<TLINK eventID="e1" relatedToEvent="e2"
relType="SIMULTANEOUS"/>
```

B. `DURING` **and** `INCLUDES`[11]: these two temporal relations are very similar. However, they correspond to two different temporal relations. To clarify their difference and to avoid annotation mistakes with other temporal relations, imagine that each event instance could be represented by means of an interval, with a beginning and an ending point, while temporal expressions can be represented either as intervals or as points in time. Now, consider the illustrations in Figure C.1 on the next page.

As it appears, the `DURING` relation is very different from `INCLUDES` and should not be confused with `SIMULTANEOUS`. This relations can hold only between an event and a temporal expression, and it is specifically applicable to those events which persists throughout a duration (look at the schematic representation of the timex, which is an interval). In case two events should persist one throughout the other, we will have an instance of a `SIMULTANEOUS` relation (last image in Figure C.1). On the other hand,

[11]And their inverse relations as well!

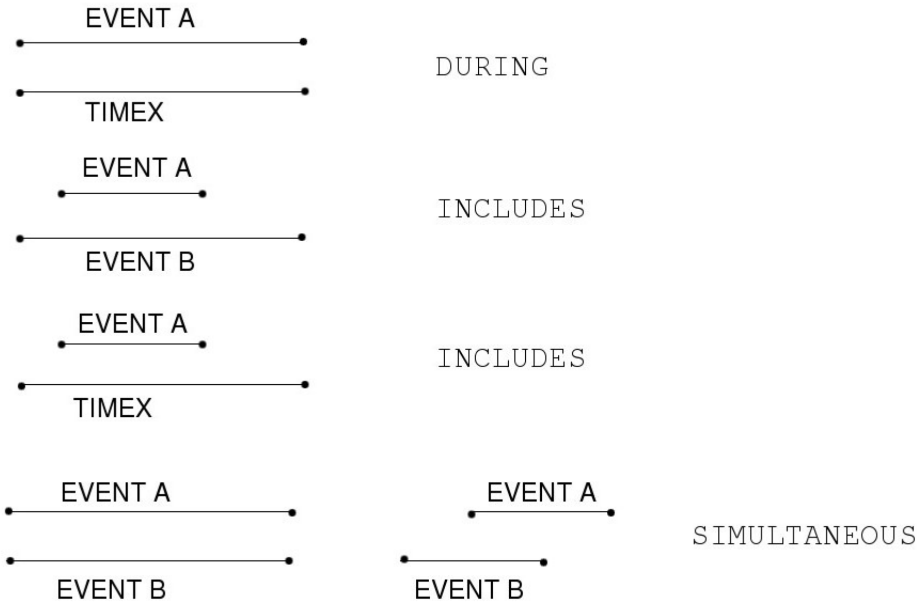

Figure C.1: *Illustrations of the temporal relations of* ***DURING****,* ***INCLUDES*** *and* ***SIMULTANEOUS****.*

the INCLUDES relations may hold between any of the markables (Figure C.1 lacks the application of the INCLUDES relation between two temporal expressions). As the the illustrations in Figure C.1 show, the INCLUDES relation signals the fact that an event (or a temporal expression) occurs inside a larger event (or temporal interval):

(C.190) *Marco era a Pisa martedì.*

```
<EVENT id="e1" pos="VERB" class="STATE" tense="IMPERFECT"
aspect="PERFECTIVE" polarity="POS">
era
</EVENT>
...
<TIMEX3 id="t1" temporalFunction="false" type="DATE"
value="XXXX-XX-XX">
martedì
</TIMEX3>

<TLINK eventID="e1" relatedToTime="t2" relType="DURING"/>
```

(C.191) *Marco è arrivato a Pisa ieri.*

```
<EVENT id="e1" pos="VERB" class="OCCURRENCE" tense="PAST"
aspect="PERFECTIVE" polarity="POS">
arrivato
</EVENT>
...
<TIMEX3 id="t1" temporalFunction="false" type="DATE"
```

```
value="XXXX-XX-XX">
ieri
</TIMEX3>

<TLINK eventID="e1" relatedToTime="t2"
relType="IS_INCLUDED"/>
```

(C.192) *Marco è arrivato a Pisa alle 3.*

```
<EVENT id="e1" pos="VERB" class="STATE" tense="PAST"
aspect="PERFECTIVE" polarity="POS">
arrivato
</EVENT>
...
<TIMEX3 id="t1" temporalFunction="false" type="DATE"
value="XXXX-XX-XXT15:00">
3
</TIMEX3>

<TLINK eventID="e1" relatedToTime="t2"
relType="SIMULTANEOUS"/>
```

(C.193) *Marco lavorava e mangiava*[12].

```
<EVENT id="e1" pos="VERB" class="STATE" tense="IMPERFECT"
aspect="IMPERFECTIVE" polarity="POS">
lavorava
</EVENT>
...
<EVENT id="e2" pos="VERB" class="STATE" tense="IMPERFECT"
aspect="IMPERFECTIVE" polarity="POS">
mangiava
</EVENT>

<TLINK eventID="e1" relatedToEvent="e2"
relType="SIMULTANEOUS"/>
```

The value INCLUDES is also used to annotate set/subset relationship between two events:

(C.194) *La polizia sta indagando su* <EVENT>*14 casi di omicidio*</EVENT>*. In* <EVENT>*6 di questi*<EVENT> *i sospetti sono stati arrestati.*

```
<EVENT id="e2" pos="NOUN" class="OCCURRENCE"
tense="NONE" aspect="NONE" polarity="POS">
14 casi
</EVENT>
...
<EVENT id="e3" pos="NOUN" class="OCCURRENCE"
tense="NONE" aspect="NONE" polarity="POS">
6
```

[12]This example corresponds to the first picture of the last image in Figure C.1 on the facing page

