Interaction Specifications as Contexts for Ontologies

Position Paper

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Abstract

Common formalisms to represent knowledge, such as Description Logics, are insufficient to represent the dynamic aspects of language when it is used in communication. However, this information can be helpful to describe the semantics of terms in interactions, and in particular to obtain useful alignments that can be used as translations between heterogeneous interlocutors. We propose to consider the specification of interactions as contexts for ontologies. To this aim, the ontology language needs to be extended with a temporal layer that allows to express properties about the possible message exchanges between agents in an interaction. We present a simple preliminary extension for taxonomies, and discuss directions to investigate.

1. Introduction

The problem of specifying interactions for artificial agents has been extensively studied in the past decades. These efforts resulted in different formalisms to describe interactions, such as agent communication languages [14], or ontologies specially designed to this aim [8]. The semantics of these formalisms has been subject of discussion for several years, mainly because it is not clear how to combine information about the intentionality of communicating agents with the representation of knowledge about the domain of conversation.

One approach to overcome these difficulties is the one presented in [13], where the authors propose a layered semantics of communication languages as a way to represent different aspects of meaning in interaction. A first layer, called the *content level*, is internal to each agent, and represents the semantics of the conversation domain. This layer describes the meaning of the contents of messages, independently from the interaction in which they are uttered. Description Logics are a natural choice to specify this layer, since they provide a way to express prop-

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erties about concepts and their relations. A second layer, the *action level*, corresponds to the specification of a particular interaction. In this layer, the meaning of a message is determined by the effect of uttering it in a conversation, or more concretely, by its possible answers. This layer is external to the agents, and can be modelled by means of interaction protocols.[2] The importance of interaction contexts can be seen clearly in human conversations; consider for example a dialogue between a waiter and a customer. If the waiter says "what would you like to drink?", an adequate answer would be "wine", while "potatoes" would likely cause confusion.

In this position paper we propose to consider interaction specifications as contexts for ontologies, extending the ontology representation language with a temporal layer that allows to describe properties of a dialogue. This leads to a formalism that is useful to reason about language in use, by modelling pragmatic aspects of meaning that depend directly on the particular interaction taking place, and the way in which they relate to the underlying ontology. A language relating ontological and pragmatic information could be useful to perform ontology matching for the particular application of agent communication, since the information on the interaction context can be very valuable when building an alignment to be used by agents that interact to perform a particular task. In [3], Atencia and Schorlemmer show how a shared interaction context can already be sufficient for artificial agents to understand each other with a certain degree of success, even if they do not share the underlying vocabulary; in [6] pre-existing ontology alignments are incorporated to this idea, showing how the interaction context can be used to fix alignments that can be incorrect and incomplete. However, in this last approach the information from the context is only considered separately; we propose to develop a language that can be used to reason in the combination of both levels. In Section 3 we discuss in particular its application in ontology matching.

Unlike the *context as a box* approach to contextualizing ontologies [10], we do not consider contexts to be a separate theory, but rather a temporal layer built over the elements in the ontology. The original ideas about temporal extensions of description logics were applied naturally to planning [1], but since this does not involve communication with other agents, it does not need branching time and uses LTL, a logic whose relation with description logics is well known [2]. In [15] the authors study *two-dimensional logics of context*, which also extends a DL-based language to describe dynamic aspects of knowledge. In our approach, the temporal layer is only used to describe how elements in the ontology are structured in a particular dialogue. To model interactions between agents that make decisions autonomously, we need to incorporate branching-time operators, in order to represent the possible messages agents can decide to utter. The relation between CTL and description logics has only been studied recently and results about decidability are not very hopeful [11]; we later discuss why this does not necessarily apply in our case.

[2]Pitt and Mandami include a third layer, which corresponds to the intention of communicating of each agent. We will focus on the first two.

2. Models of Interaction as Context

We consider interactions between agents that communicate to perform a particular task together (for example, *ordering drinks*). The messages that agents send to each other are predicates in a *content language* that may allow to describe properties about the domain of the conversation. In this position paper, for simplicity, we will only consider a simple taxonomy of concepts with an inclusion ($\sqsubseteq$) relation, but extensions to more complex formalisms (such as Description Logics) should be considered.

Interaction contexts are specifications of possible message exchanges between agents. The question of how it is best to model interaction protocols has been extensively discussed in the multi-agent community, and many options with different expressive power were proposed [7]. To keep interaction models as general as possible, we specify only possible interchanges of messages by means of Finite State Automata. Therefore a model of interaction (or context) is an FSA that has its transitions labelled with messages in the content language along with identification of the sender and receiver agents.

Example 1. The FSA in Figure 1 specifies an interaction for a waiter that communicates with a customer (c) who wants to order. State transitions should be read as $(sender, receiver) : message$. Suppose also that the waiter represents information about the domain with a taxonomy that includes the relations $\mathsf{Beer} \sqsubseteq \mathsf{Drink}$, $\mathsf{Water} \sqsubseteq \mathsf{Drink}$, $\mathsf{Wine} \sqsubseteq \mathsf{Drink}$.

