Open Interaction System Specification and Monitoring Using Semantic Web Technology

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I. Introduction

The design and development of *open distributed interaction systems*, where heterogeneous, autonomous, and self-interested agents can interact by entering and leaving dynamically the system, is widely recognized to be a crucial issue in the development of nowadays applications on the Internet: like e-commerce applications [1], collaborative social systems [2], or application to support the automatic management of virtual organizations [3]. In particular in our view the interacting agents may range from very complex autonomous software agents able to reason and to plan their actions and that behave on behalf of their human owners, to very simple software used by human beings as an interface to interact with the system.

Given that the agents are assumed to be heterogeneous because they may be developed by different designers or they may be human beings, no assumptions can be made on their internal architecture. Given that the system is open and agents may enter and leave it dynamically, it is necessary to find a standard way for specifying a communication language for the interacting agents and for defining the context and the rules of the interaction. Moreover given that the interacting agents are autonomous it is necessary to find a way to regulate interactions so that agents may have reliable expectations on the future development of the system. Furthermore given that these systems will be used to enrich and improve human beings interactions, it is crucial that the proposed design approach is defined taking inspiration from existing studies about human interactions.

Starting from these requirements in our previous works [4], [5], [6], [7], [8] we proposed a meta-model for the conceptual design of open interaction systems based on speech act theory [9], [10] and on Searle's theory on construction of social reality [11]. In particular we proposed the *OCeAN* metamodel, which is base on the definition of a set of application independent concepts that have to be used in the specification of every type of interaction system. We initially proposed an agent communicative language whose semantics is based on the notion of *social commitment* and *temporal proposition*. Therefore in order to be able to define the semantics of declarative communicative acts, we introduced in our model other institutional concepts, like the notion of *institutional action*, *institutional power*, and *role*. Finally in order to constrain agents' actions we formalized the notion of *norm* and of *sanction* or *reward* that are used for norm enforcement[12]. We model open interaction systems as a set of *artificial institutions*. In particular in our view the definition of a specific artificial institution consists of: (i) a component, called meta-model, which includes the definition of basic entities common to the specification of every institution, like the concepts of commitment, institutional power, role, and norm, and the actions necessary for exchanging messages; (ii) a component specific to the institution in question, which includes the specification of the powers and norms that apply to the agents playing roles in the institution, and the definition of the concepts pertaining to the domain of the interaction (for example the actions of paying or delivering a product, bidding in an auction, etc.).

Regarding the language used to specify the various components of the model we initially adopted a language with an operational intuitive semantics based on the notion of object and attribute close to object oriented programming. The difficult that we experimented with this approach was in developing agents able to reason on their actions and able to monitor the agent's behavior. We therefore proposed a formalization of the OCeAN meta-model based on the Discrete Event Calculus [8]. This approach resulted very fruitful for unambiguously specifying the concepts of our meta-model and for being used to simulate the time evolution of an actual interaction, but we experimented performance problems and we did not find a simple way to interface our event calculus specification with an external application used to enable agents interactions, like for instance the JADE framework[1].

We therefore decide to follow a new approach that we plan to investigate and evaluate in the future. Our idea is to use standard Semantic Web Technology to specify,

[1] http://jade.tilab.com/

to reason on, and to monitor agent's actions. In [13] we started to formalize the deontic part of the *OCeAN* meta-model using OWL 2 DL[2]), SWRL rules (Semantic Web Rule Language[3]), and a Java application, developed using OWL-API [4] and the source code of the Pellet[5] reasoner, to overcome certain expressiveness limitations of OWL. More precisely, we showed how it is possible to specify and monitor the time evolution of social commitment used to express conditioned obligations and prohibitions on time intervals.

The main advantages of using a decidable logical language like OWL to specify an open interaction system are that Semantic Web technologies are increasingly becoming a standard for Internet applications and therefore they are supported by many reasoners (like Fact++[6], Pellet[7], or Racer[8]); moreover ontologies and reasoning services are easily interfaced with applications programmed in Java or other well known languages.

When facing this approach we discovered that there may be the following main problems. Firstly the treatment of time: OWL has no temporal operators, in some cases it is possible to bypass the problem by using SWRL rules and built-ins for comparisons, but in any case this does not provide full temporal reasoning capabilities; notice furthermore that using the OWL Time Ontology[9] would not be a solution, given that its axiomatization is very weak. Secondly the open-world assumption: in many applications nor being able to infer that an action has been performed is sufficient evidence that the action has not been performed. We faced this second problem by using an external program to simulate a closed world assumption by adding certain closure axioms to the ontology. But there is still the open problem of understanding what part of the model it is better and possible to represent in the ontology in order to be able to reason on it and what part of the model it is better to represent in the external application because current semantic web standards do not support its representation.

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[7]http://clarkparsia.com/pellet

[8]http://www.sts.tu-harburg.de/ r.f.moeller/racer/

[9]http://www.w3.org/TR/owl-time/, http://www.w3.org/2006/time.rdf