```
</EVENT>

<TLINK eventID="e1" relatedToEvent="e3"
relType="INCLUDES"/>
```

The second EVENT tag is a subset of the first one and the two events will be related via a TLINK with the temporal relation INCLUDES or IS_INCLUDED, depending on the directionality.

C. IBEFORE **and** IAFTER: these relations are specifications of the more general BEFORE and AFTER relations. They are not very much widespread in documents (for instance in the TimeBank (Pustejovsky et al., 2003b) there are only 5 occurrences). Their annotation is subordinated to the presence of specific signals, like "*subito dopo*", or other discourse elements which indicate that the temporal span between the two entities involved is very short:

(C.195) *Il relax mentale è da fare subito dopo la respirazione.*

```
<EVENT id="e1" pos="NOUN" class="OCCURRENCE"
tense="NONE" aspect="NONE" polarity="POS">
relax
</EVENT>
...
<SIGNAL id="s1">
subito dopo
</SIGNAL>
<EVENT id="e3" pos="NOUN" class="OCCURRENCE"
tense="NONE" aspect="NONE" polarity="POS">
la respirazione
</EVENT>

<TLINK eventID="e1" relatedToEvent="e3"
relType="IBEFORE"/>
```

C.5.1.2 The temporalDistance attribute

This attribute is an extension to TimeML. It expresses the time distance which may exist between two event which is explicitly expressed in the document by means of a temporal expressions of type DURATION. Its value is represented by the ID of the temporal expression:

(C.196) *Marco si è ammalato 2 ore dopo la partita.*

```
Marco si è
<EVENT id="e1" class="STATE" tense="PRESENT"
aspect="IMPERFECTIVE" pos="VERB" polarity="POS">
ammalato
</EVENT>
<TIMEX3 id="t1" type="DURATION" value="PT2H"
temporalFunction="false">
due ore dopo
</TIMEX3>
```

```
la
<EVENT id="e2" class="OCCURRENCE" tense="NONE"
aspect="NONE" pos="NOUN" polarity="POS">
partita
</EVENT>

<TLINK eventID="e1" relatedToEvent="e2"
relType="AFTER" temporalDistance="t1"/>
```

C.5.1.3 Special uses of TLINK: the value IDENTITY

In section C.3.1, we have illustrated the situations in which the value IDENTITY must be used. Here we will go into the details of some of them with annotated examples.

Causative constructions: the IDENTITY value must be used only in one case of causative constructions, that is when the verb "*causare*" has two events as its arguments. IDENTITY holds with the event in subject position:

- EVENT causare EVENT

(C.197) *La pioggia ha causato delle alluvioni.*

```
La
<EVENT id="e1" pos="NOUN" class="OCCURRENCE"
tense="NONE" aspect="NONE" polarity="POS">
pioggia
</EVENT>
ha
<EVENT id="e2" pos="VERB" class="OCCURRENCE"
tense="PAST" aspect="PERFECTIVE" polarity="POS">
causato
</EVENT>
delle
<EVENT id="e3" pos="NOUN" class="OCCURRENCE"
tense="NONE" aspect="NONE" polarity="POS">
alluvioni
</EVENT>

<TLINK eventID="e1" relatedToEvent="e2"
TLINK="IDENTITY"/>
<TLINK eventID="e1" relatedToEvent="e3"
TLINK="BEFORE"/>
```

Light verb constructions (*costruzioni a verbo supporto*): in those cases when two event tags must be created to annotate a light verb construction, the TLINK value between the light verb and the nominal is IDENTITY:

(C.198) *Marco ha fatto una passeggiata.*

```
<EVENT id="e1" pos="VERB" class="OCCURRENCE"
tense="PAST" aspect="PERFECTIVE" polarity="POS">
fatto
```

```
</EVENT>
una
<EVENT id="e2" pos="NOUN" class="OCCURRENCE"
tense="NONE" aspect="NONE" polarity="POS">
passeggiata
</EVENT>

<TLINK eventID="e1" relatedToEvent="e2"
TLINK="IDENTITY"/>
```

To connect duplicated event tag: duplicated instances of an event must be linked via a `TLINK` with value `IDENTITY`:

(C.199) *Marco ha insegnato lunedì e martedì.*

```
<EVENT id="e1" pos="VERB" class="OCCURRENCE"
tense="PAST" aspect="PERFECTIVE" polarity="POS">
insegnato
</EVENT>
<TIMEX3 id="t1" type="DATE" value="XXXX-XX-XX">
lunedì
</EVENT>
e
<TIMEX3 id="t2" type="DATE" value="XXXX-XX-XX">
martedì
</EVENT>

<EVENT id="e2" pos="VERB" class="OCCURRENCE"
tense="PAST" aspect="PERFECTIVE" polarity="POS">

<TLINK eventID="e1" relatedToEvent="e2" TLINK="IDENTITY"/>
<TLINK eventID="e1" relatedToTime="t1"
TLINK="IS_INCLUDED"/>
<TLINK eventID="e2" relatedToTime="t2"
TLINK="IS_INCLUDED"/>
```

C.5.2 `ALINK`

`ALINK` are created only in presence of `ASPECTUAL` events. The following examples present also inferred temporal relations, which must be created when necessary:

(C.200) *L'assemblea inizia alle 3.*

```
L'
<EVENT id="e1" pos="NOUN" class="OCCURRENCE"
tense="NONE" aspect="NONE" polarity="POS">
assemblea
</EVENT>
<EVENT id="e2" pos="VERB" class="ASPECTUAL"
tense="PRESENT" aspect="IMPERFECTIVE" polarity="POS">
```

```
inizia
<EVENT>
<SIGNAL id="s1">
alle
</SIGNAL>
<TIMEX3 id="t1" type="DATE"
value="XXXX-XX-XXT15:00">
3
</TIMEX3>

<ALINK eventID="e1" relatedToEvent="e2"
relType="INITIATES">
<TLINK eventID="e1" relatedToTime="t1" signalID="s1"
TLINK="BEGINS"/>
```

(C.201) *Marco ha finito di leggere il libro.*

