Model Contextual Variability for Agents Using Goals and Commitments

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Abstract. Goal models have been extensively utilized in requirements engineering as they provide an expressive and qualitative way to represent requirements, while recent extensions related to contextual variability have further increased the expressiveness of the models. In addition to their application in requirements engineering however, goal models have been also proposed in the literature as a formal way to define the internal design of agents in multi-agent systems. In this paper we adopt the idea of applying goal models with contextual elements, i.e. conditional goals, decompositions and contributions, as a mean to model the internal design of agents. Furthermore, we express the way those agents can interact with each other in terms of commitments, a recently introduced modeling concept that can be used for the definition of communication protocols in multi-agent systems. In this context, we introduce a transformation process that maps all conditional elements to commitments and contributions, and hence, reasoning techniques that exist for commitments can be applied to contextual models with no further changes.

Keywords: goal models, agent-oriented models, commitments

1 Introduction

Goal models, which have been extensively utilized in requirements engineering, have been proposed in the literature as a formal way to define the internal design and objectives of agents in multi-agent systems. This idea has been also adopted by Chopra et al. in [1], where they additionally introduce the notion of *commitment* as a way to model the communication protocol, i.e. the way agents can interact with each other, in multi-agent systems. More specifically, in [1], the internal design of each agent, along with the goals it wants to achieve, are defined in terms of AND/OR decompositions, and contributions. Given that an agent has the capability to fulfil only a subset of its intended goals on its own, it cannot help but depend on others for the fulfilment of the remaining ones. These dependencies are expressed via roles the agents can adopt, and commitments that exist between agents that play those roles. In a more detailed manner, a commitment of the form *Commitment*(*Debtor*,*Creditor*, *antecedent*, *consequent*) means that the Debtor is committed to the Creditor for the consequent if the

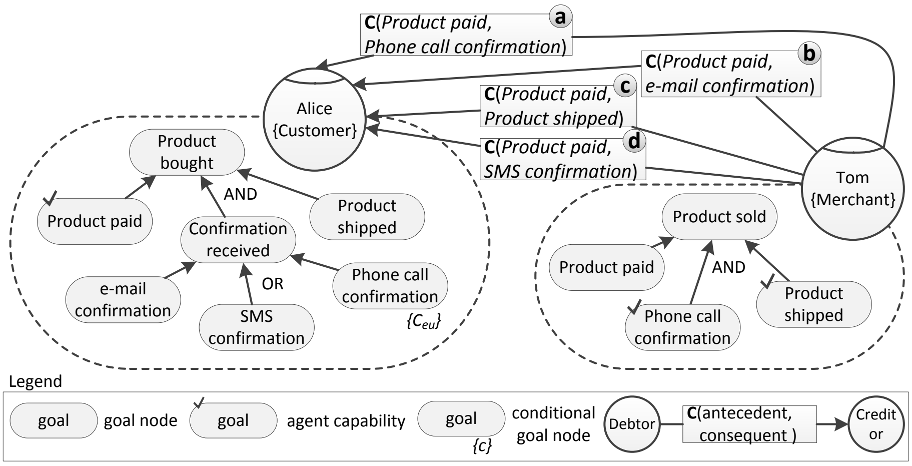

Fig. 1: Two agents that participate in an online marketplace application.

antecedent holds, where both Debtor and Creditor are roles that an agent can adopt. Once the goal model of each agent, as well as the sets of roles and commitments have been specified, the authors provide the semantics of a reasoning process that can be used to check whether the achievement of a specific agent's goal can be supported by the underlying protocol.

As an example consider the case illustrated in Fig. 1, where two agents, namely Alice and Tom, participate in an online marketplace application (ignore the conditional goal node for the moment). In this example Alice, who adopts role "Customer", can satisfy her goal "Product paid" on her own as this is a *capability* of hers. The satisfaction of her goal "Product shipped" however, can be only supported by the commitment denoted as "c" in the figure. In a nutshell, because of the existence of the commitment "c", Tom, who participates in the application as a "Merchant", is committed to provide "Product shipped", if Alice (the "Customer") fulfils "Product paid".

2 Research Objectives

In this paper, we utilize the ideas of [2] and [3] related to contextual variability of goal models, in order to capture the variability that may exist in the internal design of an agent as a consequence of alterations in the context an agent acts in. In this case however, the problem that needs to be solved is slightly different. We are now interested in studying whether a specific agent's goal can be supported by the underlying protocol *and within the given context*. Hence, the reasoning process described in [1] does not apply any more.

