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Towards a Linguistically Motivated Irish Sign Language Conversational Avatar.

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Abstract

Avatars are life-like characters that exist in a virtual world on our computer monitors. They are synthetic actors that have, in more recent times, received a significant amount of investigation and development. This is primarily due to leverage gained from advances in computing power and 3D animation technologies. Since the release of the movie "Avatar" last year, there is also a broader awareness and interest in avatars in the public domain. Ishizuka and Prendinger (2004) describe how researchers, while endeavouring to develop a creature that is believable and capable of intelligible communication, use a wide variety of terms to describe their work: avatars, anthropomorphic agents, creatures, synthetic actors, non-player characters, embodied conversational agents, bots, intelligent agents. While most of these terms are inspired from the character specific applications, some intend to draw attention to a particular aspect of the life-like character. To date it seems that there is no universal agreement with regard to terminology. The term avatar can be used to refer to the visual representation of a human being within a virtual environment whereas the term embodied conversational agent refers to a character that visually incorporates knowledge with regard to the conversational process. For the purpose of this research, the term embodied conversational agent is deemed an appropriate descriptor for the synthetic agent undergoing development. The value that RRG contributes to this is that it is a theory of grammar that is concerned with the interaction of syntax, semantics and pragmatics across grammatical systems. RRG can be characterised as a descriptive framework for the analysis of languages and also an explanatory framework for the analysis of language acquisition (Van Valin, 2008). As a lexicalist theory of grammar, RRG can be described as being well motivated cross-linguistically. The grammar model links the syntactic structure of a sentence to the semantic structure by means of a linking algorithm, which is bi-directional in nature. With respect to cognitive issues, RRG adopts the criterion of psychological adequacy formulated in Dik (1991), which states that a theory should be compatible with the results of psycholinguistic research on the acquisition, processing, production, interpretation and memorisation of linguistic expressions. It also accepts the criterion put forward in Bresnan and Kaplan (1982), that theories of linguistic structure should be directly relatable to testable theories of language production and comprehension. RRG incorporates many of the viewpoints of current functional grammar theories. RRG takes language to be a system of communicative social action, and accordingly, analysing the communicative functions of grammatical structures plays a vital role in grammatical description and theory from this perspective. The view of the lexicon in RRG is such that lexical entries for verbs should contain unique information only, while as much information as possible should be derived from general lexical rules. It is envisaged that the RRG parser/generator described in this paper will later be used as a component in the development of a computational framework for the embodied conversational agent for ISL.

This poses significant technical and theoretical difficulties within both RRG and for software (Nolan and Salem 2009, Salem, Hensman and Nolan 2009). As ISL is a visual gestural language without any aural or written form, like all other sign languages, the challenge is to extend the RRG view of the lexicon and the layered structure of the word, indeed the model itself, to accommodate sign languages. In particular, the morphology of sign languages is concerned with manual and non-manual features, handshapes across the dominant and non-dominant hand in simultaneous signed constructions, head, eyebrows and mouth shape. These are the morphemes and lexemes of sign language. How can these fit into the RRG lexicon and what are the difficulties this presents for RRG at the semantic-morphosyntax interface? This paper will discuss this research as a work in progress to date. It is envisaged that the embodied conversational agent undergoing development in this research will later be employed for real-time sign language visualisation for Irish Sign Language (ISL).

1 Introduction

The aim of this paper is to discuss research work in progress in the development of an avatar for Irish Sign Language understood as an embodied conversational agent. It is planned to use RRG as the linguistic 'engine' in this development for use in sign languages, in particular, in this work in progress, Irish Sign Language. This paper aims to discuss the development of an embodied conversational agent to encode gesture, while also discussing the use of Role and Reference Grammar, a functional model of grammar, henceforth termed RRG, in the development of an RRG parser for sign language.

Avatars are life-like characters that exist in a virtual world on our computer monitors. They are synthetic actors that have in more recent times, received a significant amount of investigation and development. This is primarily due to leverage gained from advances in computing power and 3D animation technologies. Since the release of the movie "Avatar" last year, there is also a broader awareness and interest in avatars in the public domain. Ishizuka and Prendinger, 2004, describe how researchers, while endeavouring to develop a creature that is believable and capable of intelligible communication, use a wide variety of terms to describe their work: avatars, anthropomorphic agents, creatures, synthetic actors, non-player characters, embodied conversational agents, bots, intelligent agents. While most of these terms are inspired from the character specific applications, some intend to draw attention to a particular aspect of the life-like character. To date it seems that there is no universal agreement with regard to terminology. The term *avatar* can be used to refer to the visual representation of a human being within a virtual environment whereas the term *embodied conversational agent* refers to a character that visually incorporates knowledge with regard to the conversational process. For the purpose of this research, the term embodied conversational agent is deemed an appropriate descriptor for the synthetic agent undergoing development. One topic that has been the subject of much research in the field of animated agents is whether the agent is more life-like and therefore more coherent when developed based on a more realistic human form as opposed to a cartoon-style approach. Researchers that aim to create virtual humans seem to follow the more realistic approach (Thalmann et al., 1997). It is envisaged that the depiction of the agent in a more realistic human form would be more appropriate in this instance.

RRG is a theory of grammar that is concerned with the interaction of syntax, semantics and pragmatics across grammatical systems. RRG can be characterised as a descriptive framework for the analysis of languages and also an explanatory framework for the analysis of language acquisition (Van Valin, 2008). It is a relatively new linguistic theory of grammar, which was developed in the 1980's by William Foley and Robert Van Valin Jnr. (Foley and Van Valin, 1984). As a lexicalist theory of grammar, RRG can be described as being well motivated cross-linguistically. It is a monostratal theory positing only one level of syntactic representation, the actual form of the sentence. Syntacic clause structure in RRG is represented by the layered structure of the clause (LSC). The grammar model links the syntactic structure of a sentence to the semantic structure by means of a linking algorithm, which is bi-directional in nature. In RRG the semantic representation of a sentence is described as a logical structure [LS]. With respect to cognitive issues, RRG adopts the criterion of psychological adequacy formulated in Dik (1991), which states that a theory should be "compatible with the results of phsyco-linguistic research and the acquisition, processing, production, interpretation and memorisation of linguistic expressions". It also accepts the related criterion put forward in Bresnan and Kaplan (1982), that theories of linguistic structure should be directly relatable to testable theories of language production and comprehension. RRG incorporates many of the viewpoints of current functional grammar theories, however, it takes language to be a system of communicative social action, and accordingly, analysing the communicative functions of grammatical structures plays a vital role in grammatical description and theory from this perspective. The lexicon in RRG takes the position that lexical entries for verbs should contain unique information only, while as much information as possible should derived from general lexical rules. It is envisaged that the RRG parser described in this paper will later be used as a tool or component in the development of a computational framework for the embodied conversational agent for ISL. It is envisaged that the embodied conversational agent undergoing development in this research will later be employed for real-time sign language visualisation, in particular, Irish Sign Language (ISL).

2 Avatar Technologies

MakeHuman and Blender are the core technologies used in this research. MakeHuman is an open source, innovative and professional software tool which can be utilised for the development of 3-Dimensional humanoid characters. Makehuman provides for the creation of virtual humanoid characters through the manipulation of a base polygonal mesh. It is possible to sculpt and shape the mesh provided by MakeHuman, by manipulating various user interface parameters. The mesh can then be exported in various formats for further use and development, (www.makehuman.org).

Blender is an open source, cross platform 3D graphics and animation application, which provides capabilities for the development of images and animations through 3D modelling and rendering. Blender was chosen as a tool for this research as it provides extensive capabilities that will aid in the development of an embodied conversational agent. Blender provides its own internal games engine, which renders it particularly attractive for real time processing. Some of the more important features that Blender provides for this research include: 3D modelling, rigging, skinning, animation, non-linear animation, shape keys, simulation and rendering UV mapping, texturing,. It provides a powerful character animation toolkit, advanced simulation tools including cloth and softbody dynamics and most importantly it supports the use of Python for embedded scripting. This provides Python scripting access for custom and procedural animation effects. It is expected that this area in particular will be central to the development of my research in the future. Another important feature of Blender is its cross platform capabilities, enabling it to run on multiple computer platforms including Microsoft Windows, Mac OS X and Linux.

2.1 Character Animation in Blender

In this section we provide a summary of our development in Blender of a humanoid avatar. Within the Blender environment, the initial stage of avatar development in character animation involves working with a skeleton referred to as an *armature*. An armature behaves in a similar fashion to the human skeleton. The bones of the armature can be connected by using an array of different approaches, resulting in a controllable, intuitively movable character rig. The process of building an armature is called rigging. Figure 1 below provides a front view of the avatar rig which was developed using Blender 2.49b. The armature gives the avatar structure while also providing a mechanism for creating and holding poses. Figure 1 also provides various orientations of the right and left hand armature. The right hand armature includes added constraints.

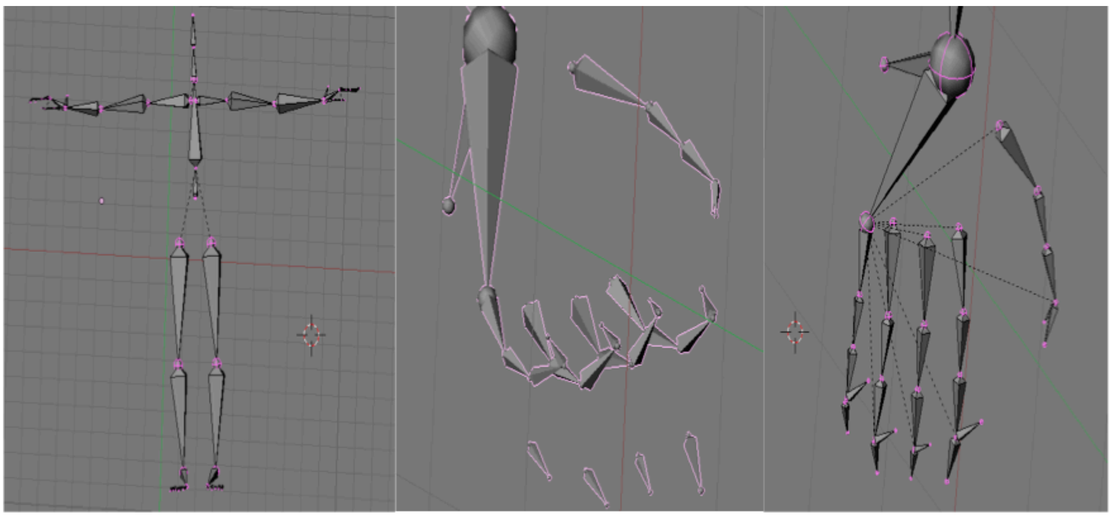

Figure 1: The Blender avatar rig and the armature of the left and the right hand respectively

2.2 Skinning

Before its possible to animate the armature it must be attached to the mesh object. The process of attaching an armature to a mesh is called skinning. The mesh used in this research was imported from MakeHuman and then the custom built armature was added to the mesh.