```
Marco ha
<EVENT id="e1" pos="VERB" class="ASPECTUAL"
tense="PAST" aspect="PERFECTIVE" polarity="POS">
finito
<EVENT>
di
<EVENT id="e12" pos="VERB" class="OCCURRENCE"
vForm="INFINITIVE"  tense="PRESENT" aspect="PERFECTIVE"
polarity="POS">
leggere
</EVENT>
il libro

<ALINK eventID="e1" relatedToEvent="e2"
relType="CULMINATES">
```

C.5.2.1 On the difference between the values TERMINATES and CULMINATES

The values TERMINATES and CULMINATES reflect a difference in the main verb lexical aspect or *Aktionsaart*. Lexical aspect is an inherent feature of verbs or verb phrases and is determined by the nature of the event that the verb describes. A major distinction in lexical aspect is that between telic and atelic events. A telic event presents an action or event as being complete in some sense: the event is considered as realized when it has reached its natural endpoint (or goal). On the other hand, atelic events don't have endpoints, they do not culminate but simply finish. Aspectual verbs which indicates the end of an event, like "*finire*", "*terminare*", "*concludere*" etc., may give rise to either to ALINK with value TERMINATES, when the main verb is atelic, or with value CULMINATES when telic:

(C.202) *Marco ha finito di scrivere.* (atelic event)

```
Marco ha
<EVENT id="e1" pos="VERB" class="ASPECTUAL"
```

```
tense="PAST" aspect="PERFECTIVE" polarity="POS">
finito
<EVENT>
di
<EVENT id="e12" pos="VERB" class="OCCURRENCE"
vForm="INFINITIVE" tense="PRESENT" aspect="PERFECTIVE"
polarity="POS">
scrivere
</EVENT>

<ALINK eventID="e1" relatedToEvent="e2"
relType="TERMINATES">
```

Marco ha finito di leggere il libro. (telic event)

```
Marco ha
<EVENT id="e1" pos="VERB" class="ASPECTUAL"
tense="PAST" aspect="PERFECTIVE" polarity="POS">
finito
<EVENT>
di
<EVENT id="e2" pos="VERB" class="OCCURRENCE"
vForm="INFINITIVE" tense="PRESENT" aspect="PERFECTIVE"
polarity="POS">
leggere
</EVENT>
il libro

<ALINK eventID="e1" relatedToEvent="e2"
relType="CULMINATES">
```

C.5.3 SLINK

As already stated SLINK can be of two types: lexically based or structurally based.
The annotator has to create an SLINK relation every time there is a subordinating relation of the kinds we have illustrated in section C.3.3 between two events. With respect to TLINK, SLINK does not necessitate to create empty EVENT tags when a single event has an SLINK relation with more that one event.

(C.203) *Marco non vuole venire.*

```
Marco non
<EVENT id="e1" pos="VERB" class="I\_STATE"
tense="PRESENT" aspect="PERFECTIVE"
polarity="NEG" modality="VOLERE">
vuole
</EVENT>
<EVENT id="e1" pos="VERB" class="OCCURRENCE"
tense="PRESENT" aspect="PERFECTIVE" polarity="NEG"
VForm="INFINITIVE">
```

```
venire
</EVENT>

<SLINK eventID="e1" relatedToEvent="e2"
relType="INTENSIONAL"/>
```

(C.204) *Marco ha detto che ha visto Chiara ma non ha chiamato Giovanni.*

```
Marco ha
<EVENT id="e1" pos="VERB" class="REPORTING"
tense="PAST" aspect="PERFECTIVE" polarity="POS">
detto
</EVENT>
che ha
<EVENT id="e2" pos="VERB" class="PERCEPTION"
tense="PAST" aspect="PERFECTIVE" polarity="POS" >
visto
</EVENT>
Chiara ma non ha
<EVENT id="e3" pos="VERB" class="OCCURRENCE"
tense="PAST" aspect="PERFECTIVE" polarity="NEG">
chiamato
</EVENT>
Giovanni.

<SLINK eventID="e1" relatedToEvent="e2"
relType="EVIDENTIAL"/>
<SLINK eventID="e1" relatedToEvent="e2"
relType="NEG\_EVIDENTIAL"/>
```

C.5.3.1 Annotating lexically based SLINKs

Lexically based SLINK are typically introduced by those event classes which normally take, or may take, an event as its complement argument, i.e. REPORTING, PERCEPTION, I_ACTION and I_STATE. The directionality of the SLINK is always from the main event to the subordinate one. The SLINK **relType** values may be constrained by the main event classes:

(a.) PERCEPTION events always instantiate SLINKs of type EVIDENTIAL or NEG_EVIDENTIAL.

(b.) I_STATEs and I_ACTIONs may introduce SLINKs of type INTENSIONAL, FACTIVE or COUNTER_FACTIVE. Modals verbs, which are always assigned the class I_STATE will always introduce SLINK of type INTENSIONAL.

(c.) REPORTING events may instantiate SLINKs of any type with the exception of INTENSIONAL. A preference value, however, may be identified for EVIDENTIAL:

(C.205) *Abbiamo appreso che l'attacco è concluso.*

```
Abbiamo
<EVENT id="e1" pos="VERB" class="REPORTING"
```

```
tense="PAST" aspect="PERFECTIVE" polarity="POS">
appreso
</EVENT>
che l'
<EVENT id="e2" pos="NOUN" class="OCCURRENCE"
tense="NONE" aspect="NONE" polarity="POS">
attacco
</EVENT>
è
<EVENT id="e3" pos="VERB" class="ASPECTUAL"
tense="PAST" aspect="PERFECTIVE" polarity="POS">
concluso
</EVENT>

<SLINK eventID="e1" relatedToEvent="e3"
relType="FACTIVE"/>
```

(C.206) *L'andamento del mercato conferma che la congiuntura è difficile.*

```
L'
<EVENT id="e1" pos="NOUN" class="OCCURRENCE"
tense="NONE" aspect="NONE" polarity="POS">
andamento
</EVENT>
del mercato
<EVENT id="e2" pos="VERB" class="REPORTING"
tense="PRESENT" aspect="IMPERFECTIVE" polarity="POS">
conferma
</EVENT>
che la
<EVENT id="e3" pos="NOUN" class="STATE"
tense="PRESENT" aspect="NONE" polarity="POS">
congiuntura
</EVENT>
e' difficile.