To overcome this problem, and in an attempt to keep the reasoning mechanism unchanged, we propose the framework illustrated in Fig. 2. In a more descriptive manner, we firstly extend the metamodel introduced in [4] so as to

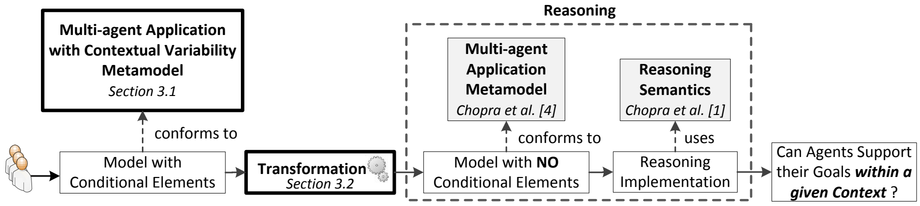

Fig. 2: The proposed framework.

support contextual elements, i.e. goals, decompositions and contributions (see section 3.1), and we then introduce a transformation process that will allow us to express those context-related modeling elements in terms of commitments and contributions (see section 3.2). Thus, by applying this transformation, we can produce a model that captures the multiple variations that may exist in the initial model, while at the same time we can reuse the reasoning semantics proposed in [1]. It is important to note that the produced model is only intended to be used for the generation of the rules required for the reasoning process.

3 Scientific Contribution

3.1 Agents with Context-dependent Goal Models

Using the conceptual model defined in [4] as a starting point, and taking into consideration the way contextual variability is captured in goal models in [2] and [3], we ended up with the metamodel depicted in Fig. 3. While the part of the metamodel related to the definition of a service engagement in terms of commitments and roles is identical to the one introduced in [4] (and thus not included in the figure), the goal-oriented representation of agents is extended with the addition of *conditions*. More specifically, the proposed metamodel allows for goals, decompositions, and contributions to be defined as *conditional*, in the sense that each one of those modeling elements can be related to one or more conditions, the truth values of which dictate the existence of the corresponding element in the goal model. Hence, a conditional element is included in the model only if at least one of the attached conditions is true, otherwise it must be removed. In this respect, the metamodel can capture the contextual variability of the internal model of an agent, where a specific context is mirrored by the assignment of truth values to all conditions in the model.

For the example illustrated in Fig. 1, lets assume that the online marketplace application serves only e-shops that are located in Europe, and that the goal node *"Phone call confirmation"* is conditional and exist in the model only if Alice is located in Europe when she interacts with the application (C_{eu} is true), and is removed otherwise. Lets also assume that Alice happens to be in the USA (i.e. condition C_{eu} is false), and hence she can only receive a confirmation via an e-mail or an SMS. As Tom cannot provide neither of them to Alice, she will not be able to achieve her goal as a consequence of the context she acts in.

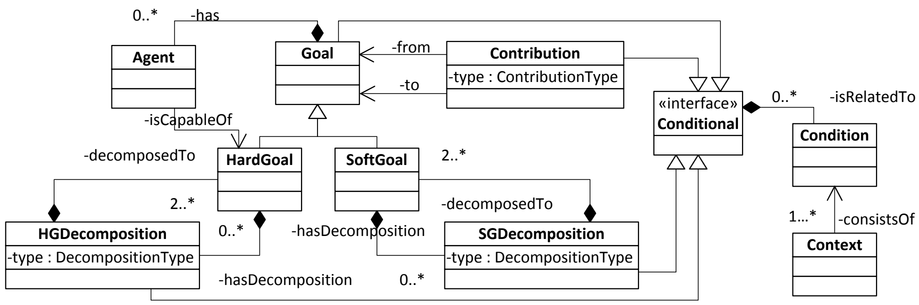

Fig. 3: The metamodel for the contextual variability of agents' goals.

3.2 From Conditional Elements to Commitments

In this section we are going to define a transformation process for the mapping of conditional elements to commitments. Initially, we define a dummy agent called *ContextAgent* which has no goals to achieve, and always adopts the role *Reasoner*. The purpose of this agent is to provide other agents with goals that belong to the set of its capabilities (set G_C), something that can be done by enriching the existing protocol with additional commitments. More than that, for each condition in the model we create a corresponding role that can be adopted by the agents that participate in the application.

The mapping from conditional contributions to commitments for the four possible types ($++S/D$ and $--S/D$) [1], along with the corresponding transformation steps are summarized in Table 1. Because of space limitations we will only discuss in detail the transformation process for the $--D$ conditional contribution. We start by adding two new goal nodes to the model, namely g'_s and g'_t, with the latter being a capability of the ContextAgent. Those two goal nodes are then connected to the goal model via two *unconditional* contributions, one of type $--D$ from g_s to g'_s, and a second one of type $++S$ from g'_t to g_t. Subsequently, the commitment $\mathit{Commitment}(\mathit{Reasoner}, r_{\text{cond}}, g'_s, g'_t)$ is inserted in the protocol of the application. What remains to be proved is the soundness of the mapping from the $--D$ conditional contribution, to the rules that use commitments and unconditional contributions. In other words, we must show that when condition C_{cond} is true, and g_s is not satisfied, goal g_t is fulfilled.

