TOWARDS A UNIFIED META-MODEL FOR GOAL ORIENTED MODELLING

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Abstract

Goal oriented modelling (GOM) is one of the most prominent and widely accepted techniques in information systems research. Since the early 1990's, a large number of GOM approaches have been proposed aiming to a better alignment between business strategy and the behaviour of supporting systems. Different GOM approaches focus on different activities in the early stages of system development and propose a variety of strategies for reasoning about goals. A number of researchers have stressed the advantages of integrating different GOM techniques, especially in the context of modern global business environments. This is evidenced in the increasing number of publications in this area. However as each GOM language (even versions of the same language) comes with its own syntactic and semantic singularities, such integration requires a number of complicated transformations which is a major obstacle to model and tool interoperability, and prevent wider adoption by practitioners. In order to provide a unified view of GOM, one needs a common understanding of GOM concepts, their semantics and deployment. To this end, this paper proposes a language independent meta-model based on the analysis of eight GOM languages. Generic concepts were identified and a robust semantic definition among these concepts was built in a unified meta-model. We claim that the unified GOM meta-model could help in a) analysing existing goal models in order to provide insights regarding different goal modelling perspectives b) identify semantic similarities / overlaps between existing GOM techniques c) provide the basis for a reference model for GOM.

Keywords: Goal oriented modelling, goal oriented meta-model, goal oriented language.

1 INTRODUCTION

In general, goal-oriented actions are actions directed towards the realization of some specific state of the world (Castelfranchi and Paglieri, 2007). Inspiring by this way of thinking, the goal oriented modelling approaches in information systems (IS) rooted to three decades back as a requirements elicitation, modelling, analysis and validation technique. That time practitioners realized the need to trace the rationale of IS development which was impossible to capture by other software engineering techniques. Goal-oriented modelling adopts a top-down analysis approach in order to elicit system requirements from the systems environment aiming to develop a valid information system. Goal oriented approaches offer rich semantic and syntax presented either in terms of natural language specifications or graphical notations. Goal oriented approaches and techniques come under different names such as goal-driven engineering, goal modeling (GM), goal oriented requirement engineering (GORE), goal oriented modelling (GOM). The goal concept has emerged from research in Artificial Intelligence (goal-directed autonomous agents) as well as organizational/enterprise modeling (goal-directed organizational behavior). Furthermore, GOM research has its roots in design problem solving and cognitive research that suggest the use of goal-driven processes in many kinds of activities that humans perform. Hence GOM languages use a vocabulary inherited from these fields e.g. agents, roles, constraints, obstacles, beliefs, expectations, strategies, plans and so on. Supplementary concepts have been added in order to describe the process of goal setting and refinement including scenarios and context, among others.

Since the early 1990's, goal-oriented modeling has become an essential element of the IS research filed and, to a lesser extent, industrial practice. In particular, for requirements engineering (RE) activities goal models have been used to elicit, represent and analyze a) Organization requirements e.g. strategic goals (Bleistein et al., 2006), risk (Asnar et al. 2011), operation (Santos et al., 2010), organizational change (Kavakli and Loucopoulos, 2006), etc. b) Multiple stakeholders requirements e.g. agents tasks (Lapouchnian and Lespérance, 2006), trust (Yu and Liu, 2000), point of view (Kaiya and Saeki, 2004), collaboration (Yu et al., 2011), resources and capabilities (Danesh and Yu, 2014) c) Information systems requirements e.g. system requirements (Lamsweerde, 2001), software functions (Schnabel and Pizka, 2006; Lapouchnian et al., 2006), self-adaptive systems (Bryl and Giorgini, 2006; Liaskos et a;, 2012), security (Liu et al., 2003), safety (Kelly and Weaver, 2004), general non-functional evaluation (Chung et al., 2000) etc. As a result, different goal modeling approaches have been proposed each having different semantics, concepts and notations due to the fact that researchers have adopted different views on what is actually a goal and what are the boundaries of the goal model in a particular context and for a particular purpose.