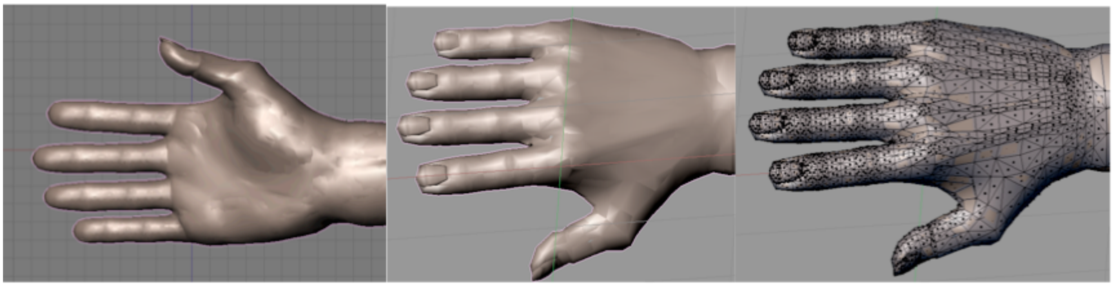

Figure 2: Various orientations and views for the avatar right hand mesh in Blender

Figure 2 provides the various orientations of the right hand mesh of the avatar, including the mesh object in Edit mode, where the polygonal mesh and the painted skin layer are visible.

2.3 Animating with Blender using a Python Script

Blender can be used in conjunction with Python. Blender provides Python scripting access for custom and procedural animation effects. Creating Python scripts using Blenders text editor makes it possible to extend Blenders functionality. Scripts in the text editor can be linked to scenes, materials and objects in the 3D view. These linked scripts can then be set to run whenever the frame changes or screen redraws. This functionality provides Python scripts with the ability to control and alter objects in real-time over the course of an animation. It is envisaged that for this research, Python scripting will be used to create specific deformations of the avatar mesh in Blender. The particular deformations will depend on the English text that has been inputted into the system. It is envisaged that once the inputted text has been converted into a meta-representation in RRG logical structures, that Python scripting will be used to generate ISL as output to the embodied conversational agent.

2.4 Animating with the Game Engine

2.4.1 Blender Games Engine

The Blender environment includes a built-in Blender Game Engine (BGE) that provides tools for the development of interactive 3D applications. The main focus of this engine is game development, however it can also be used to develop interactive 3D software. The BGE provides logic bricks fro users without any programming language knowledge. This provides an easy to use visual interface for designing interactive applications. There are three types of logic bricks. These are: sensors, controllers and actuators. Blender also provides its own Python API, which can be utilised to create scripts to control the real-time interactive environment. This is realised by creating a python controller and linking it to a python script.

2.4.2 Blender Sensors

Sensors are used to trigger events. When a sensor is triggered, a pulse is sent to all controllers that the particular sensor is connected to. Sensors therefore can be described as sending pulses to controllers. The pulses can be TRUE or FALSE. Different parameters on the sensor's logic block control when a sensor fires a particular pulse. The controllers are programmed to react on TRUE and FALSE pulses as is necessary. There are 14 different types of sensors available with Blender. These are: Always, Delay, Keyboard, Mouse, Touch Collision, Near Radar, Property, Random, Ray, Message, Joystick, Actuator. One sensor that is of particular interest to this research is the Keyboard sensor. This is used in Blender for detecting keyboard input.

It can save keyboard input to a String property. The Game Logic Python API is used to create scripts for interaction with these sensors.

2.4.3 Creating a Python Controller (Python Scripting)

Controllers are used to collect data sent by a sensor. When a sensor is activated it produces a positive pulse and when it is deactivated it produces a negative pulse. The controllers' job is to check and combine these pulses so that the correct response is triggered. There are 8 different types of controllers available in Blender. These are AND, OR, XOR, NAND, NOR, XNOR, Expression and Python. Table 1 provides a quick overview of the various controller types provided by Blender ([Blender_Controllers]).

Table 1: Blender Controller Types ([Blender_Controllers])

Positive sensors	**Controllers**					
	AND	OR	XOR	NAND	NOR	XNOR
None	False	False	False	True	True	True
One	False	True	True	True	False	False
Multiple, not all	False	True	False	True	False	True
All	True	True	False	False	False	True

2.4.4 Using Blender Actuators

Actuators are used in Blender to perform actions, such as creating, moving or destroying objects, editing a mesh etc. Actuators are triggered by receiving a positive pulse from a controller. There are many actuators available in Blender and the majority of these are particularly interesting for this research. Table 2 ([Blender_Actuators]) provides a list of the actuators available in Blender and also a brief description of their function.

Table 2: Blender Actuators ([Blender_Actuators])

Motion	Sets object into motion and/or rotation, there are different options from "teleporting" to physically push rotate objects.
Shape Action	Handles animations stored in shape keys and animated with shape actions.
Action	Handles armature actions, this is only visible if an armature is selected.
Constraint	Constraints are used to limit object's locations, distance or rotation. These are useful for controlling the physics of the object in game.
Ipo	Controls Ipo animations, these can move, rotate, scale, change colour of objects and more.
Camera	Has options to follow objects smoothly, primarily for camera objects but any object can use this.
Sound	Used to play sounds in the game.
Property	Manipulates the object's properties, like assigning, adding or copying.
Edit Object	Edits the object's mesh, adds objects or destroys them, it can also change the mesh of an object (and soon also recreate the collision mesh).
Scene	Manage the scenes in your blend file; these can be used as levels or for UI and background.
Random	Creates random values which can be stored in properties.
Message	Sends messages, which can be received by other objects to activate them.
CD	Plays CD music (might not make it to 2.5).
Game	Handles the entire game and can do things as restart, quit, load and save.
Visibility	Changes visibility of the object.
2D Filter	Filters for special effects like sepia colours or blur.
Parent	Can set a parent to the object, or unparent it.
State	Changes states of the object.

3. Gesture in human communications and language

Human conversation is known to encompass a myriad of complex behaviours. Further to using our vocal organs to produce a speech signal, there are a wide range of complex bodily behaviours underlying human communication (Abercrombie, 1956). It is important to realise, that even though speech is prominent in conveying content in face-to-face conversation, spontaneous gesture is also integral to conveying propositional content. In fact 50% of gestures add non-redundant information to the common ground of the conversation (Cassell, Stone et al. 2000). In face-to-face dialogue, utterances consist of co-ordinated ensembles of coherent verbal and non-verbal actions (McNeill, 1992) (Bavelas and Chovil, 2000) (Engle, 2000).

With regard to sign language, signs use visual imagery to convey ideas instead of single words. Sign language is used worldwide by the hearing-impaired, as a form of communication with each other and with those that hear. It is a visual, spatial language, which utilises a combination of body and facial expression, lip formation and hand signs. Sign languages are fully developed natural languages and are used by deaf communities all over the world (Gordon, 2005). Sign language is heavily reliant on gesture and facial expression, which play a very important role in the expression of meaning. It can be described as a natural language. It was not consciously invented by anyone, but was developed spontaneously by deaf people and passed down without instruction from one deaf generation to the next (Sandler and Lillo-Martin, 2001).

In terms of production, signed languages are articulated in three dimensional space, using not only the hands and arms, but also the head, shoulders, torso, eyes, eye-brows, nose, mouth and chin to express meaning (O'Baoill and Matthews, 2000). Communication occurs using a visual-gestural modality, encompassing manual and non-manual gestures. Manual gestures make use of hand forms, hand locations, hand movements and orientations of the palm. Non-manual gestures include the use of eye gaze, facial expression, head and upper body movements. Both manual and non-manual gestures must be performed to produce a valid understanding and interpretation of the sign language ([deafsa]).

3.1 Irish Sign Language (ISL)

ISL is the indigineous language of the Irish deaf community and is the first language of deaf people in Ireland. It is a visual, spatial language, with its own distinct grammar. ISL is not only a language of the hands, but also of the face and body. In both modality and linguistic terms, ISL is very different to spoken English or Irish. “While ISL is used by approximately 5,000 Irish deaf people, it is estimated that some 50,000 people also know and use the language, to a greater or lesser extent” (Leeson 2001). ISL can be described as a minority language and therefore there is currently no real framework in place to describe its architecture. We propose to use RRG as a theory of grammar that will allow for the development of a lexicon architecture that is sufficiently universal with regard to content to accommodate ISL. We discuss RRG as a model of grammar in a later section.

3.2 Potential of an avatar to deploy sign Language communication in ISL

ISL is a fully developed natural language used by the Irish deaf community, however, ISL can be described as a minority language and therefore it is not currently recognised as a language in the Republic of Ireland. As a consequence, access to important information in relation to education, employment and a myriad of other resources are not available to members of the deaf community in Ireland. Currently in Ireland, highly skilled interpreters must be employed to facilitate the communication between the deaf or hearing impaired and the hearing. The use of an interpreter may not always be appropriate or even possible. The development of a three dimensional (3D) computer generated conversational avatar to deploy sign language communication would solve this problem. Conversational agents are believable humanoid avatars, capable of intelligible communication. In this particular instance communication would be through the articulation of Irish Sign Language.

4 Role and Reference Grammar (RRG)

Van Valin, (2008) describes how RRG theory was developed in an attempt to answer two simple questions: (i) What would linguistic theory look like if it was based on the analysis of other languages such as Lakhota, Dyirbal and Tagalog, rather than the analysis of English, and (ii) how can the interaction of syntax, semantics and pragmatics in different grammatical systems best be captured and explained?”. Figure 3 shows the organisation of RRG.