<SLINK eventID="e2" relatedToEvent="e3"
relType="EVIDENTIAL"/>
```

C.5.3.2 Structurally based SLINKs

A. Purpose clauses: the event in the main clause will correspond to the value of the attribute `eventID`. The event in the purpose clause will be taken as the `subordinatedEvent` value. The `relType` value between the event in the main and in the subordinated clause will always be `INTENSIONAL`. Prepositions, like "*per*", or conjunctions, like "*affinché*", when introducing a purpose clause must always be marked as `SIGNAL` (see section C.2.4), and make explicit in the `SLINK` annotation by means of the attribute `signalID`:

(C.207) *I Fumagalli hanno incaricato un agente di cambio milanese di mettere a punto il progetto per la quotazione in Borsa.*

```
il
<EVENT id="e3" pos="NOUN" class="OCCURRENCE"
tense="NONE" aspect="NONE" polarity="POS">
progetto
</EVENT>
<SIGNAL id="s1">
per
</SIGNAL>
la
<EVENT id="e4"pos="NOUN" class="OCCURRENCE"
tense="NONE" aspect="NONE" polarity="POS">
quotazione
</EVENT>
in Borsa

<SLINK eventID="e2" relatedToEvent="e3" signalID="s1"
relType="INTENSIONAL"/>
```

(C.208) Il Consiglio dei ministri ha approvato gli interventi per calmierare i mutui a tasso variabile.

```
Il Consiglio dei ministri ha
<EVENT id="e3" pos="VERB" class="I\_ACTION"
tense="PAST" aspect="PERFECTIVE" polarity="POS">
approvato
</EVENT>
gli
<EVENT id="e2"pos="NOUN" class="OCCURRENCE"
tense="NONE" aspect="NONE" polarity="POS">
interventi
<SIGNAL id="s1">
per
</SIGNAL>
<EVENT id="e3" pos="VERB" class="OCCURRENCE"
tense="PRESENT" aspect="PERFECTIVE" vForm="INFINITIVE"
polarity="POS">
calmierare
</EVENT>
i mutui a tasso variabile.

<SLINK eventIID="e2" subordinatedEvent="e3" signalID="s1"
relType="INTENSIONAL"/>
<SLINK eventIID="e1" subordinatedEvent="e2"
relType="FACTIVE"/>
```

B. Conditional constructions: the event in the antecedent clause (*apòdosi*) corresponds to the value in the `eventID` attribute. The one in the consequent (*protasi*), to the value of the `subordinatedEvent`. The conditional conjunction (e.g. "*se*" or "*quando*") will be marked as `SIGNAL`. The `relType` value of these `SLINK`s will always be `CONDITIONAL`.

(C.209) *Se da una parte si sviluppa la strategia delle acquisizioni, dall' altra si afferma il progetto di ricorrere al mercato.*

```
<SIGNAL id="s1">
se
</SIGNAL>
da una parte si
<EVENT id="e1" pos="VERB" class="OCCURRENCE"
tense="PRESENT" aspect="IMPERFECTIVE" polarity="POS">
sviluppa
</EVENT>
la
<EVENT id="e2" pos="NOUN" class="STATE"
tense="NONE" aspect="NONE" polarity="POS">
strategia
</EVENT>
delle
<EVENT id="e3" pos="NOUN" class="OCCURRENCE"
tense="NONE" aspect="NONE" polarity="POS">
acquisizioni
</EVENT>
dall'altra è ormai in fase avanzata il
<EVENT id="e4" pos="NOUN" class="OCCURRENCE"
tense="NONE" aspect="NONE" polarity="POS">
progetto
</EVENT>
di
<EVENT id="e5" pos="VERB" class="OCCURRENCE"
tense="PRESENT" aspect="PERFECTIVE" vForm="INFINITIVE"
polarity="POS">
ricorrere
</EVENT>
al mercato.

<SLINK eventIID="e5" subordinatedEvent="e1" signalID="s1"
relType="CONDITIONAL"/>
```

The presence of the same event in several SLINKs is also possible in structurally-based SLINKs:

(C.210) *Marcos ha promesso di riprendere i negoziati se la zona di conflitto verrà smilitarizzata e il Parlamento approverà la legge sui diritti degli indigeni*

```
...
<EVENT id="e2" pos="VERB" class="ASPECTUAL"
tense="PRESENT" aspect="PERFECTIVE" vForm="INFINITIVE"
polarity="POS">
riprendere
</EVENT>
<SIGNAL id="s1">
```

```
se
</SIGNAL>
...
<EVENT id="e4" pos="VERB" class="OCCURRENCE"
tense="FUTURE" aspect="PERFECTIVE" polarity="POS">
smilitarizzata
</EVENT>
...
<EVENT id="e5" pos="VERB" class="OCCURRENCE"
tense="FUTURE" aspect="PERFECTIVE" polarity="POS">
approverà
</EVENT>

<SLINK eventID="e2" subordinatedEvent="e4"
signalID="s1" relType="CONDITIONAL"/>
<SLINK eventID="e2" subordinatedEvent="e5"
signalID="s1" relType="CONDITIONAL"/>
```

C.6 Annotated examples

In all examples we assume that the document creation time (DCT) corresponds to `id="t0" value="2008-11-28"`

C.6.1 TIMEX3 and TLINK

(C.211) *il periodo '92 - '93.*