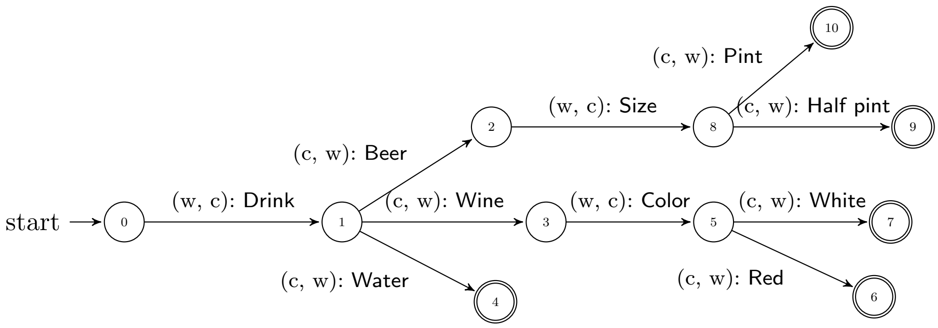

Figure 1. Interaction model for ordering drinks

A language to talk about interaction contexts should allow to express properties about the temporal structure of the automaton. In our example, one could want to say that *if the waiter asks the customer what she wants to drink, the customer can answer that she wants a beer*. More generally, we are interested in expressing properties like the following ones:

- something is a possible answer in a particular state
- something can or must be said eventually from a particular state

To this aim, it is necessary to define a *context language* that extends the content language describing these aspects of a particular interaction. A natural way to express properties about Finite State Automata is to use the μ-calculus formalism, but we do not need all its expressive power. For properties like the ones above, it is enough to consider only the CTL operators that express necessity (A) and possibility (E), together with the ones for *next state* ($\bigcirc$) and *eventually* ($\Diamond$). We also need to include in the signature a set of agent names $\mathcal{A}$ and a predicate *utter*, that relates two agents with a term in the ontology. If C is a concept in the content language and $a, a' \in \mathcal{A}$, well-formed terms in the context language are $E\bigcirc\ utter(a,a',C)$, $E\Diamond utter(a,a',C)$, $A\Diamond utter(a,a',C)$, $A\bigcirc\ utter(a,a',C)$, $utter(a,a',C)$. We consider a very simple semantics for the *utter* predicate: $utter(a,a',C)$ is true if agent a has sent message C to a'. More complex underlying languages may need other predicates. For example, for first-order logics it would be desirable to identify a query from an answer, for which two predicates (commonly *ask* and *tell*) are necessary.

With the context language defined in this way, we can now express the fact that Beer is a proper answer to Drink with the following predicate:

$$utter(w,c,\mathsf{Drink}) \implies E\bigcirc utter(c,w,\mathsf{Beer})$$

The language allows for interesting combinations with description logics that should be analysed. For example, by introducing a new concept name D playing the role of a fresh variable, we can express properties such as *if the waiter asks to the customer what she wants to drink, the customer will answer specifying a drink* in the following way:

$$utter(w,c,\mathsf{Drink}) \implies A\bigcirc utter(c,w,\mathsf{D}) \land \mathsf{D} \sqsubseteq \mathsf{Drink}$$

Note that, unlike previous work, we do not apply temporal operators directly to elements of the underlying domain language, but rather to a predicate that states who utters a message to whom. Therefore the results presented in [11] about the complexity of CTL and DL should be reconsidered for this case in particular.

While our interaction models only describe who sends messages and when, other kinds of information, such as preconditions and effects of utterances, are also relevant in a conversation. However, this information can be encoded in the underlying logics, if one uses, for example, a combination of description logics and action formalisms [4] or knowledge and action bases [12]. The consequences of considering this aspects as part of the context or as part of the content knowledge should be investigated.

3. Alignment Between Contextualized Ontologies

One prominent application of using interaction specifications as context is to build alignments between vocabularies of different agents that are adequate for particular tasks. As argued in [5], maintaining standard ontologies in open and distributed environments is a difficult task, particularly when they represent dynamic domains. Although there exist multiple ontology alignment tools that find translation between vocabularies, they are not particularly designed to be used

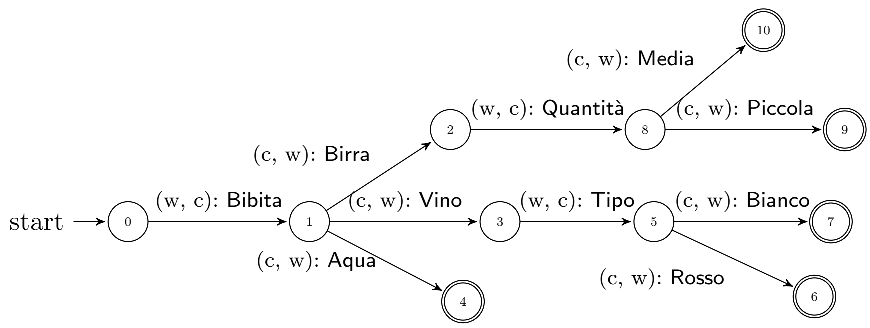

Figure 2. Italian interaction model for ordering drinks

for agent communication, and therefore do not take into account the second layer of meaning [9]. On the other side, as mentioned in the introduction, there exist approaches to align vocabularies using only the interaction models, without taking into account any underlying knowledge [3].

To illustrate the problem of aligning vocabularies in the context of a particular interaction, consider again the *ordering drinks* example, but we now suppose that, while the waiter speaks English, the customer is Italian and follows the interaction model in Figure 2. We consider agents that speak different languages but share a basic knowledge of how to perform the task, which is represented as having interaction protocols with similar structure (or equal in this case, for simplicity). This gives place to an alignment between their vocabularies that allows agents to interact successfully, for example, the term Piccola should be in this case interpreted as Half Pint. While this equivalence is reasonable in the context of ordering drinks, general ontology matchers would likely never find it without additional information, such as the fact that Piccola is a proper answer to Quantità and Half pint to Size. Our approach to contextualizing ontologies by describing properties of a particular interaction can be used, on one side, to specify this kind of pragmatic properties that can be clues for the alignment, and on the other, to describe the contexts for which an alignment is valid.

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