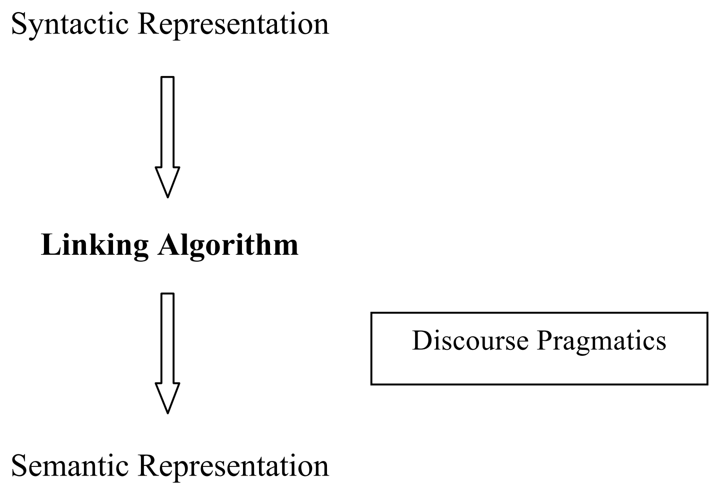

Figure 3: Organisation of Role and Reference Grammar (Van Valin 2005)

RRG can be described as a monostratal theory positing only one level of syntactic representation, the actual form of the sentence. Therefore there is only one syntactic representation for a sentence. This representation corresponds to the actual form of the sentence. RRG does not allow any phonologically null elements in the syntax; if there's nothing there, there's nothing there (Van Valin, 2003).

With respect to cognitive issues RRG adopts the criterion of phsycological adequacy formulated in Dik, (1991), which states that a theory should be "compatible with the results of phsycolinguistic research on the acquisition, processing, production, interpretation and memorization of linguistic expressions." The RRG approach to language acquisition rejects the theory that grammar is radically arbitrary and therefore unlearnable. RRG maintains that grammar is relatively motivated (in Saussure's sense) semantically and pragmatically. Therefore it maintains that there is sufficient information available for a child in the speech to which it is exposed to enable it to construct a grammar.

Syntactic clause structure in RRG is represented by the layered structure of the clause. Within RRG a clause is said to be universally composed of a nucleus (which contains the predicating element) a core (which is composed of the nucleus and the predicating elements of the nucleus) and a periphery (which is composed of the temporal and locative modifiers of the core) RRG applies the use of operators to modify the layers of the clause. Operators include gramatical categories such as tense, aspect, modality, negation and illucutionary force. Within RRG complex sentences may be composed of a nuclear juncture (nucleus + nucleus), a core juncture (core + core), and a clausal juncture (clause + clause). The units in a juncture may also be connected to each other in one of three relationships: co-ordination, subordination and co-subordination.

RRG links the syntactic structure of a sentence to the semantic structure by means of a linking algorithm. In RRG the semantic representation of a sentence is described as a logical structure [LS]. The semantic structure is based on a system of lexical representation and semantic roles. The system of lexical representation is based on Vendler's Aktionsart classification of verbs into state, activity, acheivement and accomplishment, and also uses an added class called active accomplishment. RRG introduces us to the concept of semantic macrorole, where there is an actor and an undergoer. These macroroles and other arguments are linked to the syntax by means of the linking algorithm. In addition to the syntactic and semantic representations there is also a representation of the focus structure of the sentence. Van Valin, (2008) describes how the focus structure indicates the scope of the assertion of an utterance in contrast to the pragmatic supposition.

4.1 Clause Structure

Van Valin (2005) states that regarding clause structure, there are two fundamental aspects of theory that must be dealt with; relational and non-relational. Relational structure is concerned with relations between a predicate and its argument(s), while non-relational structure is concerned with the hierarchical organisation of phrases, clauses and sentences. With regard to RRG, there are two general considerations that a theory of clause structure must meet. The general considerations for a theory of clause structure are that a) a theory of clause structure must capture all of the universal features of clauses, without imposing features on languages in which there is no evidence for them, and b) a theory should represent comparable structures in different languages in comparable ways.

4.1.1 The Layered structure of the clause

Within RRG theory, non-relational clause structure is referred to as the layered structure of the clause. The layered structure of the clause is based on two fundamental contrasts. Between the predicate and non-predicating elements, on one hand, and among the non-predicating elements, between arguments and non-arguments on the other, Van Valin, 2005. Since these contrasts are found within all languages, RRG describes the primary constituent units of the clause as the 'nucleus', the 'core' and a 'periphery', where the 'nucleus' contains the predicate (usually a verb), the 'core' contains the nucleus and the arguments of the predicate and the 'periphery' subsumes non-arguments of the predicate. This is informally represented in the two figures following.

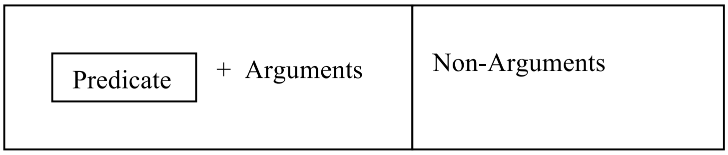

Figure 4: Universal oppositions underlying clause structure (Van Valin 2005)

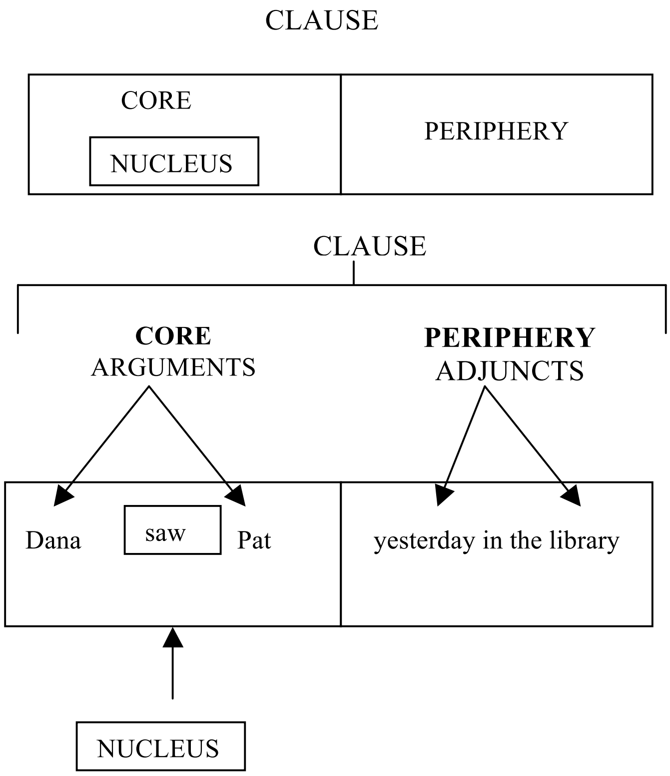

Figure 5: Components of the layered structure of the clause (Van Valin 2005)

Table 3 below shows the semantic units underlying the layered structure of the clause.

Table 3: The semantic units underlying the layered structure of the clause (Van Valin 2005)

Semantic Elements	Syntactic Unit
Predicate	Nucleus
Argument in semantic representation of predicate	Core argument
Non-arguments	Periphery
Predicate + Arguments	Core
Predicate + Arguments + Non-Arguments	Clause = (Core + Periphery)

Since these hierarchical units are defined semantically and not syntactically, they are not dependent upon their immediate dominance or linear precedence relations. The elements in these units can therefore occur in any order, provided that a given language permits it. There are additional elements, which may occur in a simple sentence i.e. a single clause sentence.

The first is the 'precore slot' [PrCS], the position in which question words appear in languages in which they do not occur in *situ* e.g. English, Italian, and Zapotec. The precore slot is also the position in which the fronted element in a sentence occurs, e.g. *Bean soup* I can't stand. This can be described in RRG as core external as opposed to clause internal.

There is also a 'postcore slot' [PoCS], to be taken into consideration. This must be taken into account in verb-final languages, e.g. Japanese and Dhivehi. In addition to a clause, a sentence may also include a clause in a detached position, most commonly in the 'left detached position' [LDP]. This is the location of sentence initial elements, most commonly adverbials, which are set off from the clause by a pause e.g. Yesterday, I bought myself a new car, or as for Jane, I haven't seen her in weeks. There is also a 'right detached position' [RDP] as in sentences like 'I know them, those children'. When an element in a detached position functions as a semantic argument of the verb, there is normally a resumptive pronoun in the core referring to it. The layered structure of the clause applies equally to fixed word-order and free word-order languages, to head-marking and dependent-marking languages and also to languages with or without grammatical relations.

4.1.2 Operators in the layered structure of the clause

Each of the major layers (nucleus, core and clause) is modified by one or more operators, which are closed-class grammatical categories including tense, aspect, negation, illocutionary force, modality and evidentiality. Operators are another important component of the RRG theory of clause structure. An important property of operators is that they modify specific layers of the clause. This is summarized in Table 4.

Table 4: Operators in the layered structure of the clause (Van Valin 2008)

Nuclear operators: Aspect Negation Directionals (only those modifying orientation of action or event without reference to participants)
Core operators: Directionals (only those expressing the orientation or motion of one participant with reference to another participant or to the speaker) Event quantification Modality (root modals, e.g. ability, permission, obligation) Internal (narrow scope) negation
Clausal operators: Status (epistemic modals, external negation) Tense Evidentials Illocutionary Force

Languages normally do not have all of these operators as grammatical categories; the absolutely universal ones are illocutionary force and negation. Grammatical categories like tense, aspect and modality are treated as operators, modifying different layers of the clause. Each of the clause levels may be modified by one or more different operators. The nuclear operators have scope over the nucleus. They modify the action, event or state itself without reference to the participant. Core operators modify the operation between a core argument, normally the actor and the action. Clausal operators modify the clause as a whole. They fall into two groups. One containing tense and status and the other evidentials and illocutionary force. Since operators are technically not seen as part of the nucleus, core or periphery in RRG, but are modifiers of these units and combinations of them, they are represented separately from the predicates and the arguments that they modify. Predicates and arguments are subject to language specific constraints on their ordering, while the principal governing the ordering of operators is the universal scope constraint.

The main language specific consideration which affects their occurrence is the basic word order type of the language, which governs if the operators are prefixes or suffixes, if they are bound or free morphemes or if they occur before or after the nucleus. But the ordering among them is determined by the scope principle. Johnson, 1987, proposed a formalisation of the layered structure of the clause to capture the differences between restrictions on predicates and arguments on one hand and operators on the other. He called this formalisation a 'projection grammar'. In RRG syntactic representations are not specified by phrase structure rules or the like.

The different parts are stored in 'syntactic templates' in a 'syntactic inventory'. While the layered structure of the clause is seen as universal, there is a cross-linguistic variation with regard to the syntactic templates in the syntactic inventory in each language. Languages that lack a precore or postcore slot will not have templates for them. In languages with a fixed word order, this would be specified in the template, while languages with a flexible word order will have unordered templates in varying degrees. Included within the NP operators are determiners, quantifiers and adjectival and nominal modifiers. In the formal representation of the layered structure of the clause Johnson (1987), operators are presented in a distinct projection of the clause from the predicates and arguments (the constitute projection). The structure in figure 6 taken from Van Valin (2008) describes this.