```
<TIMEX3 id="t1" type="DURATION" value="P1Y"
beginPoint="t2" endPoint="t3" temporalFunction="true">
il periodo
</TIMEX3>
<TIMEX3 id="t2" type="DATE" value="1992-XX-XX"
temporalFunction="false">
'92
<TIMEX3>
<SIGNAL id="s1">
-
</SIGNAL>
<TIMEX3 id="t3" type="DATE" value="1993-XX-XX"
temporalFunction="false">
```

(C.212) *Partirò tra tre giorni.*

```
<EVENT id="e1" class="OCCURRENCE" tense="FUTURE"
aspect="PERFECTIVE" pos="VERB" polarity="POS">
Partirò
</EVENT>
<SIGNAL id="s1">
tra
</SIGNAL>
<TIMEX3 id="t1" type="DURATION" value="P3D"
beginPoint="t0" endPoint="t2" temporalFunction="false">
tre giorni
</TIMEX3>

<TIMEX3 id="t2" type="DATE" value="2008-12-01"
anchorTimeID="t0" temporalFunction="false"/>

<TLINK eventID="e1" relatedToTime="t1"
signalID="s1" relType="AFTER"/>
<TLINK eventID="e1" relatedToTime="t2"
signalID="s1" relType="IS_INCLUDED"/>
```

(C.213) *Marco è partito due giorni fa.*

```
Marco è
<EVENT id="e1" class="OCCURRENCE" tense="PAST"
aspect="PERFECTIVE" pos="VERB" polarity="POS">
```

```
partito
</EVENT>
<TIMEX3 id="t1" type="DATE" value="2008-11-26"
anchorTimeID="t0" temporalFunction="true">
due giorni fa
</TIMEX3>

<TLINK eventID="e1" relatedToTime="t1"
signalID="s1" relType="IS_INCLUDED"/>
```

(C.214) *nello scorso quadrimestre.*

```
<SIGNAL id="s1">
nello
</SIGNAL>
<TIMEX3 id="t1" type="DURATION" value="P4M"
beginPoint="t2" endPoint="t0" temporalFunction="false">
scorso quadrimestre
</TIMEX3>

<TIMEX3 id="t3" type="DATE" value="2008-07-XX"
anchorTimeID="t0" temporalFunction="true">
```

(C.215) *Nel secondo quadrimestre*

```
<SIGNAL id="s1">
nel
</SIGNAL>
<TIMEX3 id="t1" type="DATE" value="2008-Qu2"
temporalFunction="false">
secondo quadrimestre
</TIMEX3>
```

C.6.2 Complex TLINK

(C.216) *Marco è arrivato ieri e Giovanna è partita due giorni fa.*

```
Marco è
<EVENT id="e1" class="OCCURRENCE" tense="PAST"
aspect="PERFECTIVE" pos="VERB" polarity="POS">
arrivato
</EVENT>
<TIMEX3 id="t1" type="DATE" value="2008-11-27"
anchorTimeID="t0" temporalFunction="true">
ieri
</TIMEX3>
e Giovanna è
<EVENT id="e2" class="OCCURRENCE" tense="PAST"
aspect="PERFECTIVE" pos="VERB" polarity="POS">
partita
```

```
</EVENT>
<TIMEX3 id="t2" type="DATE" value="2008-11-26"
anchorTimeID="t0" temporalFunction="true">
due giorni fa
</TIMEX3>

<TLINK timeID="t1" relatedToTime="t2" relType="AFTER"/>
<TLINK timeID="t1" relatedToEvent="e1" relType="INCLUDES"/>
<TLINK timeID="t2" relatedToEvent="e2" relType="INCLUDES"/>
```

(C.217) *Marco va in palestra per un'ora ogni mattina.*

```
Marco
<EVENT id="e1" class="OCCURRENCE" tense="PRESENT"
aspect="IMPERFECTIVE" pos="VERB" polarity="POS">
va
</EVENT>
in palestra
<SIGNAL id="s1">
per
</SIGNAL>
<TIMEX3 id="t2" type="DURATION" value="PT1H"
temporalFunction="false">
un'ora
</TIMEX3>
<TIMEX3 id="t3" type="SET" value="2008-XX-XXTMO"
anchorTimeID="t0" temporalFunction="true" quant="OGNI">
ogni mattina
</TIMEX3>

<TLINK timeID="t2" relatedToTime="t3" relType="IS_INCLUDED"/>
<TLINK timeID="t2" relatedToEvent="e1" relType="DURING\_INV">
```

(C.218) *Marco è partito tra mercoledì e giovedì.*

```
Marco è
<EVENT id="e1" class="OCCURRENCE" tense="PAST"
aspect="PERFECTIVE" pos="VERB" polarity="POS">
partito
</EVENT>
<SIGNAL id="s1">
tra
</SIGNAL>
<TIMEX3 id="t1" type="DATE" value="2008-11-26"
anchorTimeID="t0" temporalFunction="true">
mercoledì
</TIMEX3>
e
<TIMEX3 id="t2" type="DATE" value="2008-11-27"
anchorTimeID="t0" temporalFunction="true">
```

```
mercoledì
</TIMEX3>

<TLINK eventID="e1" relatedToTime="t1" relType="IAFTER"/>
<TLINK eventID="e1" relatedToTime="t2" relType="IBEFORE"/>
```

(C.219) *Marco ha insegnato linguistica dal 2006 al 2008*[13].