In modern business environments, there are increasingly more situations (e.g. joint-venture, multi-level strategies, joint and distributed multi-projects) where a single GOM technique is neither practical nor feasible as project participants may use different modeling languages. Recent research has stressed the need for a holistic unified GOM language, in order to maximize its usage and deployment (Patrício et al. 2011). Such unification requires a clear and robust understanding of the semantics as well as the differences and similarities between different GOM concepts. This will allow the definition of a unified view of GOM languages in systematic manner. This unified view can assist the analysis of existing goal models in order to provide insights regarding different goal modeling perspectives, as well as to identify semantic similarities / overlaps between existing GOM techniques. To this end, this paper adopts an abstraction process that integrates eight well-known GOM techniques' concepts into a single and unified meta-model, described in section 2. Section 3 presents the unified goal oriented meta-model and discusses the different aspects of GOM. Related work is discussed in section 4. Finally, section 5 concludes the paper highlighting open issues that provide the foundation for further research in the GOM field.

2 THE PROCESS OF BUILDING A UNIFIED META-MODEL

A meta-model is an explicit model of the constructs and rules needed to build specific models within a domain of interest, in this case goal modeling. The intention in this paper is to use metamodeling in order to create a unified meta-model for the purpose "integrating" existing GOM approaches, bringing together existing artifacts suggested in different GOM meta-models. The resulting extensible unified goal oriented meta-model provides a language independent goal oriented ontology. The mainstream GOM approaches which this meta-model is based on are: The Knowledge Acquisition in automated Specification (KAOS) (Dardenne et al. 1993; Objectiver, 2007), the Enterprise Knowledge Definition (EKD) goal meta-model (Loucopoulos et al., 1997; Kavakli and Loucopoulos, 1999), the Business Motivation Model (BMM) (OMG, 2010), the ***i**** framework (Yu et al., 2011), the Goal-Structuring Notation (GSN) (Kelly and Weaver, 2004; Attwood et al., 2011), the Non-Functional Requirements (NFR) framework (Mylopoulos et al., 1992; Chung et al., 2000), the Goal-Based Requirements Analysis Method (GBRAM) (Anton, 1996) and Techne (Borgida et al., 2009).

Figure 1 depicts the integration process in terms of 3 levels: model-level, meta-level and meta-meta level. Different representations of a single goal model in the aforementioned GOM languages are shown at the lowest level of abstraction (model level), together with their meta-level representations as the second level. An integrating meta-meta model is presented at the highest level. The unified GOM meta-model development process includes the following steps: (1) generating individual GOM meta-models, (2) concept mapping, and (3) concept integration.

In the first step, for each GOM approach, its concepts and their interrelations is described as a meta-model using a common foundation language (in this case UML). Generation of the meta-models was based on studying existing models' descriptions found in the literature. This was not straightforward since most languages do not provide an abstract syntax. Even if a meta-model was provided, in most cases non-standard constructions were used to visualize it, omitting multiplicities, specialization-related constraints and abstract classes. Integrity constraints were only given partially and informally. Thus, special attention was necessary in order to cover all represented concepts and their relations in the developed meta-models.