Actually, if g_s is denied, g'_s is satisfied because of the existence of the $--D$ contribution from the former to the latter. This implies that if the agent adopts the role r_{cond} (this is the role that corresponds to C_{cond}), and because of the commitment previously specified, ContextAgent will provide it with g'_t which is one of ContextAgent's capabilities. Finally, the truth of g'_t has as a consequence the satisfaction of g_t goal node because of the $++S$ contribution introduced earlier. Hence, if g_s is denied and the agent adopts the role r_{cond}, g_t becomes true, while if r_{cond} is not adopted, g_t can not be satisfied as a consequence of the

[1] In the context of this paper we adopt the semantics of [1] for contributions

Table 1: Mapping conditional contributions to commitments.

Conditional Contribution	**Mapping to Commitments**
$g_s \xrightarrow[\{\text{cond}\}]{++S} g_t$	$Commitment(Reasoner, r_{\text{cond}}, g_s, g_t')$ $g_t' \in G_C,\ g_t' \xrightarrow{++S} g_t$
$g_s \xrightarrow[\{\text{cond}\}]{--S} g_t$	$Commitment(Reasoner, r_{\text{cond}}, g_s, g_t')$ $g_t' \in G_C,\ g_t' \xrightarrow{--S} g_t$
$g_s \xrightarrow[\{\text{cond}\}]{--D} g_t$	$Commitment(Reasoner, r_{\text{cond}}, g_s', g_t')\ ,\ g_t' \in G_C$ $g_s \xrightarrow{--D} g_s'\ ,\ g_t' \xrightarrow{++S} g_t$
$g_s \xrightarrow[\{\text{cond}\}]{++D} g_t$	$Commitment(Reasoner, r_{\text{cond}}, g_s', g_t')\ ,\ g_t' \in G_C$ $g_s \xrightarrow{--D} g_s'\ ,\ g_t' \xrightarrow{--S} g_t$

denial of g_s, as in this case the corresponding commitment cannot be applied. This means that by substituting the initial $--D$ *conditional* contribution with a commitment and an appropriate combination of unconditional contributions, we end up with a model that does not contain the initial conditional element but still has the same behavior as if it was part of the model.

Finally, the remaining two conditional elements, i.e. decompositions and goals, can be fully described by utilizing conditional contributions, and so, the same transformation process can also apply in those cases. The way a conditional decomposition, and an OR-child node are encoded as conditional contributions is illustrated in Fig. 4a and 4b respectively, while because of the duality between AND and OR-decomposition the former has been omitted.

4 Conclusion

In this paper we use goal models with conditional elements as a mean to capture the contextual variability of agents that participate in a multi-agent application. Consequently, we propose a set of rules for the transformation of those conditional elements to commitments and contributions. This transformation allows us to apply the same reasoning process introduced in [1] even in the presence of conditional goals, decompositions and contributions. Hence, we have succeeded in increasing the expressiveness of the metamodel introduced in [4], while at the same time the proposed reasoning techniques can still apply without changes.

5 Ongoing and future work

The extended metamodel presented in this paper is intended to be used for modeling policies that must apply in multi-layer systems at run-time. The formal representation of those policies, along with a proper reasoning engine, and in combination with advanced monitoring techniques, can then be utilized in order to check whether the system complies with the required policies or not.

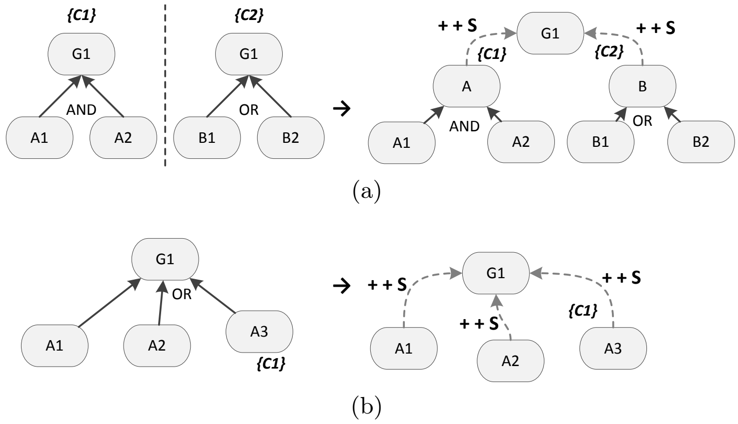

Fig. 4: Conditional a) decomposition ($G1$ is AND-decomposed if $C1$ holds, or OR-decomposed if $C2$ holds) and b) goal encoded as conditional contributions.

In our work we mainly focus on the former two parts, namely policy modeling, and reasoning, and we examine the applicability of probabilistic and fuzzy logic reasoners to the problem of policy validation.

An application of the proposed modeling is presented in [5]. The problem we are trying to solve in this paper is quite different, as we are interested in predicting the satisfaction of goals related to software project development. However, we show how a goal model with conditional modeling elements can be transformed to a first order logic knowledge base, which can then be used to perform probabilistic reasoning.

Acknowledgment This research is co-funded by the European Union (European Social Fund ESF) and Greek National funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: Heracleitus II. Investing in knowledge society through the European Social Fund.

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