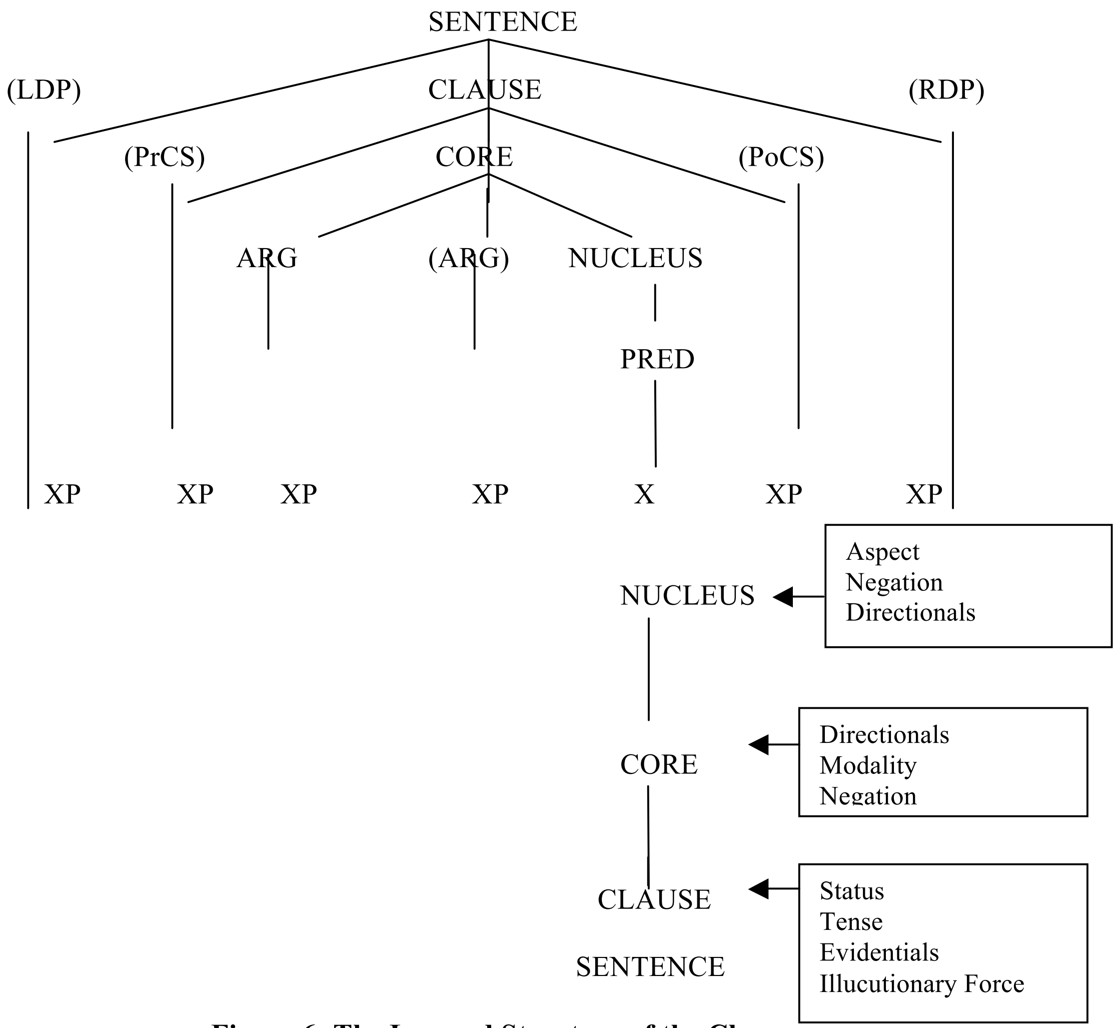

Figure 6: The Layered Structure of the Clause

Operators are represented in a separate projection of the clause, which is the mirror image of the constituent projection. Within the theory of RRG, the layered structure of the clause is a semantically based theory of non-relational syntactic structure. The fundamental units in the hierarchical organisation of sentences and clauses are semantically motivated by the contrast between predicate and argument on one hand and between NPs and PPs which are related to the predicate and which are not.

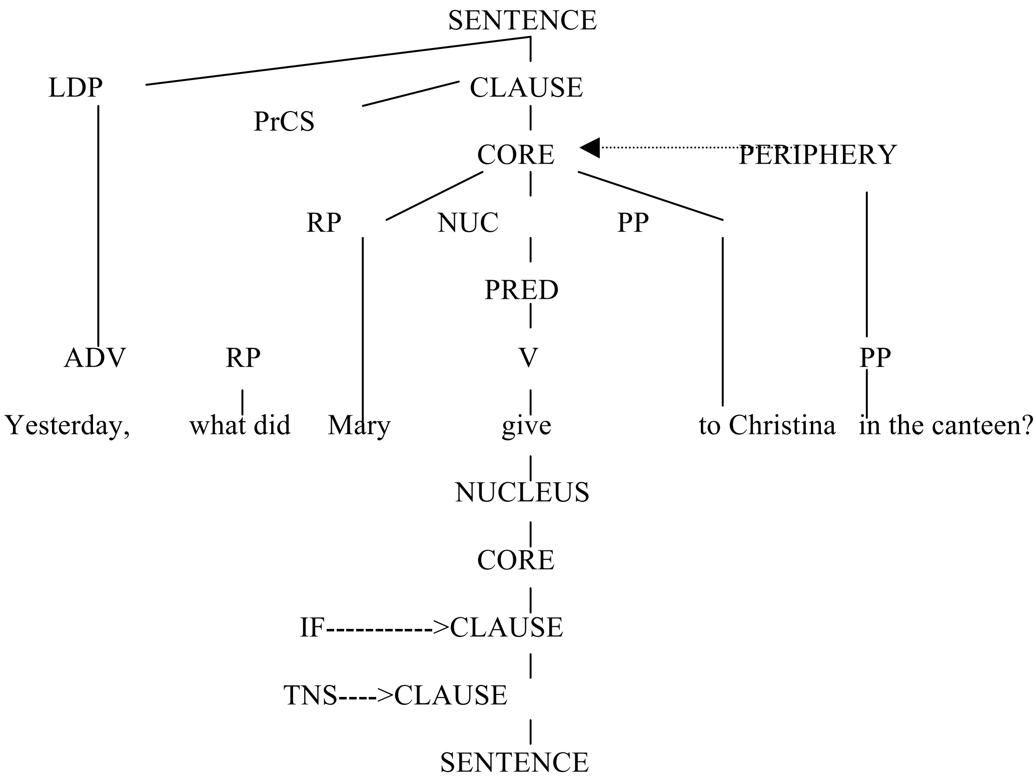

Figure 7: An English sentence with both constituent and operator projections

4.2 The layered structure of the noun phrase

There are many fundamental similarities in the structure of NPs and clauses. The primary link between NPs and clauses in RRG is that both clause and NPs have a layered structure and also both have operators modifying the layers. In the layered structure of the NP there is a nominal nucleus and a nominal core consisting of a nucleus and the arguments of a complex derived nominal, but there is only one level, the NP level corresponding to the clause and sentence levels of the layered structure of the clause.

4.3 Clause structure in independent marking languages

Nichols, 1986, proposes a fundamental typological contrast with respect to the way the syntactic relationship between a head and its dependents is signalled morphologically. In languages like English, Russian and Japanese, the relationship between a verb and the argument(s) it governs is indicated on the dependent arguments in the form of case or adpositional marking. An example is given below:

(1) *The young doctor gave a/the new book to an/the old man.*

The relationship of each of the NPs in the sentence to the verb is expressed by its case: the subject, ‘the young doctor, is in the nominative case; the direct object, ‘a new book’, is in the accusative case, and the indirect object, ‘the old man, is in the dative case. In Tzotzil however, this relationship is marked on the head, the verb; where there is no marking on the dependent NPs to indicate their relationship with respect to the verb, but the verb itself or the governing head carries morphemes, which indicate the person and number of its arguments.

Nichols labels languages in which the first pattern predominates as 'dependent-marking' languages, and those in which the second pattern is primary are seen as 'head-marking' languages. This contrast is very important syntactically, as in the head-marking pattern, the head bears the morphemes, which indicate its governed dependents. These dependents can be omitted without grammatically affecting the phrasal unit. Therefore the head can act as the whole unit. The same cannot be said of the dependent-marking pattern. In English a finite verb alone cannot constitute a clause, and if the possessor is dropped from a possessive construction, e.g. the man's daughter → (the) daughter, the result is grammatical, but no longer a grammatical construction. This is very important within syntactic theory as many theories are based primarily if not exclusively on the analysis of dependent marking languages. Van Valin strives to capture this contrast in his theory of clause structure. In Van Valin (1977, 1995, 1987), it was argued that with respect to clauses in head marking languages, the pronominal affixes on the verb are the core arguments of the clause, not the optional independent lexical NPs and pronouns.

4.4 Adjunct and Periphery

In the layered structure of the clause the distinction between the core and the periphery is based on the distinction between arguments and non-arguments. There are two types of argument or adjunct. Phrasal adjuncts such as PPs, and non-phrasal adjuncts such as adverbs. PP adjuncts modify the core when they express locational or temporal features of the state of affairs coded by the core. The periphery containing them can therefore be described as a core modifier. Some modifiers modify the core also and they too occur in the periphery. In fact it is noted in Van Valin (2005) that adverbs may actually modify all three layers of the clause, however they are not operators. McConnell and Ginet (1982) pointed out that manner adverbs interact in an important way with the tense operator. Those that occur before the tense operator can be seen as clausal modifiers, and those occurring after tense cannot.

(2) a. *Ann cleverly hid the present*
b. *Ann hid the present cleverly*
c. *Cleverly, Ann hid the present*

The first sentence is ambiguous in that it can refer to the manner in which Ann hid the present was clever, or that the fact that Ann hid the present was clever. The next two sentences are unambiguous. When there are multiple adverbs in a sentence, they are constrained by the layered structure of the clause, in that adverbs related to more outer operators occur outside of adverbs related to adverbs of more inner operators. In the simplest case 'outside' means 'further from the verb'.

(3) *Evidently, Triona has been slowly immersing herself in the new language.*

Unlike operators, which have fixed positions, adverbs may occur either before or after the verb, but in both cases the scope constraints require that the nuclear adverb be closer to the verb than the core adverb and likewise for the core adverb with respect to the clausal adverb. This makes them unlike PP adjuncts, which normally follow the core in English. If the PP adjunct precedes the core in English it must be in the precore slot or left-detached position.