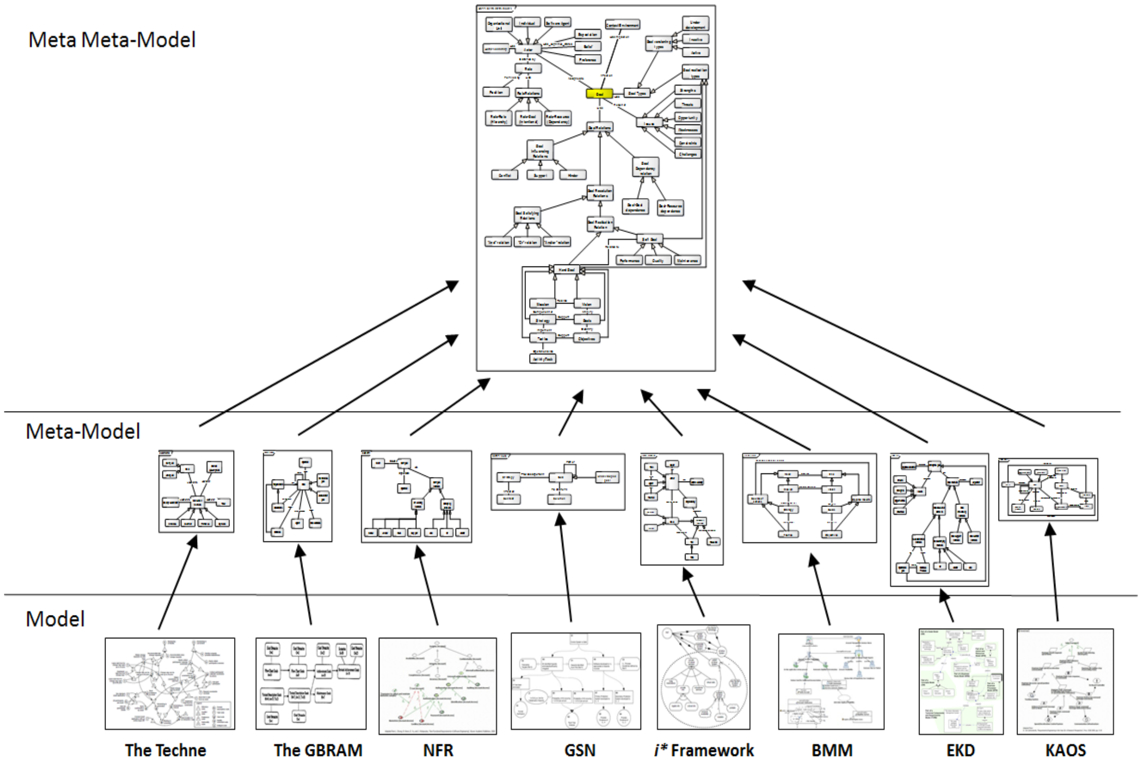

Figure 1. Unifying goal oriented modelling languages

Although, different GOM meta-models include similar concepts these are captured by different meta-models in different ways, e.g. using different names or different structure. Therefore, it is necessary to perform a mapping between concepts of the different meta-models eliminating any redundancies (step 2). This mapping involves the analysis of GOM concepts based on their definition found in the literature. A review of goal modeling constructs is shown in Table 1. Concepts expressing similar aspects of reality are grouped together.

The third and final step *concept integration*, refers to the unification of the concepts representing the same aspects of reality to a single general concept at the meta-meta-level. Indeed, we identified a number of overlapping concepts. For instance, assumption and expectation can be read the same; also achievement goal and objective are equal. Maintenance goal and quality goal can be non-functional or soft goal, while undeveloped goal appears as a type of versioning and goal status. Goal types such as hard and soft goals were proposed for modeling goals, other types such as End, Mean and sub-goals presented to describe the operationability of the goal. For instance, strategy and plan can say the same thing, operation and process can be equally reflected in real life scenarios. Also if we look at issues, obstacles, constraints and challenges constructs, we also assume those can all grouped in issues, where issues can be challenges, obstacles, constrains (can also be part of the environment/context, similar to events). Belief, assumption, expectation and claim are cognitive states of either the actor or the analyst, which those also can be overlapping in essence when it comes to industrial practice. Relations in ***i**** such as (make, help, hurt, break positive and negative, unknown) can be summarized in three scales (support, conflict and hinder). We comprehend that most of the GOM approaches focused on the modelling of the system environment, requirements and constraints. The purpose is to better feed into the software applications design; we locate events into goal execution aspects, where multi-directional events may impact on goal achievement, goal execution and its surrounded context. Finally we also see claim as equal to belief. Table 2 summarizes our findings based on definition analysis of the eight methods concepts.