```
Marco ha
<EVENT id="e1" class="OCCURRENCE" tense="PAST"
aspect="PERFECTIVE" pos="VERB" polarity="POS">
insegnato
</EVENT>
linguistica
<SIGNAL id="s1">
dal
</SIGNAL>
<TIMEX3 id="t1" type="DATE" value="2006-XX-XX"
temporalFunction="false">
2006
</TIMEX3>
<SIGNAL id="s12">
al
</SIGNAL>
<TIMEX3 id="t2" type="DATE" value="2008-XX-XX"
temporalFunction="false">
2008
</TIMEX3>

<TIMEX3 id="t3" type="DURATION" value="P2Y"
temporalFunction="true" beginPoint="t1" endPoint="t2"/>

<TLINK eventID="e1" relatedToTime="t1" relType="BEGUN\_BY"/>
<TLINK eventID="e1" relatedToTime="t2" relType="ENDED\_BY"/>
```

C.6.3 Annotated Text Sample

La Repubblica 30/01/1985

La Fiom contesta le scelte dell'Flm.
I DELEGATI RESPINGONO L'ACCORDO CORNIGLIANO.

GENOVA - L'assemblea dei lavoratori Italsider di Cornigliano (erano presenti duemila operai) ha sostanzialmente contestato l'accordo raggiunto venerdì scorso tra la Finsider e la Flm nazionale e regionale, in base al quale lo stabilimento genovese riprenderà a produrre dal primo maggio con 1600 addetti e sarà gestito da una società pubblica(Nuova Italsider, Dalmine e Acciaierie di Piombino), in attesa dei privati .

[13] In this case there is no need to annotate the inferred relation of `DURING` but it is necessary to create the empty TIMEX3 tag

I delegati della lega Fiom di Cornigliano e dell' "Oscar Senigallia", in particolare, come già il consiglio di fabbrica, hanno attaccato la Flm nazionale e regionale accusandole di averli esclusi dalle trattative, e non hanno firmato la bozza di intesa.
Essi chiedono, e l'assemblea è stata d'accordo, alcune fondamentali integrazioni, che dovrebbero scaturire da nuove trattative che i delegati Fiom intendono aprire con la Nuova Italsider a livello locale.

La Repubblica
<TIMEX3 functionInDocument="PUBLICATION_TIME"
 temporalFunction="false" tid="t2" type="DATE"
value="1985-01-30">
30/01/1985
</TIMEX3>
La Fiom contesta le scelte dell' Flm.
I DELEGATI RESPINGONO L' ACCORDO CORNIGLIANO .

GENOVA - L' assemblea dei lavoratori Italsider di Cornigliano (
erano
<EVENT id="e1" class="STATE" tense="IMPERFECT"
aspect="PERFECTIVE" pos="ADJECTIVE"
mood="NONE" polarity="POS">
presenti
</EVENT>
duemila operai) ha sostanzialmente
<EVENT id="e2" class="I_ACTION" tense="PAST"
aspect="PERFECTIVE" pos="VERB"
mood="NONE" polarity="POS">
contestato
</EVENT>
l'
<EVENT id="e3" class="OCCURRENCE" tense="NONE"
 aspect="NONE" pos="NOUN"
mood="NONE" polarity="POS">
accordo
</EVENT>
<EVENT id="e4" class="STATE" tense="PAST"
aspect="PERFECTIVE" pos="VERB" vForm="PARTICIPLE"
mood="NONE" polarity="POS">
raggiunto
</EVENT>
<TIMEX3 id="t3" anchorTimeID="t2" functionInDocument="NONE"
temporalFunction="false" type="DATE"
value="1985-01-25">
venerdi' scorso
</TIMEX3>
tra la Finsider e la Flm nazionale e regionale , in base al quale lo stabilimento genove
<EVENT id="e5" class="ASPECTUAL" tense="FUTURE"
aspect="IMPERFECTIVE" pos="VERB"
mood="NONE" polarity="POS>
riprenderà

</EVENT>
a
<EVENT id="e6" class="OCCURRENCE" tense="PRESENT"
aspect="IMPERFECTIVE" pos="VERB" vForm="INFINITIVE"
mood="NONE" polarity="POS">
produrre
</EVENT>
<SIGNAL sid="s1">
dal
</SIGNAL>
<TIMEX3 id="t4" anchorTimeID="t2" functionInDocument="NONE"
temporalFunction="true" type="DATE"
value="1985-05-01">
primo maggio
</TIMEX3>
con 1600 addetti e sarà
<EVENT id="e7" class="OCCURRENCE" tense="FUTURE"
aspect="PERFECTIVE" pos="VERB"
mood="NONE" polarity="POS">
gestito
</EVENT>
da una società pubblica (Nuova Italsider, Dalmine e Acciaierie di Piombino),
<EVENT id="e29" class="STATE" tense="NONE"
aspect="NONE" pos="PREPOSITION"
mood="NONE" polarity="POS">
in attesa
</EVENT>
dei privati. I delegati della lega Fiom di Cornigliano e dell’
"Oscar Senigallia", in particolare , come
<SIGNAL sid="s2">gia’</SIGNAL>
il consiglio di fabbrica , hanno
<EVENT id="e8" class="OCCURRENCE" tense="PAST"
aspect="PERFECTIVE" pos="VERB"
mood="NONE" polarity="POS">
attaccato
</EVENT>
la Flm nazionale e regionale
<EVENT id="e9" class="REPORTING" tense="PRESENT"
aspect="PERFECTIVE" pos="VERB" vForm="GERUNDIVE"
mood="NONE" polarity="POS">
accusando
</EVENT>
le di averli
<EVENT id="e10" class="I_ACTION" tense="PAST"
aspect="PERFECTIVE" pos="VERB" vForm="INFINITIVE"
mood="NONE" polarity="POS">
esclusi
</EVENT>
dalle

<EVENT id="e11" class="OCCURRENCE" tense="NONE"
aspect="NONE" pos="NOUN"
mood="NONE" polarity="POS">
trattative
</EVENT>
, e non hanno
<EVENT id="e12" class="OCCURRENCE" tense="PAST"
aspect="PERFECTIVE" pos="VERB"
mood="NONE" polarity="NEG">
firmato
</EVENT>
la bozza di intesa . Essi
<EVENT id="e13" class="I_ACTION" tense="PRESENT"
aspect="IMPERFECTIVE" pos="VERB"
mood="NONE" polarity="POS">
chiedono
</EVENT>
, e l'assemblea è stata d'accordo, alcune fondamentali
<EVENT id="e20" class="OCCURRENCE" tense="NONE"
aspect="NONE" pos="NOUN"
mood="NONE" polarity="POS">
integrazioni
</EVENT>
, che
<EVENT id="e30" class="I_STATE" tense="PRESENT"
aspect="NONE" pos="VERB"
mood="COND" polarity="POS">
dovrebbero
</EVENT>
<EVENT id="e16" class="I_ACTION" tense="PRESENT"
aspect="NONE" pos="VERB" vForm="INFINITIVE"
mood="NONE" polarity="POS">
scaturire
</EVENT>
da nuove
<EVENT id="e17" class="I_STATE" tense="NONE"
aspect="NONE" pos="NOUN"
mood="NONE" polarity="POS">
trattative
</EVENT>
che i delegati Fiom
<EVENT id="e18" class="I_STATE" tense="PRESENT"
aspect="IMPERFECTIVE" pos="VERB"
mood="NONE" polarity="POS">
intendono
</EVENT>
<EVENT id="e19" tense="PRESENT"
aspect="NONE" pos="VERB" vForm="INFINITIVE"
mood="NONE" polarity="POS">