4.5 Adpositional and noun phrase structure

Adpositions come in two basic varieties: predicative and non-predicative. Predicative adpositions function like predicates in that they contribute substantive semantic information to the clause in which they occur. Non-predicative Adpositions do not add any substantive semantic information to the clause and do not license the argument that they mark; in actual fact their argument is licensed by the predicate i.e. it is a core argument. These prepositions are a function of the semantics of the predicate. E.g. *to Pat* is a non-predicative PP functioning as a core argument, whereas *in the library* is a predicative PP functioning as an adjunct.

4.6 Semantic Structure

The semantic representation is based on a system of lexical representation and semantic roles. The system of lexical representation is based on Vendler's (1967) Aktionsart classification of verbs into states, activities, achievements and accomplishments. There are two additional classes; active accomplishments, which describe telic uses of activity verbs (e.g. devour) and also semelfactives (punctual events; Smith, 1997). Examples of each class and their formal representation, including their causative counterparts are given in (4) and (5) below:

(4) a. States: *be sick, be tall, be dead, love, know, believe, have*
b. Activities: *march, swim, walk* (– goal PP); *think, eat* (+ mass noun/bare plural RP)
c. Semelfactives: *flash, tap, burst* (the intransitive versions), *glimpse*
d. Achievements: *pop, explode, shatter* (all intransitive)
e. Accomplishments: *melt, freeze, dry* (the intransitive versions), *learn*
f. Active accomplishments: *walk* (+ goal PP), *eat* (+ quantified RP), *devour*

(5) a. State: The teacher is upset about the school situation.
a'. Causative state: The school situation upsets the teacher.
b. Achievement: The bubble popped.
b'. Causative achievement: The baby popped the bubble.
c. Semelfactive: The light flashed
c'. Causative semelfactive: The man flashed the light.
d. Activity: The soccer ball rolled around the field.
d'. Causative activity: The girl rolled the soccer ball around the field.
e. Active accomplishment: The soldiers marched to the barracks.
e'. Causative active accomplishment: The sergeant marched the soldiers to the barracks.
f. Accomplishment: The snow melted.
f ' Causative accomplishment: The hot sun melted the snow.

A single verb can have more than one *Aktionsart* interpretation. For example the verb *'march'* would be listed in the lexicon as an activity verb, and lexical rules would derive the other uses from the basic activity use. The lexical representation of a verb or other predicate is termed its LOGICAL STRUCTURE [LS]. State predicates are represented simply as **predicate´**, while all activity predicates contain **do´**. Accomplishments, which are durative, are distinguished from achievements, which are punctual. Accomplishment LSs contain BECOME, while achievement LSs contain INGR, which is short for 'ingressive'. Semelfactives contain SEML. In addition, causation is treated as an independent parameter that crosscuts the six *Aktionsart* classes. It is represented by CAUSE in LSs. The lexical representations for each type of verb shown above are given in Table 5.

Table 5: Lexical Representation for Aktionsart classes (Van Valin 2003)

Verb Class	**Logical Structure**
State	predicate' (x) or (x, y)
Activity	do' (x, [predicate' (x) or (x, y)]}
Achievement	INGR predicate' (x) or (x, y), or INGR do' (x, [predicate' (x) or (x, y)]}
Accomplishment	BECOME predicate' (x) or (x, y), or BECOME do' (x, [predicate' (x) or (x, y)]}
Active accomplishment	do' (x, [predicate$_1$,' (x, (y))]) & BECOME predicate$_2$; (z, x) or (y)
Causative	α CAUSE β where α, β are representations of any type

Examples of simple English sentences with the LS of the predicate are presented following.

(6) a. STATES

Peter is a clown.
be´ (Peter, [**fool´**])
Sean saw the photo.
see´ (sean, photo)
The mirror is shattered.
shattered´ (mirror)
Joe is at the club.
be-at´ (club, Joe)

b. ACTIVITIES

The baby cried.
do´ (baby, [**cry´** (baby)])
James ate pizza.
do´ (James, [**eat´** (James, pizza)]

c. SEMELFACTIVES

The light flashed.
SEML **do´** (light, [**flash´** (light)])
John glimpsed Mary.
SEML **see´** (John, Mary)

d. ACHIEVEMENTS

The window shattered.
INGR **shattered´** (window)
The balloon popped.
INGR **popped´** (balloon)
John glimpsed the picture.
INGR **see´** (John, picture)

e. ACCOMPLISHMENTS

The snow melted.
BECOME **melted´** (snow)
The sky reddened.
BECOME **red´** (sky)
Niamh learned Spanish.
BECOME **know´** (Niamh, Spanish)

f. ACTIVE ACCOMPLISHMENTS

James ate the pizza. **do´** (James, [**eat´** (James, pizza)]) & BECOME **eaten´** (pizza)
John ran to the shelter. **do´** (John, [**run´** (John)]) & BECOME **be-at´** (shelter, John)

g. CAUSATIVES

The monster scared the boy. [**do´** (monster, Ø)] CAUSE [**feel´** (boy, [**afraid´**])]
Brian broke the window. [**do´** (Brian, Ø)] CAUSE [BECOME **broken´** (window)]
The cat popped the balloon. [**do´** (cat, Ø)] CAUSE [INGR **popped´** (balloon)]
The girl walked the dog to the park.
[**do´** (girl, Ø)] CAUSE [**do´** (dog, [**walk´** (dog)]) & BECOME **be-at´** (park, dog)]

Full semantic representations of sentences also contain lexical representations of the RPs, adjuncts, and grammatical operators like tense and aspect. For the linking between syntactic and semantic representations, the semantic interpretation of an argument is a function of its position in the LS of the predicate. Thematic relations as such play no role in the theory of RRG. The traditional thematic role labels are used only as mnemonics for the LS argument positions, e.g. ‘theme’ is the mnemonic for the second position (y) in a two-place locational LS like be-at´ (x, y). RRG defines two generalized semantic roles or semantic macroroles, which play a crucial role in the linking system. The two macroroles defined by RRG are ACTOR and UNDERGOER, and they are the two primary arguments of a transitive predication. The single argument of an intransitive predicate can be either an actor or an undergoer, depending upon the semantic properties of the predicate. The basic distinction is illustrated in the following German examples below are taken from Van Valin (2005).

(7)
a. Der Junge [SUBJ, ACTOR] hat den Kuchen [OBJ, UNDERGOER] aufgegessen.
   'The boy ate the cake.'
b. Der Hund [SUBJ, ACTOR] ist um das Haus herumgelaufen.
   'The dog [SUBJ, ACTOR] ran around the house.'
c. Der Hund [SUBJ, UNDERGOER] ist gestorben.
   'The dog [SUBJ, UNDERGOER] died.'
d. Der Kuchen [SUBJ, UNDERGOER]wurde vom Jungen [ACTOR] aufgegessen.
   'The cake [SUBJ, UNDERGOER] was eaten by the boy [ACTOR].'

In (7a), *der Junge* 'the boy' is the actor and *den Kuchen* 'the cake' is the undergoer of the transitive verb *aufessen* 'eat up'; in the sentences with intransitive verbs, *Der Hund* is an actor with the activity verb *herumlaufen* 'run around' and an undergoer with the accomplishment verb *sterben* 'die'. Actor is not equivalent to syntactic subject, nor is undergoer equivalent to syntactic direct object, as the examples in (7c) and (7d) show: in both of these sentences the syntactic subject is an undergoer, and in the passive sentence in (7d) the actor is an oblique adjunct. In an English clause with an active voice transitive verb, the actor is the initial RP (the traditional subject) and the undergoer, when it occurs, is always the direct RP immediately following the verb. In an English passive construction, the undergoer is the subject and the actor, if it occurs, is in an adjunct PP in the periphery to the CORE. Actor and undergoer are generalizations across specific semantic argument types, as defined by LS positions. This is illustrated in (8).

(8) *kill* [**do´** (x, Ø)] CAUSE [BECOME **dead´** (y)]
see [**see´** (x, y)
put [**do´** (x, Ø)] CAUSE [INGR **be-LOC´** (y, z)]
present [**do´** (x, Ø)] CAUSE [INGR **have´** (y, z)]

Actor Undergoer

The *x* argument of all of these verbs functions as the actor, regardless of whether it is the first argument of the generalized activity verb **do´** (conventionally labeled 'effector'), as with *kill, put* and *present,* or the first argument of a two-place state predicate, as with *see*. With two-place transitive verbs like *kill* and *see,* the *y* argument is the undergoer. With three-place verbs like *put* and *present* (as in *Bill presented Mary with the flowers*)*,* on the other hand, the situation is more complex. The relationship between LS argument positions and macroroles is captured in the Actor-Undergoer Hierarchy, henceforth termed AUH, in Figure 8. The basic idea of the AUH is that in a LS the leftmost argument in terms of the hierarchy will be the actor and the rightmost will be the undergoer. This was true for *kill, see* and *put* in (8). It was not true for *present,* however, and this illustrates how the leftmost argument in a LS (in terms of the AUH) is always the actor, but the rightmost argument is only the default choice for undergoer.

ACTOR **UNDERGOER**

Arg of DO	1st arg of **do´** (x,...	1st arg of **pred´** (x,y)	2nd arg of **pred´** (x,y)	Arg of state **pred´** (x)

['▶' = increasing markedness of realization of argument as macrorole]

Figure 8: The Actor-Undergoer Hierarchy (from Van Valin, 2003).

RRG treats the notion of 'agent' rather differently from other theories. The basic notion is 'effector', which is the first argument of **do′** and is unspecified for agentivity. With many verbs, a human effector may be interpreted as an agent in certain contexts. If the verb lexicalizes agentivity, as with *murder*, then the logical structure contains 'DO', which indicates that the argument must be interpreted as an agent. Transitivity in RRG is defined semantically in terms of the number of macroroles a predicate takes. This is termed 'M-transitivity' in RRG. The number of syntactic arguments a predicate takes is described as its 'S-transitivity'. The three M-transitivity possibilities are: transitive (2 macroroles), intransitive (1 macrorole), and atransitive (0 macroroles). The theoretical label for the third argument in a ditransitive predication, e.g. *the picture* in the English sentence *Sam showed Sally the picture*, is 'non-macrorole direct core argument'. The principles determining the M-transitivity of verbs are given in (9).

(9) Default Macrorole Assignment Principles

A. Number: the number of macroroles a verb takes is less than or equal to the number of arguments in its LS.

1. If a verb has two or more arguments in its LS, it will take two macroroles. RRG treats the notion of 'agent' rather differently from other theories. The basic notion is 'effector', which is the first argument of **do′** and is unspecified for agentivity. With many verbs, a human effector may be interpreted as an agent in certain contexts. If the verb lexicalizes agentivity, as with *murder*, then the logical structure contains 'DO', which indicates that the argument must be interpreted as an agent. Also, primary-object languages patterns require a modified undergoer selection principle, namely that the undergoer is the second-highest ranking argument in the LS.
2. If a verb has one argument in its LS, it will take one macrorole.