Concept		KAOS	EKD	BMM	i*/Tropos	GSN	NFR	GBRAM	Techne
Goal achievement	Goal	x	x	x	x	x		x	x
	Soft goal	x			x		x		x
	Maintenance goal							x	
	Achievement goal							x	
	Quality goal								x
	Undeveloped goal					x			
	Vision			x					
	Mission			x					
	Objectives			x					
	Strategy			x		x			
	Tactics			x					
	Plan				x				
	Operation	x	x				x	x	
	Process		x						
	Task				x				x
Goal ownership	Agent	x			x			x	
	Actor				x				
	Role				x				
	Position				x				
	Organization		x	x					
	Actor Boundary				x				
	Context					x			
	Domain property	x							
Goal execution	Issues		x	x					
	Obstacles	x						x	
	Constraint							x	
	Requirements	x						x	
	Event	x							
	Solution					x			
	Resource				x				
Goal formulation	Expectation	x							
	Belief				x				
	Claim						x		
	Argument		x						
	Assumption								x
	Option								x
	Scenario							x	
	Preference								x

Table 1. Overview of goal oriented modelling constructs

Concept	Overlapped concept
Hard Goal	Functional Goal
Soft Goal	Non-functional Goal
Maintenance goal	Type of Non-functional Goal or Constraint
Achievement goal	Objective
Quality goal	Type of Non-functional Goal
Undeveloped goal	Claim or goal status
Plan	Strategy
Operation	Process
Requirements	Technical type of goals
Constraint	Part of the requirements
Solution	Type of goal to be achieved
Belief	Claim
Argument	Belief + assumptions
Scenario	Part of argument
Option	Part of argument
Preference	Part of argument
Expectation	Type of goal, also it can be an assumption. But we see it in our integrated metamodel as an cognitive element relevant to prediction of unknown

Table 2. Goal oriented modelling overlapped constructs

Based on the previous analysis we have constructed our unified GOM meta-model. It should be noted that meta-model integration relies significantly on the analysts' experience in finding appropriate logic of ontological and taxonomical relations without losing the expressiveness of the meta-model concepts. Figure 2, presents an overview of the integrated GOM meta-model using UML class diagram. Generalization has been used in order to represent the generic concept for several concepts that represent the same aspect of reality.

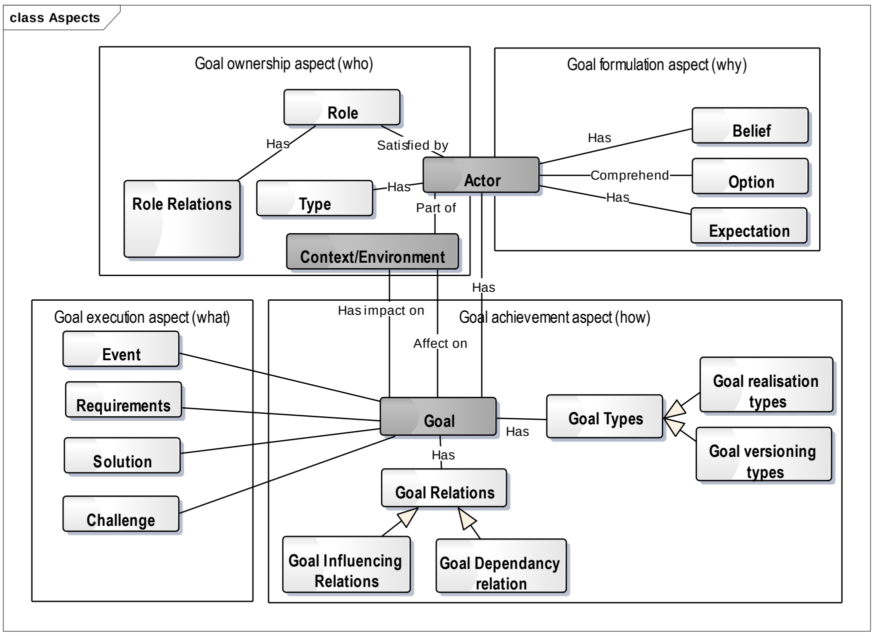

Figure 2. The overview of the integrated GOM meta-model

The main assumption in the proposed integration is that GOM languages express similar concepts. This makes it possible to create a common integrated meta-model. Conceptually, this integrating meta-model represents a union of all the concepts found in the GOM languages. This paper, focus on semantic interoperability only. Additional work is needed in order to address technical interoperability issues. However, we believe that this meta-model is a first step towards the definition of a common goal reference model.

