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Social Coordination Systems with Ontology and Protocol Heterogeneity

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Abstract. We tackle the problem of semantic heterogeneity between participants in social coordination systems for multi-agent interactions, focusing on electronic institutions. We propose an ontology aligning mechanism for systems organised in a centralised way, in which agents match their own ontology and protocol against central ones while executing the interaction. We base on the Interaction-Situated Semantic Alignment technique, considering meaning to be dependent on the context of interaction. At the same time, we extend I-SSA with new features such as allowing first-order messages.

1. Introduction

Multi-agent systems (MAS) are open environments in which heterogeneous and autonomous agents interact to accomplish some goal. Its qualities of *openness* and *heterogeneity* are essential, as allowing participants of different nature is more important now than ever given the growth of large distributed systems. As it is discussed in [6], these characteristics create the need for developing social organising systems that help agents success in their interactions. Usually, these systems avoid tackling the problem of semantic heterogeneity between participants, assuming they all share a common ontology. This leaves only one possibility for heterogeneous agents: forcing an ontology matching process before the interaction starts. There exist many well-known ontology matching techniques (see [7] and [5]); however, aligning entirely before the dialogue starts may not be the best choice. On the one side, ontologies can be very large, and possibly only a small part of them is used in the interaction. But in addition, we argue that meaning in conversations is not always previously fixed, but instead evolves together with the interaction, depending on the context. The moment when a message is uttered, its illocutionary force, who the interlocutor is, and what has been previously said can drastically change its meaning. There exist very few alignment techniques specially designed for multi-agent conversations ([2], [8]) and to our knowledge, none of them takes into account the interaction context.

In this paper, we present a semantic alignment method for social coordination systems, with a focus on the electronic institutions framework ([3]). Our method is based on the Interaction-Situated Semantic Alignment (I-SSA) technique, introduced in [1], which considers meaning to be dependent on the interaction context. The method we propose allows agents to align with a central ontology dynamically and at conversation time. It has been implemented for electronic institutions and tested for simple cases with the expected results.

The rest of the paper is organised as follows. In Section 2, we introduce electronic institutions and discuss semantic heterogeneity. In Section 3, we present a semantic alignment method that extends I-SSA to centralised, multi-agent, first-order interactions. In Section 4 we discuss future work.

2. Semantic Heterogeneity in Electronic Institutions

An electronic institution is a computational analogue of a human one ([3]). Institutions are organised in scenarios, called *scenes* in the electronic version, where participants with different roles interact to perform a task. These interactions are specified with protocols, that are finite state machines with its arcs labelled with messages. The electronic institution defines a *dialogical framework*, conformed by a set of names of roles, one of illocutionary particles, and an *ontology* that denotes a vocabulary fixing the possible content of messages. In the current version, all the elements of the dialogical framework, as well as the interaction protocols, are considered to be shared by all agents. Being autonomous, the agents *can* say anything they want, but they are not expected to do so: if a message that is not in the specification is uttered, it is intercepted by the electronic institution and an error occurs.

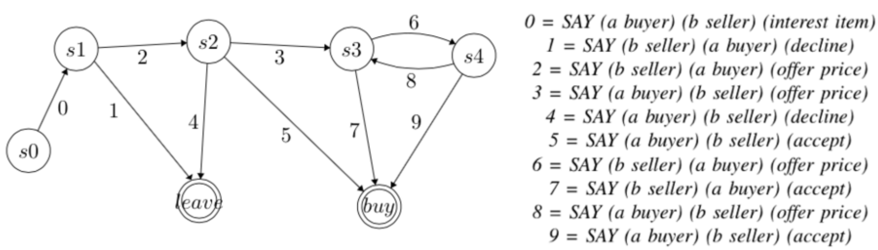

Figure 1. Specification of a bargaining interaction protocol in electronic institutions