B. Nature: for predicates which have one macrorole:

1. If the verb LS contains an activity predicate, the macrorole is actor.
2. If the predicate has no activity predicate in its LS, it is undergoer.

If a verb is irregular and has exceptional transitivity, it will be indicated in its lexical entry by '[MRα]', where 'α' is a variable for the number of macroroles.

Examples of lexical entries for some English verbs are given in (10).

(10) a. *kill*
[**do′** (x, Ø)] CAUSE [BECOME **dead′** (y)]
b. *receive*
BECOME **have′** (x, y)
c. *own*
have′ (x, y)
d. *belong (to)*
have′ (x, y) [MR1]
e. *see*
see′ (x, y)
f. *watch*
do′ (x, [**see′** (x, y)])
g. *show*
[**do′** (w, Ø)] CAUSE [BECOME **see′** (x, y)]
h. *run*
do′ (x, [**run′** (x)])
i. *drink*
do′ (x, [**drink′** (x, y)])

Within the theory of RRG no syntactic subcategorization information of any kind is required in the lexical entries for verbs. For regular verbs, all that is required is the LS and nothing more, as in all except (6d). For most irregular verbs, only the macrorole number needs to be specified. All of the major morphosyntactic properties of verbs and other predicates follow from their LS together with the linking system.

Arg of DO > 1st arg of **do´** > 1st arg of **pred´** (x,y) > 2nd arg of **pred´** (x,y) > **pred´** (x)

Figure 9: Privileged syntactic argument selection hierarchy (Van Valin 2003)

SYNTACTIC FUNCTIONS: PSA Direct Core Arguments Oblique Core Arguments

Privileged Syntactic Argument [PSA] Selection:
Highest ranking MR = default (e.g. English)
Lowest ranking MR = default (e.g. Dyirbal)

SEMANTIC MACROROLES Actor Undergoer

ACTOR UNDERGOER

Arg of DO | 1st arg of **do'** (x… | 1st arg of **pred'** (x,y) | 2nd arg of **pred'** (x,y) | Arg of state **pred'** (x)

[‘' = increasing markedness of realization of argument as macrorole]

Transitivity = No. of Macroroles [MRα]
Transitive = 2
Intransitive = 1
Atransitive = 0

Argument Positions in **LOGICAL STRUCTURE**

Verb Class Logical Structure

STATE **predicate'** (x)or(x,y)
ACTIVITY **do'** (x, [**predicate'** (x) or (x, y)])
ACHIEVEMENT INGR **predicate'** (x) or (x,y)
ACCOMPLISHMENT BECOME:**Predicate'** (x) or (x,y)
ACTIVE ACCOMPLISHMENT
do' (x, [**predicate** 1' (x, (y»]) & BECOME **predicate** 2' (z, x) or (y)
CAUSATIVEα CAUSE β , Where α , β are LSs of any type

Figure 10: RRG Linking System (Van Valin 2005).

4.7 Grammatical relations

Grammatical relations like subject and direct object are considered to be non-universal in RRG. In place of these notions, RRG employs the notion of ‘privileged syntactic argument’ [PSA], which is a construction-specific relation and is defined as a restricted neutralization of semantic roles and pragmatic functions for syntactic purposes. The other arguments in a clause are characterized as direct or oblique core arguments; there is nothing in RRG corresponding to direct or indirect object (Van Valin 2005, chapter 4). Languages have selection hierarchies to determine the PSA. The privileged syntactic argument selection hierarchy is shown in figure 9.

In syntactically accusative languages like English and Croatian, the highest ranking macrorole is the default choice for PSA, whereas in syntactically ergative languages like Dyirbal and Sama (Austronesian, Philippines; Walton 1986), the lowest ranking macrorole is the default choice. That is, in a syntactically accusative language the unmarked choice for the PSA of a transitive verb is the actor, with the undergoer being a marked choice possible only in a passive construction. On the other hand, in a syntactically ergative language, the unmarked choice for the PSA of a transitive verb is the undergoer, with the actor being a marked choice possible only in an anti passive construction. With an intransitive verb, the hierarchy is irrelevant, as the single macrorole functions as PSA regardless of whether it is actor or undergoer. The linking system relating semantic and syntactic representations is summarized in Figure 10. Syntactic functions like PSA and direct core argument (which are structurally instantiated in the LSC) represent the syntactic pole of the system, while LSs represent the semantic pole. The linking system in RRG is described as bi-directional, in that it maps from syntax to semantics and from semantics to syntax. The linking between semantics and syntax has two phases. The first phase consists of the determination of semantic macroroles based on the logical structure of the verb (or other predicate) in the clause. The second phase is concerned with the mapping of the macroroles and other arguments into the syntactic functions.

Worked example:

Analysis of simple intransitive sentence: 'The book is sitting on the table'

Step 1: Construct semantic representation in Lexicon.

a. Access LS for *sitting* and select prepositional LS to fill **be-LOC′** slot in LS, *on*:

do′ (x [**sit′** (x, [**be-LOC′** (y, x)]) + **be-on′** (__, __)]) =>

do′ (x [**sit′** (x, [**be-on′** (y, x)])])

b. Determine the value of the operators to be expressed:

<IF *DEC* <TNS *PRES* < **do′** (x, [**sit′** (x, [**be-on′** (y, x)])])>>>

c. Select the referring expressions to fill the variable positions in LS:

<IF *DEC* <TNS *PRES* < **do′** (Book, [**sit′** (Book, ([**be-on′** (Table, Book))])]>>>

Step 2: Determine actor and undergoer assignments:

<IF *DEC* <TNS *PRES* < **do′** (ACT: Book, [**sit′** (Book, [**be-on′** (Table, Book)])])>>>

Step 3: Determine the morphosyntactic coding of the arguments

a. PSA selection: Actor as sole macrorole is selected as PSA.

b. Actor is assigned nominative case as highest ranking macrorole; preposition *on* is assigned to *the table*, which receives dative case due to being the first argument of **be-on**′, a static location.

c. As the tense is present, the agreement marking is on the nucleus. The nucleus will agree with the actor since it is the highest ranking macrorole.

Step 4: Select syntactic templates:

a. Select the PrCS template, which is obligatory in main declarative clauses.

b. d. n. a.

c. Select a two-place core, one place for the nucleus and one for the PP.

d. Select the non-branching nucleus template.

e. Select two common noun NP templates and a predicative PP template.

Step 5: Assign LS elements to positions in the syntactic representation:

a. Assign the predicate to the nucleus.

b. Join the operator projection template to the nucleus and attach the morphemes expressing operators to it.

c (1.a). Since the nucleus is finite, link it to the first position in the core.

d. Link the nominative case-actor *The Book* to the PrCS.

e. Link the PP to the remaining core position.

Lexicon:

Verb: *sit* **do´** (x, [**sit´** (x, ([**be-LOC´** (y, x)]))])
Operators:
<IF <TNS <STA <NEG <MOD <DIR<ASP <LS>>>>>>>>

Nuclear auxiliaries: (attach to the nucleus when they are non-finite; they do not attach to the nucleus when they are finite): [‘be’] locative predication

Preposition: on’ **be-on´** (x, y)
Nouns:
Book n
Table n
Articles: Definite: *the*

do´ (Book, [**sit´** (Book, [**be-on´** (Table, LEXICON Book)])])

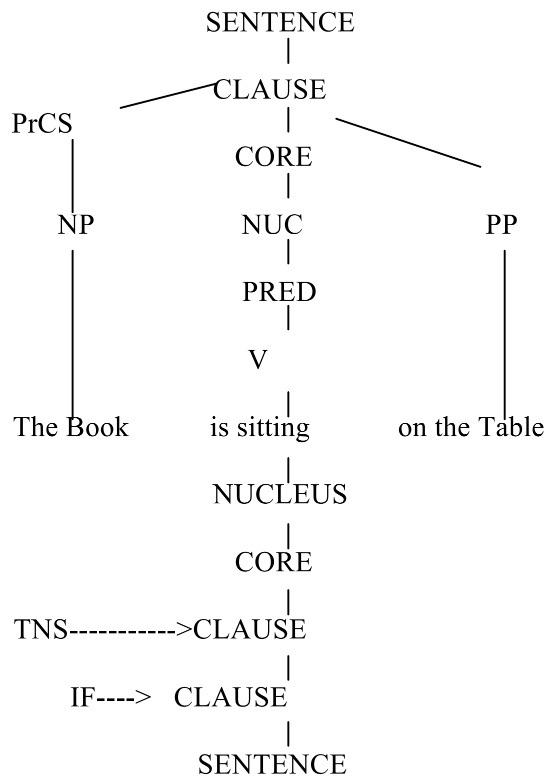

Figure 11: Resulting tree structure with constituent and operator projections

5 The Basic Components of Irish Sign Language

5.1 The handshapes of ISL

Ó Baoill and Matthews, 2000, describe how signs are formed within ISL by applying a set of phonological rules to a combination of handshapes and also how “identification of these handshapes and permissible combinations (noting that alteration of a single aspect provides the potential for expansion to the lexicon) provides us with an understanding of the building blocks of the formation of signs". Figure 12 below, taken from Ó Baoill and Matthews, 2000, indicates the 66 different handshapes that are utilised within ISL in the formation of signed vocabulary.

Figure 12: The handshapes of ISL, part 1 of 2, from Ó Baoill and Matthews (2000)

Figure 13: The handshapes of ISL, part 2 of 2, from Ó Baoill and Matthews (2000)

Studies carried out by Ó Baoill and Matthews, 2000, reveal a high correlation between ease of articulation in handshapes and frequency of occurrence. Less complicated or unmarked handshapes tend to occur more often than more intricate or marked handshapes. Figure 14 and 15 below categorise some of the more frequent handshapes of ISL, unmarked and marked.

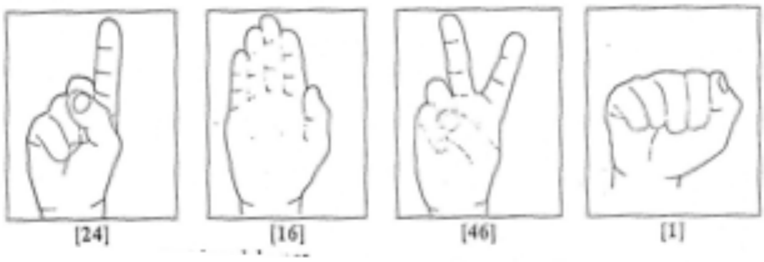

Figure 14: Unmarked handshapes of ISL, from Ó Baoill and Matthews, 2000.