3 ANALYSIS OF THE META-META-MODEL CONSTRUCTS

A shown in Figure 2, the concepts of the unified goal oriented meta-model can be categorized into four different aspects with respect to the type of goal reasoning that they support, namely: goal ownership (who), goal formulation (why), goal achievement (how), goal execution (what), aspects. Figures 3 to 6 present the classification of the general GOM concepts of the integrated meta-model with respect to the four GOM aspects, as well as their inter-aspects relationships (in dark grey). In particular, Figure 3, describes the goal ownership aspect including all concepts related to the organizational entities that are responsible for achieving a goal. Figure 4, depicts the concepts representing the goal formulation aspect (why), including the concepts related to the cognitive process of goal formulation.

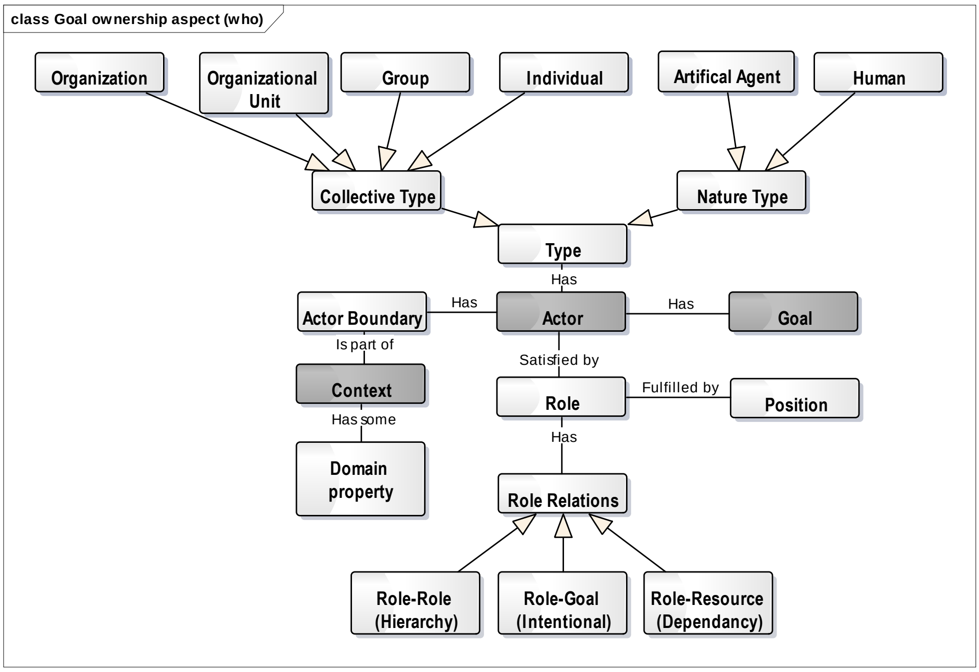

Figure 3. Goal ownership aspect (who)

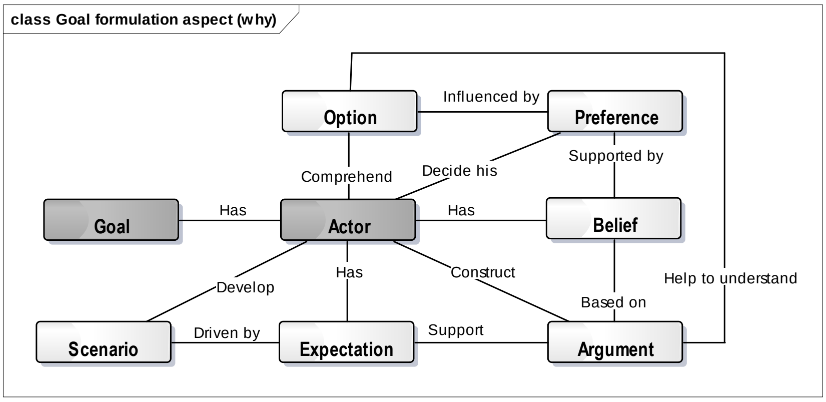

Figure 4. Goal formulation aspect (why)

Figure 5, depicts the concepts involved in the goal achievement aspect. These concepts are relevant to the process of goal analysis and decomposition of high-level goals to operational goals.