```
aprire
</EVENT>
con la Nuova Italsider a livello locale.

<TLINK lid="l11" origin="USER"
relType="BEFORE" relatedToTime="t2" timeID="t3" />
<TLINK lid="l13" origin="USER"
relType="AFTER" relatedToTime="t4" timeID="t2" />
<TLINK eventID="e4" lid="l14"
origin="USER" relType="IS_INCLUDED" relatedToTime="t3" />
<TLINK eventID="e2" lid="l15"
origin="USER" relType="AFTER" relatedToEventInstance="e4" />
<TLINK eventID="e6" lid="l19"
origin="USER" relType="BEGUN_BY" relatedToTime="t4" signalID="s1" />
<TLINK eventID="e7" lid="l20"
origin="USER" relType="BEGUN_BY" relatedToTime="t4" signalID="s1" />
<TLINK eventID="e29" lid="l21"
origin="USER" relType="DURING" relatedToEventInstance="e7" />
<TLINK eventID="e11" lid="l27"
origin="USER" relType="BEFORE" relatedToTime="t3" />
<TLINK eventID="e1" lid="l34"
origin="USER" relType="SIMULTANEOUS" relatedToEvent="e2" />
<TLINK eventID="e2" lid="l30"
origin="USER" relType="BEFORE" relatedToTime="t2" />
<TLINK eventID="ei8" lid="l31"
origin="USER" relType="BEFORE" relatedToTime="t2" />

<ALINK eventID="e5" lid="l2"
origin="USER" relType="REINITIATES" relatedToEventInstance="e6" />

<SLINK eventID="e3" lid="l1"
origin="USER" relType="FACTIVE" subordinatedEvent="e4" />
<SLINK eventID="e9" lid="l3"
origin="USER" relType="FACTIVE" subordinatedEvent="e10" />
<SLINK eventID="e10" lid="l4"
origin="USER" relType="FACTIVE" subordinatedEvent="e11" />
<SLINK eventID="e13" lid="l5"
origin="USER" relType="FACTIVE" subordinatedEvent="e20" />
<SLINK eventID="e30" lid="l6"
origin="USER" relType="INTENSIONAL" subordinatedEventInstance="e16" />
<SLINK eventID="ei16" lid="l7"
origin="USER" relType="EVIDENTIAL" subordinatedEventInstance="e17" />
<SLINK eventID="e18" lid="l8"
origin="USER" relType="INTENSIONAL" subordinatedEventInstance="e19" />
```

C.7 It-TimeML DTD

```
<!ELEMENT It-TimeML ( #PCDATA | EVENT | TIMEX3 | SIGNAL
TLINK | ALINK | SLINK )* >
<!ATTLIST It-TimeML xsi:noNamespaceSchemaLocation CDATA #IMPLIED >
<!ATTLIST It-TimeML xmlns:xsi CDATA #IMPLIED >

<!ATTLIST TimeML comment CDATA #IMPLIED >

<!ELEMENT EVENT ( #PCDATA ) >
<!ATTLIST EVENT id ID #REQUIRED >
<!ATTLIST EVENT class ( ASPECTUAL | I_ACTION | I_STATE |
  OCCURRENCE | PERCEPTION | REPORTING | STATE ) #REQUIRED >
<!ATTLIST EVENT pred CDATA #IMPLIED >
<!ATTLIST EVENT pos ( ADJECTIVE | NOUN | VERB | PREPOSITION
   | NONE ) #REQUIRED >
<!ATTLIST EVENT tense ( NONE | PAST | PRESENT |
 IMPERFECT | FUTURE ) #REQUIRED >
<!ATTLIST EVENT aspect ( NONE | PERFECTIVE | IMPERFECTIVE |
   PROGRESSIVE) #REQUIRED >
<!ATTLIST EVENT vForm ( NONE | INFINITIVE | GERUNDIVE |
   PARTICIPLE) #REQUIRED >
<!ATTLIST EVENT polarity ( POS | NEG ) #REQUIRED >
<!ATTLIST EVENT mood ( SUBJUNCTIVE | COND | NONE ) #REQUIRED >
<!ATTLIST EVENT modality CDATA #IMPLIED >
<!ATTLIST EVENT comment CDATA #IMPLIED >