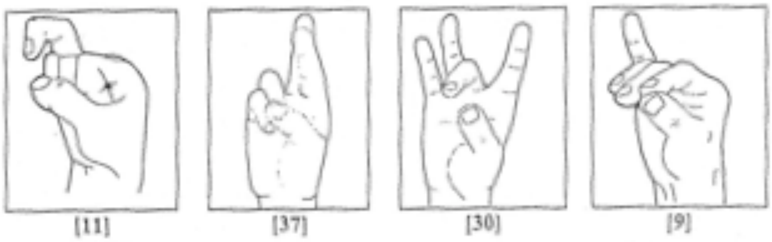

Figure 15: Marked handshapes of ISL, from Ó Baoill and Matthews, 2000.

5.2 The signing space

Ó Baoill and Matthews, 2000, describe the signing space as the space within which all signs must be articulated. The signing space usually extends from the waist outwards and includes the shoulders and the face. To ensure grammatical clarity, the signing space can be sub-divided for meaning. Morphemes are articulated at particular points or *loci* in relation to the signer for pronominal and anaphoric reference. A diagram of the signing space taken from Ó Baoill and Matthews, 2000, is shown in Figure 16.

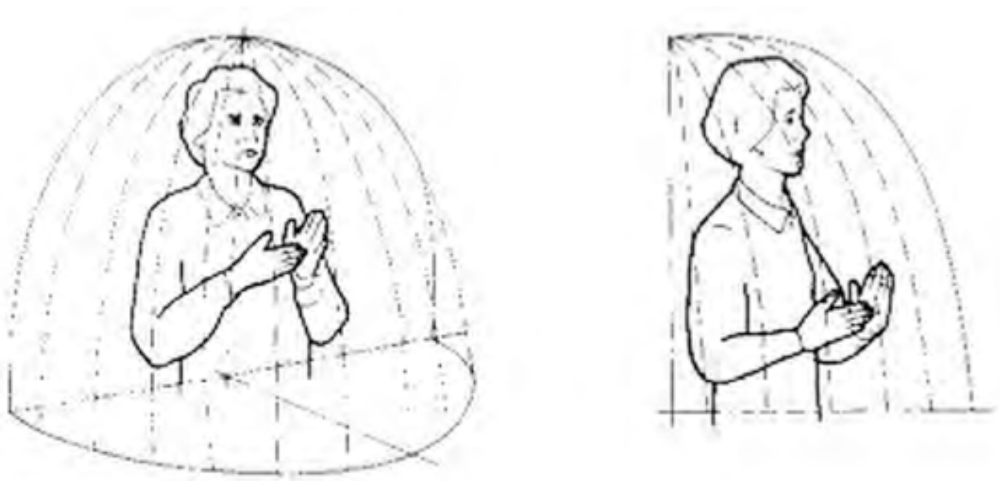

Figure 16: Sign Language Signing Space, from Ó Baoill and Matthews, 2000.

Neutral space is the space immediately in front of the signer and close to the signer's body. It encompasses the area from the head to the waist and extends the width of the signer's body. Neutral space is the space that is used when producing the citation form of an item and generally does not act as a referent for particular or special meaning.

5.3 The signs of ISL

The signs of ISL can be divided into eight different categories according to the manner and mode of production. Their description is based on the following parameters, which relates mostly to whether a signer uses one or two hands in the articulation of a particular sign.

(11).

a) One-handed signs, including body or near body contact during articulation.
b) One-handed signs, where the sign is articulated in free space without any body contact.
c) Two-handed signs having identical shape, where the hands touch during the articulation of the sign in space.
d) Two-handed signs having identical shape, where the hands move in symmetry but without any contact taking place during the articulation of the sign in space.
e) Two-handed signs having identical shape, where the hands perform a similar action and come in contact with the body.
f) Two-handed signs having identical shape, where the hands are in contact during articulation, however, using one dominant articulator and one passive articulator.
g) Two-handed signs showing a different shape, each hand having an active articulator and having equal importance.
h) Two-handed signs showing a different shape, where the dominant hand (depending on whether the signer is left-handed or right-handed) is the active articulator and the other hand is the subordinate or passive articulator.

5.4 The non-manual features of ISL

Non-manual features (NMF) or markers in signed languages refer to those meaningful units of the visual-gestural language, which are used to convey additional information to the meaning being expressed by manual handshapes. The existence of NMF within signed languages has been well documented by researchers, including Nolan (1993), Coerts (1990), Bellugi and Klima (1990), Baker and Padden (1978b). NMF consist of various facial expressions such as eyebrow movement, movement of the eyes, mouth patterns, blowing of the cheeks and also include head tilting and shoulder movement. While NMF are normally accompanied by a signed lexical item, they can be used to communicate meaning independent to manual accompaniment.

Within the linguistic system of ISL, NMF are used to express various emotions. They are also used to modulate or intensify the content of the information. In this sense NMF function as intensifiers. The use of NMF to express various syntactic properties is an identifying feature of sign languages and ISL is no exception to this. Ó Baoill and Matthews, 2000, point out that NMF function as both morphological and syntactic markers in ISL. While the majority of functions expressed through the use of NMF occur at the single lexical item level, there are certain syntactic functions that are expressed by means of NMF, but are not attached to any lexical item. The following list identified by Ó Baoill and Matthews, 2000, include all the relevant functions provided by NMF.

(12)

a) To show the degrees of emotion
b) To denote intensification or modulation
c) To distinguish declarative or interrogative sentences
d) To denote negation
e) To define topic or comment structures
f) To indicate conditional clauses
g) To show sarcasm

5.5 Hand configuration in ISL

William Stokoe, (1960) identified the various parameters which are relevant for the analysis of sign language. He suggested that the articulation of a sign encompassed three different parameters. A designator*,* which was used to refer to the specific combination of hand configuration, abbreviated to *dez*. A tabulation, used to refer to the location of the hands and abbreviated to *tab*, and a *signation* used to refer to the movement of the hands and abbreviated to *sig*. Dez, tab and sig were examples of what he called *cheremes*, the signed equivalent of phonemes.

Figure 17 is taken from Peporte (2009), and shows a step by step real-time video capture of the ISL sign for "adult". The signer starts with the hands in the "start position" where the hands are resting on the legs.

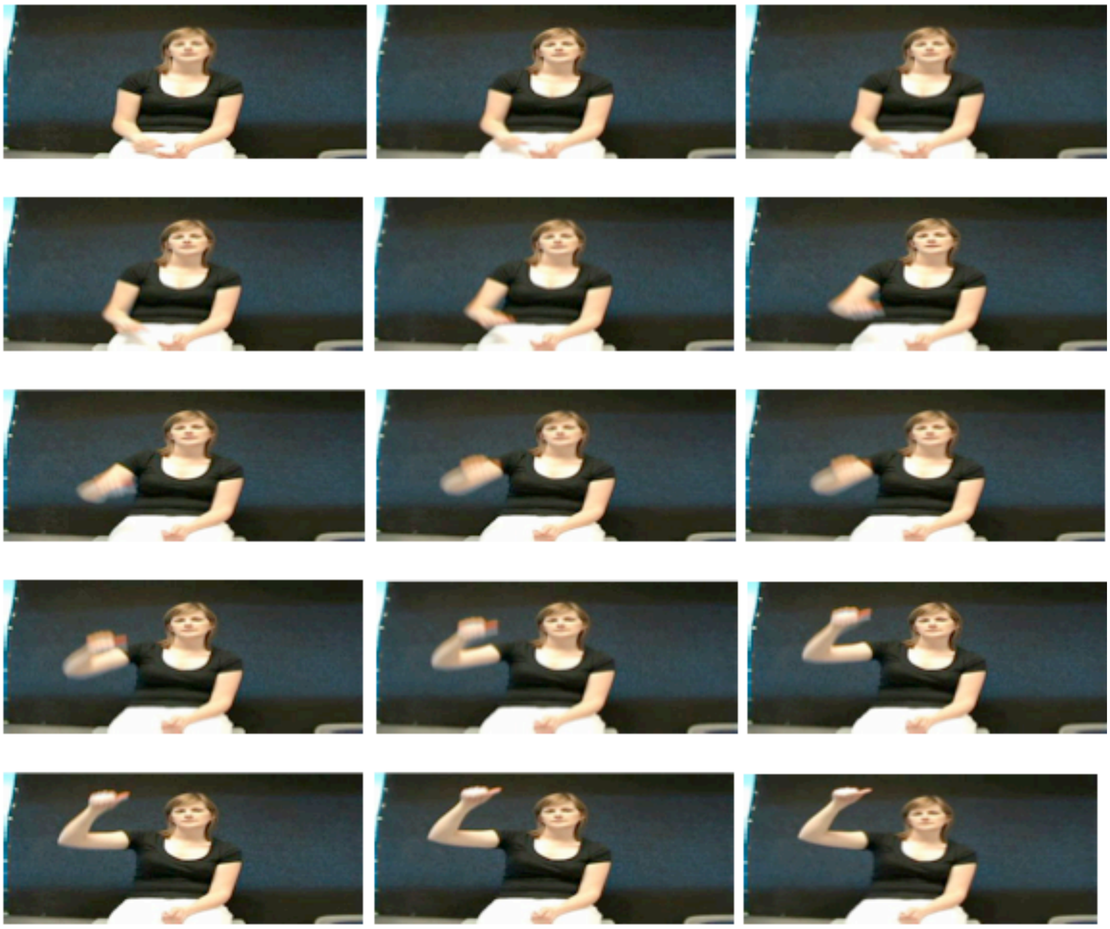

Figure 17: ISL sign for "Adult" taken using real-time video, from Peporte, 2009.

Later research refers to the parameters of sign language as *handshape*, *location* and *movement,* (Sutton-Spence & Woll 1999, Valli & Lucas, 1995). Battison, (1974) claimed that a fourth parameter is necessary in order to be able to fully transcribe signs. This fourth parameter was called orientation, and denotes the orientation of the hands and fingers during the articulation of the sign. The abbreviation of orientation is *ori.*

6 The Parse and Generate Process for ISL Avatar

6.1 Overview of the process

The architecture of the parse and generate process for the ISL avatar is shown in figure 18 below. This architecture describes the flow of processing. It documents the processes from the user inputs text until the an ISL articulation is produced via the Blender interface. The model accepts input in the form of an English sentence or English text. Once the inputted text has been parsed into its various parts of speech it is stored in the parts of speech (POS) lexicon. The next phase involves the syntactic parser. This parser retrieves the tokens or lexical items with their various information from the POS lexicon. It then uses the RRG linking system to convert from a syntactic description to a semantic description of the sentence or text. The output of this phase of parsing is a rich logical structure.