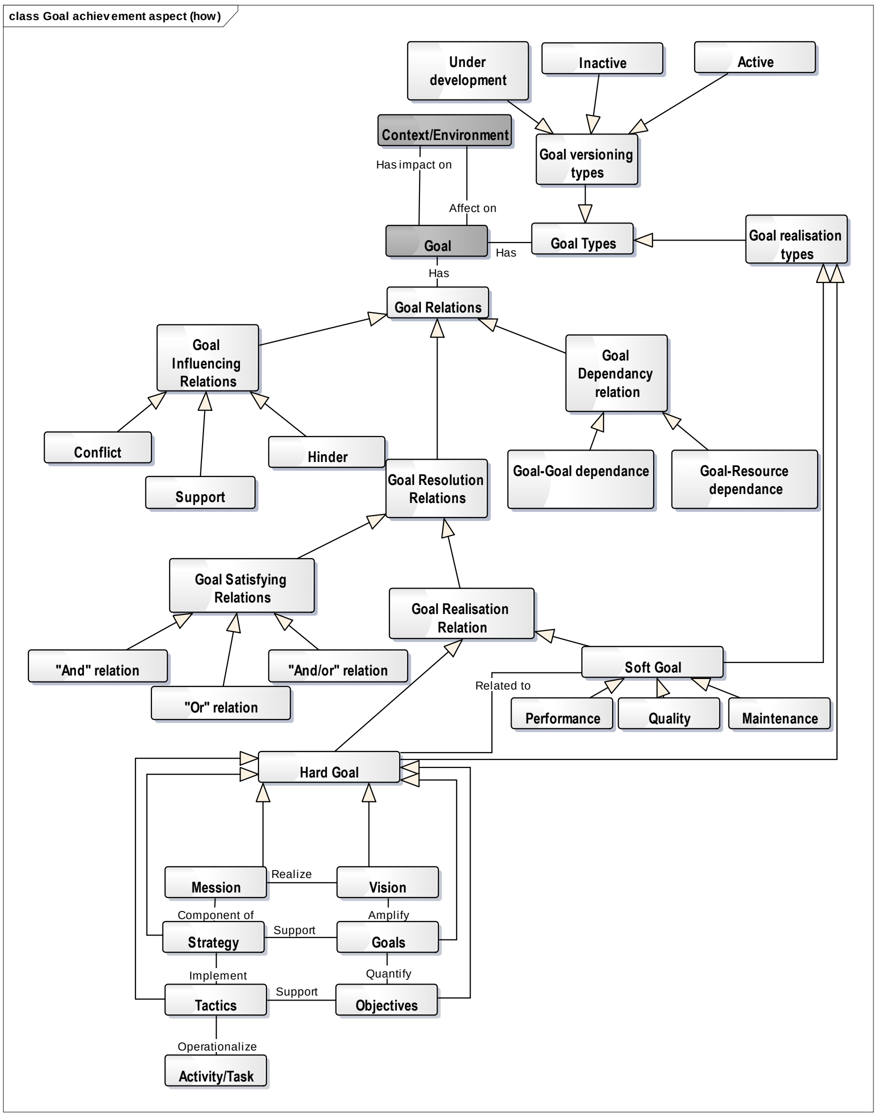

Figure 5. Goal achievement aspect (how)

Finally, Figure 6, corresponds to the goal execution aspect (what) representing the concepts internal and external to the organization that influence (cause, trigger or control) the goal execution.