<!ELEMENT TIMEX3 ( #PCDATA ) >
<!ATTLIST TIMEX3 id ID #REQUIRED >
<!ATTLIST TIMEX3 type ( DATE | DURATION | SET | TIME ) #REQUIRED >
<!ATTLIST TIMEX3 value NMTOKEN #REQUIRED >
<!ATTLIST TIMEX3 anchorTimeID IDREF #IMPLIED >
<!ATTLIST TIMEX3 beginPoint IDREF #IMPLIED >
<!ATTLIST TIMEX3 endPoint IDREF #IMPLIED >
<!ATTLIST TIMEX3 freq NMTOKEN #IMPLIED >
<!ATTLIST TIMEX3 functionInDocument ( CREATION_TIME |
EXPIRATION_TIME | MODIFICATION_TIME | PUBLICATION_TIME |
RELEASE_TIME | RECEPTION_TIME | NONE ) #IMPLIED>
<!ATTLIST TIMEX3 mod ( BEFORE | AFTER | ON_OR_BEFORE | ON_OR_AFTER
   | LESS_THAN | MORE_THAN | EQUAL_OR_LESS | EQUAL_OR_MORE | START |
   MID | END | APPROX )  #IMPLIED >
<!ATTLIST TIMEX3 quant CDATA #IMPLIED >
<!ATTLIST TIMEX3 temporalFunction ( false | true ) #IMPLIED >
<!ATTLIST TIMEX3 valueFromFunction IDREF #IMPLIED >
<!ATTLIST TIMEX3 comment CDATA #IMPLIED >

<!ELEMENT SIGNAL ( #PCDATA ) >
<!ATTLIST SIGNAL sid ID #REQUIRED >
<!ATTLIST SIGNAL comment CDATA #IMPLIED >
```

```
<!ELEMENT TLINK EMPTY >
<!ATTLIST TLINK lid ID #REQUIRED >
<!ATTLIST TLINK relType ( BEFORE | AFTER | INCLUDES | IS_INCLUDED
   | DURING | DURING_INV | SIMULTANEOUS | IAFTER | IBEFORE | IDENTITY
   | BEGINS | ENDS | BEGUN_BY | ENDED_BY ) #REQUIRED >
<!ATTLIST TLINK eventID IDREF #IMPLIED >
<!ATTLIST TLINK timeID IDREF #IMPLIED >
<!ATTLIST TLINK relatedToEvent IDREF #IMPLIED >
<!ATTLIST TLINK relatedToTime IDREF #IMPLIED >
<!ATTLIST TLINK signalID IDREF #IMPLIED >
<!ATTLIST TLINK origin CDATA #IMPLIED >
<!ATTLIST TLINK comment CDATA #IMPLIED >
<!ATTLIST TLINK temporalDistance IDEREF #IMPLIED>

<!ELEMENT ALINK EMPTY >
<!ATTLIST ALINK lid ID #REQUIRED >
<!ATTLIST ALINK relType ( CONTINUES | CULMINATES | INITIATES |
   REINITIATES | TERMINATES ) #REQUIRED >
<!ATTLIST ALINK eventID IDREF #REQUIRED >
<!ATTLIST ALINK relatedToEvent IDREF #REQUIRED >
<!ATTLIST ALINK signalID IDREF #IMPLIED >
<!ATTLIST ALINK comment CDATA #IMPLIED >

<!ELEMENT SLINK EMPTY >
<!ATTLIST SLINK lid ID #REQUIRED >
<!ATTLIST SLINK relType ( CONDITIONAL | COUNTER_FACTIVE |
   EVIDENTIAL | FACTIVE | INTENSIONAL | NEG_EVIDENTIAL ) #REQUIRED >
<!ATTLIST SLINK eventID IDREF #REQUIRED >
<!ATTLIST SLINK subordinatedEvent IDREF #REQUIRED >
<!ATTLIST SLINK signalID IDREF #IMPLIED >
<!ATTLIST SLINK comment CDATA #IMPLIED >
```

C.8 Annotation Instructions

In this section we present detailed instructions on how the annotation should be performed in order to obtain reliable inter-annotators' agreement.

1. Read carefully the document to be annotated;
2. Annotate all temporal expressions, including the DCT. Do not annotate any other temporal expression in the title of the document. Do not pay attention to their relations;
3. Complete all attributes' values of the `TIMEX3` tag. To do this, you should start looking to relations between temporal expressions, but DO NOT mark them yet;
4. Annotate all signals. Pay attention to those expressions which mark structurally based `SLINK`;
5. Annotate all events: starts with verbs, then concentrate on prepositional phrases, adjectives and finally nouns. Use all lexical resources you have access to in order to disambiguate possible eventive reading of nouns, when in doubt. Do not pay attention to the event attributes. Do not annotate event in the title of the document;
6. Complete the attributes' values of the `EVENT` tag: starts with verbs, assign them `tense`, `aspect`, `mood`, `modality` (when necessary), `vForm` and then `class`. Do the same for all other events you have marked;
7. Go through events and annotate all cases of event identity with the `TLINK` tag;
8. Read the text again and check if you have missed some markables; do not start to question your annotation, except there are clear mistakes. Motto: *First marked, it's good!!*.
9. Annotate all `ALINK`s;
10. Start the annotation of `TLINK`s:
    - (i.) Annotate all temporal relations between temporal expressions;
    - (ii.) Annotate all temporal relations between an event and a temporal expression which are explicitly signalled by a `SIGNAL`. Pay attention to the necessity of creating duplicated `EVENT` tags. If you have the necessity to to this, then remember to create a `TLINK` with `relType="IDENTITY"` , between the source `EVENT` tag and its duplicate;
    - (iii.) Annotate all temporal relations between an event a temporal expression which are not explicitly signaled. Do not annotate inferred relations yet;
    - (iv.) Annotate all temporal relations between two events which are explicitly signalled by a `SIGNAL`. Pay attention to the necessity of creating duplicated `EVENT` tags. If you have the necessity to to this, then remember to create a `TLINK` with `relType="IDENTITY"` , between the source `EVENT` tag and its duplicate;
    - (v.) Annotate all temporal relations between two events. Do not annotate inferred relations yet;

(vi.) Annotate the easiest inferrable temporal relations between markables; do not go too far.

11. Start the annotation of SLINKs:

    (i.) Mark all structurally based SLINKs;

    (ii.) Mark all lexically based SLINKs. Pay attention to the event class constraints.

12. You have almost done: Read the text again and check if you have missed some relations: do not start to question your annotation, except there are clear mistakes. Motto: *First marked, it's good!!*.

13. You've finished!! Well done!! Get a break (coffee is a good choice!!) and then start with another doc!!