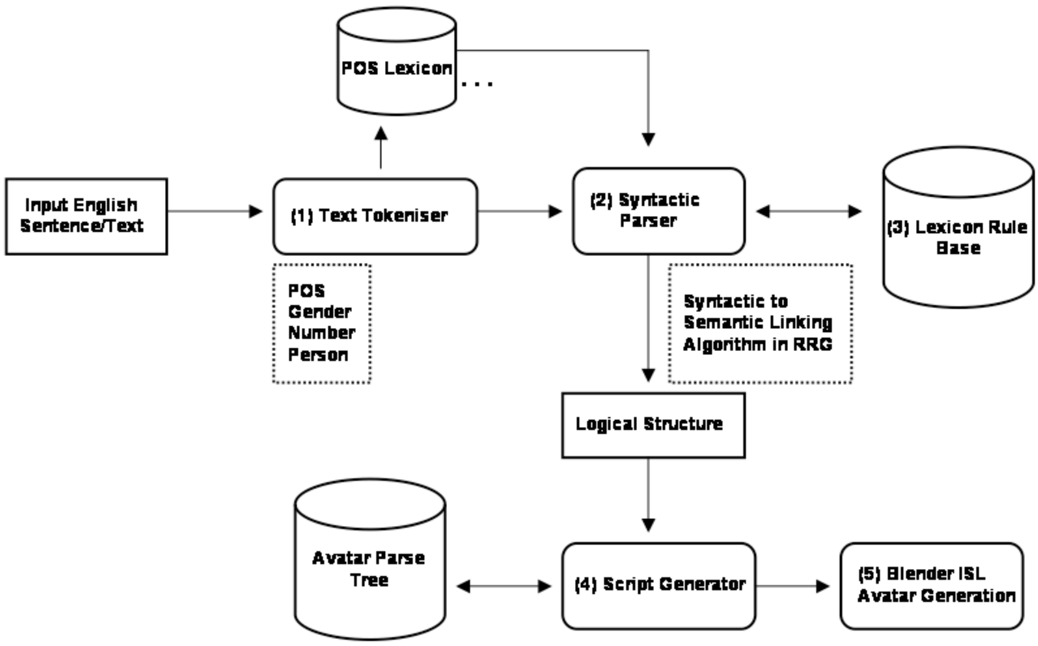

Figure 18: Architecture of the Parse and Generate Process for the ISL Avatar

Phase 4 is concerned with expanding the logical structure to produce what can be described as a meta representation of the parsed sentence. This will include agreement features, operators and constituents as well as information pertaining to the modality of the target language, i.e. the manual and non-manual features of ISL. The final phase or phase 5 of the processing is the generation of an articulation in our target language which is ISL. ISL is a visual gestural language and therefore the ISL is outputted to the user by the implementation of a conversational avatar via the Blender UI. Blender provides Python programming interfaces and Python scripting access for the development of custom and procedural animation effects. The Python script developed at phase 4 will be used as input for the Blender interface and the result will be the generation of an articulation of the input sentence or text in ISL by the conversational avatar.

6.2 Phase 1 processing – finding the lexical items

In the initial processing phase, an English sentence will be inputted and stored in the form of a String. With regard to RRG, the sentence will be classified as one of the following: State, Activity, Achievement or Accomplishment.

The sentence will then be tokenised and saved in a suitable data structure, where each token is a word. For each token the lexicon must be searched to see if the word is present and decipher its parts of speech (POS) (gender, number, person).

The information must then be stored with the lexical item in the specified data structure. Once this step has been carried out for all tokens, there will be a better sense of the word order of the String.

6.3 Phase 2 processing – creating the rich logical structure of the utterance

The initial step for phase 2 is to identify where the NP is in the String? Then it must be interpreted as transitive, ditransitive or intransitive? This will clarify the type of sentence that is being processed.

The next step for this phase involves the extraction of the logical structure for the verb from the lexicon.

(13) < …. < …. < …. [do [x… pred x, y, z] >>>

The tokens from phase 1 can then be retrieved and mapped based on the RRG theory of grammar :

(14) The 1st NP into x, the 2nd. into y and the 3rd (typically in preposition.) into z.

From the information recorded above (in the verb and the form of the verb for example run, ran, will run) information regarding the tense can be extracted and consequently the verbal and nominal structure can be determined. At the conclusion of this phase a rich logical structure will have been generated.

6.4 Phase 3 – The ISL Lexicon as an XML structure

It is envisaged that the lexicon will be developed using Extensible Markup Language (XML). XML is a platform neutral markup language, which is easily understood, while also lending itself well to computational parsing. XML will be used as a data structure for the storage and organisation of the various lexical entries i.e. verbs, nouns etc. to include the lexical items of ISL. It will be necessary at this phase of development to extend the lexicon to provide for the storage of the morphophonological handshapes of ISL as a visual gestural language. Signs are composed of both manual and non-manual features. Non-manual features are used to convey additional information to the meaning being expressed by manual handshapes. The lexicon architecture must be extended so that it is sufficiently universal to encompass both the syntactic and the semantic content of an articulation in ISL. This constitutes present work. We describe the characteristics of ISL in the next section of this paper.

6.5 Phase 4 processing – expanding the logical structure to sign the utterance

This part of the processing will involve the development of the underlying linguistic model with bi-directional RRG. This will enable the conversion of the English text into a meta-representation in RRG logical structures and generate ISL on output to the embodied conversational agent in real time using Python scripting. ISL language specific information, for example manual and non-manual features will have to be considered at this phase of processing. The structure will then have to be expanded so that it is sufficiently universal to encompass all of the necessary parameters consistent with ISL.

6.6 Phase 5 processing – generate the utterance via Blender

This phase will allow for the interaction between the Blender interface and the output from phase 4 processing. It is anticipated that the gap between Blender and the generated logical structures from phase 4 will be bridged by the utilization of Python scripts. The Blender API provides Python scripting access for custom and procedural animation effects. The output of this phase will be the generation of the ISL articulation via the Blender UI.

6.7 Challenges and Issues

ISL, our target language, is a visual gestural language and by its very nature will prove challenging at the generation phase of this research. The development of a computational framework that will be capable of bridging the gap between the lexicon and the generation of ISL is a very complex and challenging issue. The development of a meta representation of the data, which must be sufficiently rich to encompass all of the necessary information consistent with ISL is also very challenging. Factors such as synchronisation of various articulators including articulators for manual and non-manual features of the language are currently being researched. Figure 19 is a first draft at resolving the question of how any given sign may be generated using our 3D animation tool, Blender.

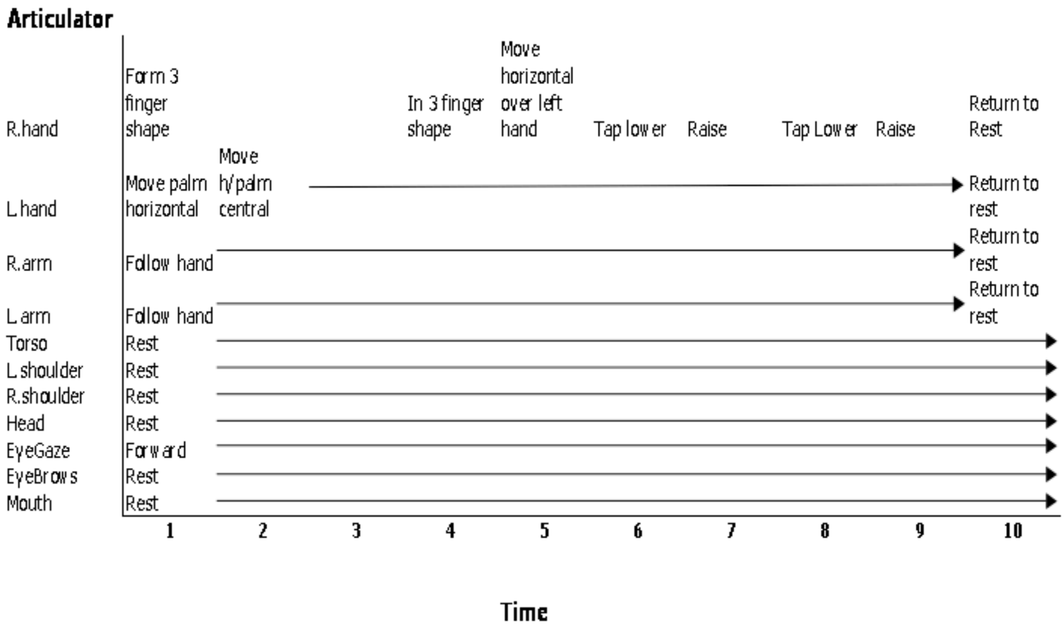

Figure 19: Method for the sign for "Mother" in ISL

It is envisaged that the articulators as shown in figure 19 will be choreographed and orchestrated simultaneously, equivalent to instruments in an orchestra at the generation phase. This provides a signature for the orchestration of a method to generate the sign for Mother in ISL. It is followed by the pseudocode for this signature in Figure 20.

```
sign: mother = method
{         do{
                    RHand(sign 51, orientation)
                    Tap(RH, LH, 2, x, y)
                    LHand(sign 51, orientation)
                    RArm(rest)
                    LArm(rest)
                    Head(rest)
                    LShoulder(rest)
                    RShoulder(rest)
                    Torso(rest)
                    Eyebrow(rest)
                    Eyegaze(forward)
                    Mouth(rest)
          }
}
```

Figure 20: Pseudocode for the sign for "Mother" in ISL

The pseudocode for the sign for "Mother in ISL" as shown above, lists the various articulators of the avatar which will be triggered on execution, together with their various arguments or information that must be passed to each articulator to generate the utterance.

7 Discussion

The research presented here is a work in progress. To date the armature and the mesh of the avatar have been developed using MakeHuman and Blender. The signs of ISL and the various handshapes of ISL have been identified and the RRG linguistic framework including the lexicon has been mapped to XML. The proposed parse and generate process for this research has been outlined and the envisaged simultaneous orchestration and choreography of articulators for an utterance method have also been outlined together with Pseudocode for the same. The next phase of my research will involve the development of the underlying linguistic model with bi-directional RRG. This will enable the conversion of English text into a meta-representation in RRG logical structures and allow for the generation of ISL on output to the embodied conversational agent in real time using Python scripting.

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