We consider the case in which agents do not necessary need to share the complete ontology with the electronic institution; they can differ both in the vocabulary they use and in the structure of the protocols they follow. To illustrate this, consider the case of an institution representing a street market, in which there is a bargaining scene where a buyer and a seller fix the price to be paid in a transaction. The protocol of this interaction can be found in Fig. 1. Suppose two agents engage in the interaction. The seller does not speak English, so she follows the same protocol translated to Spanish (for example, she would say *rechazar* instead of *decline*). The buyer, meanwhile, is not very experienced in bargaining, and follows a different protocol; she thinks she can leave without buying at any time in the interaction, while this behaviour is actually not allowed. Her protocol therefore has an arrow labeled with the message *decline* between states $s3$ and *leave*. In this example, the seller shares the structure of the interaction with the electronic institution and it differs only in the vocabulary. A translation between Spanish and English would be enough for this agent to interact in the institution. The case of the buyer is more complex, as she follows another protocol. The core of the difference is in the meaning of the first utterance *offer*. In the central protocol, this offer has a special meaning, different from the following ones; it implies a commitment to buy the product, in addition to a specific price offer. The buyer does not assign this meaning. This is a clear example of how the context in which a message is uttered can change its semantics. This mismatch cannot be solved by aligning the vocabularies, since the meaning of *offer* changes for the same agent during the interaction.

3. An Interaction-Based Alignment Technique for Social Coordination Systems

We propose an alignment method for centralised social coordination systems in which agents apply a technique similar to I-SSA to align with a central ontology. We consider a MAS to be a set of agents plus a special one called the *central mechanism*. We model interactions in a MAS as follows. Three sets are shared by everyone: the illocutionary particles, the names of roles, and a set of predicates called *state properties*. Each agent speaks its own many-sorted first-order language and follows its specification of the interaction, which is described in an *interaction model*. This is a finite state machine where each arc is labelled with a *message pattern*, conformed by an illocutionary particle, the sender and receiver (any agent in the MAS except the central mechanism), and a predicate name. Each state in the interaction model is associated with a subset of state properties. During a conversation, agents follow their model sending *messages*, built by grounding the content of message patterns. Messages are first sent to the central mechanism, who can perform checks or controls and then forwards them to the receiver.

Our alignment procedure uses the central mechanism as an active participant: agents align against its language (that works as an *interlingua*), and its protocol (the expected behaviour). Agents who want to align identify themselves as *aligners* when the interaction begins. The alignment takes when an aligner agent sends or receives a message. When the central mechanism receives a message from an aligner agent, it performs a matching algorithm (explained later) to choose one between the messages it is expecting in the current state according to its protocol. If the algorithm was successful, he forwards the chosen message to the receiver. If the receiver is also an aligner, it aligns the message with its own protocol by performing the same operations. After each alignment, agents send to the central mechanism information about the states they are in by uttering a special message with illocutionary particle *inform* and all the state properties that hold in the reached state as content. If this information does not match the one of the central mechanism, the alignment is considered a failure and the interaction is aborted; if not it continues and the match between the messages is stored.

The matching algorithm to choose between the expected messages works as follows. We consider the languages of all the interlocutors to share a partially ordered set of sorts S. Contents of messages are predicates, associated with a sort signature represented by a list of elements in S. Our algorithm finds possible matches for a predicate p, which are predicates q such that the sort signature of p can be transformed into the one of q by successively applying a *signature transforming operation*. This operations, inspired in the work in [4], are: 1. Permuting two elements 2. Deleting one element 3. Replacing one element with a more general one . The final choice of a match is made considering a probability distribution over the possibilities that is computed taking into account the matches made in past successful interactions, as in I-SSA (see Section 5.1.2 in [1]).

4. Future work

We presented a method for allowing semantically heterogeneous agents to participate in a social coordination system, aligning their ontologies and protocols on-demand while interacting. The technique has been implemented in the electronic institutions framework and is currently functional. In addition, we extended I-SSA with support for fist-order messages. The work is still in a preliminary phase and many directions for future work can be followed from this point. Our method needs to be extensively tested and evaluated. We plan to create realistic examples that explore different kinds of heterogeneity and to analyse how our method works on each of them. On a more theoretical side, we plan to extend our mechanism to more general models of interaction, to embrace a broader spectrum of social coordination systems. Also, in its current version, our matching only takes in account past experiences. In the future, we plan to analyse how it integrates with other notions of alignment, both at concept and structural level.

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