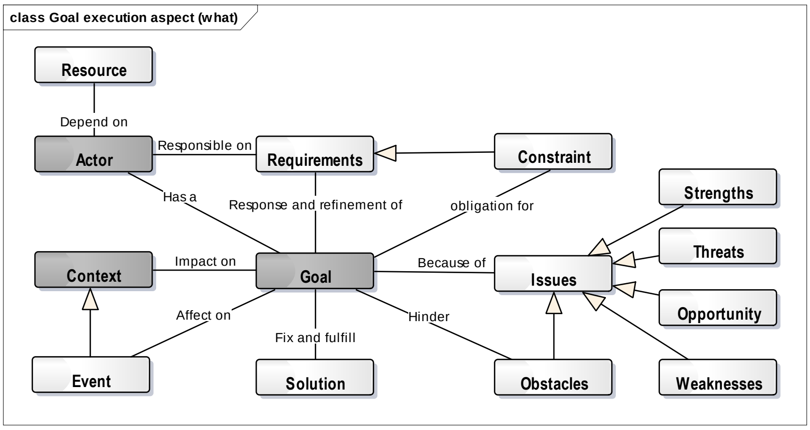

Figure 6. Goal execution aspect (what)

4 RELATED WORK

This work is in line with our previous work reported in Kavakli and Loucopoulos (2005), which reported the analysis of 15 GOM languages along four dimensions: “usage” (what RE activity does goal modelling contribute to?), “subject” (what is the nature of goals?), “representation” (how are goals expressed?) and “development” (how are goal models developed and used?). The result of this analysis indicated the fragmented nature the need for more integration in the field of GOM. In Kavakli (2002) we further proposed a unification of goal meta-models at the “usage” level.

Analysis of relevant literature reported in Horkoff et al. (2014) shows that a decade later the GOM picture has not changed since the authors reach the conclusion that “many approaches are narrowly focused, with most approaches focusing only on a few stages of the software lifecycle, not often providing an end-to-end solution”.

A number of recent approaches have dealt with the horizontal transformation between GOM languages. For example Matulevičius et al. (2007) describes a comparison of KAOS and ***i**** (GRL) using UEML as the foundation ontology. Rather than providing a unified GOM model their aim is to identify semantic discrepancies of the two approaches. Patricio et al. (2011) focus on syntactical mapping between the two approaches mentioned previously. Similar to our work, Nwokeji et al. (2013) define a consolidated intentional modeling language using a Model Based Software Engineering (MBSE) language integration technique; however the scope of this work were limited to two goal modelling languages (once again KAOS and ***i****). The work presented in this paper presents a holistic approach in terms of a) the number of GOM techniques integrated b) the semantic mapping between GOM constructs c) the clarification of GOM syntax using UML class diagrams and d) the classification of the GOM meta-model constructs with respect to different aspects of goal modeling.

5 CONCLUSION AND FUTURE WORK

This paper proposes an integrated goal oriented meta-model that is language-independent. The meta-model was developed through abstraction based on eight well-known GOM approaches.

The value of a unified, language independent, GOM meta-model is that it provides a unique semantic specification of goal oriented concepts and their relationships thus eliminating invalid interpretations by experts in different domains. As such it can act as a reference between multiple GOM techniques of the same project.

In addition, this work contributes to the clarification of the GOM syntax using UML class diagrams. Furthermore, the mapping process has revealed ontological redundancies of GOM concepts meaning that two concepts have the same or overlapping semantics i.e., they refer to the same things.

Furthermore, analysis of the integrated meta-model concepts may reveal further issues such as incomplete domain coverage, when a language does not convey information on a certain aspect of the application domain. Indeed, the analysis of the integrated meta-model constructs indicates that current GOM approaches focus on goal setting and execution and do not address goal evaluation an important aspect of goal formulation. Aligned to goal evaluation is goal adaptation, also not dealt with in current GOM approaches, whereby goals are supposed to be steady and there can only be predefined alternative plans of goal execution. However, evaluation of the results of goal execution might in turn trigger the adaptation of existing goals or the formulation of new goals. Incorporating goal dynamics requires the definition of appropriate goal states and a set of operations for moving between states.

We claim that modeling of goal dynamics is more suitable for todays’ open service oriented systems characterized by the heterogeneity and autonomy of the participating agents. Furthermore, it could better fit the requirements of intelligent, context aware systems.

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