Semantic Integration of Goal and Business Process Modeling[1]

Evellin C.S. Cardoso, Paulo Sérgio dos Santos Jr., João Paulo A. Almeida,
Renata S.S. Guizzardi, Giancarlo Guizzardi

e-mail: {ecardoso, paulossjunior, jpalmeida, rguizzardi, gguizzardi}@inf.ufes.br

Ontology and Conceptual Modeling Research Group (NEMO)
Computer Science Department, Federal University of Espírito Santo (UFES)
Av. Fernando Ferrari, s/n, Vitória, ES, Brazil

Abstract. While business processes and business goals are considered intrinsically interdependent, a comprehensive modeling approach that includes both the business process and the goal perspectives is still lacking. This paper proposes a semantic integration between the domains of goal modeling and business process modeling. We integrate the ARIS framework with the Tropos goal modeling language. While ARIS is widely employed for business process modeling, it offers an overly simplistic set of goal-related concepts. In contrast, Tropos offers a rich set of goal-related concepts (and associated goal analysis methods), while refraining from addressing business process modeling in detail. In order to investigate the relation between the Tropos modeling constructs and the ARIS elements, we propose an ontological account for both architectural domains through the usage of the UFO ontology.

Keywords: *Semantic Integration, Goal Modeling, Business Process Modeling EPC, Tropos, ARIS*

l. INTRODUCTION

The increasing competitiveness drives organizations to promote change in an attempt to improve the quality of the services and products they offer. Predicting how a given enterprise environment should respond to changes by simply adopting a business-process centered view ([8][21][22]) is challenging since there are a large number of issues to be considered, such as infrastructure, power and politics, managerial control, organizational culture, among others [35]. Given this multitude of issues, understanding an organizational setting often requires a number of perspectives [35].

Among these perspectives, the domain of "motivation" has been recognized as an important element of enterprise architectures [36] as highlighted in Zachman framework's motivation column [34]. Goal modeling may be employed for capturing

[1] This research is funded by the Brazilian Research Funding Agencies FAPES (grant number 45444080/09) and CNPq (grants number 481906/2009-6 and 309059/2008-9).

the motivational aspect and strategies behind the organizational practices [35], helping in clarifying interests and intentions from different stakeholders [20]. Moreover, by adopting goal modeling, organizations can systematically express the choices behind multiple alternatives and explore new possible configurations for an organizational setting. This is essential for business improvement since changes in a company's strategy and business goals have significant consequences within all domains of the enterprise [23]

While the goal dimension of enterprise architectures focuses on "why" [20][35], a behavioral business process dimension also has significant importance in enterprise architectures, since it addresses the way the enterprise organizes work and resources to fulfill its strategies [33], focusing on "how" business activities are performed and supported by information systems. Moreover, since business processes are the way in which the strategy and goals are incorporated into the behavior of the organization, adopting business process modeling can provide high-level insights into general operations of the organization to identify means to better addresses strategic concerns.

Since business process and goals are intrinsically interdependent, establishing an alignment between both domains arises as a natural approach. The central idea is to create enterprise models that describe not only the entities in a business context, but also include motivations for those entities [2].

This paper contributes to this vision by proposing a semantic integration between the domains of goal modeling and business process modeling. We integrate the ARIS framework [32] with the Tropos methodology and modeling language [4][5]. While ARIS is widely employed for business process modeling, it offers an overly simplistic set of goal-related concepts. In contrast, Tropos offers a rich set of goal-related concepts (and associated goal analysis methods), while refraining from addressing business process modeling in detail.

Since each modeling language focuses on different architectural domains of the organization (which is manifested through the existence of different sets of concepts in each modeling language), we use an ontological approach for bridging the semantic gap between the two modeling languages. This involves the interpretation of the related concepts in each of these languages and a subsequent harmonization of the languages. For this interpretation, we employ a foundational ontology, i.e., a formal and ontologically sound system of domain-independent categories. In particular, we make use here of the Unified Foundational Ontology (UFO) [17] as our semantic foundation. The ontological interpretation allows us to establish a rigorous definition for fragments of the ARIS and Tropos modeling languages in terms of real-world entities defined by the UFO foundational ontology. We regard the semantic integration discussed here as pre-requisite for language-level (syntactic) integration.

This paper is further structured as follows: section 2 presents the relevant fragments of the ARIS and Tropos metamodels; section 3 presents ontological foundation; section 4 discusses the interpretation of these metamodels in terms of UFO and presents the integration of both approaches; section 5 presents our conclusions and identifies topics for further investigation.

2 THE ARIS AND TROPOS METAMODELS

Before interpretation, we must identify the relevant language constructs and their relations. This is discussed in this section, which presents fragments of the ARIS and Tropos language metamodels (represented here in Ecore [11]).

2.1 The Tropos Metamodel

The i* framework [35], consists in an agent-oriented conceptual framework whose focus is on intentional characteristics of organizational actors. The Tropos methodology has been conceived with basis on the i* framework and adopts the same concepts in early requirements stages for software development [34]. The language is structured in terms of two main components: the Actor Diagram and the Goal Diagram. The former describes the organizational context in terms of dependency relationships between actors, while the latter describes the actors' goals and rationales in order to justify the actors' relationships and their adoption of particular plans. The metamodels of these two diagrams are extensively described in [12]. In this section, we present fragments of these metamodels and provide some examples of usage of the modeling constructs.

Figure 1 depicts the metamodel of the Actor Diagram. In this metamodel, *Actor* is the agent-oriented concept which represents an intentional entity of the organizational setting. An *Actor* is specialized into other three concepts, namely: *Agent*, *Role* and *Position*. A *Role* is a characterization (set of properties) that apply to actors playing that role in a given social domain (it is transferable to other individuals). An *Agent* is an actor which displays a physical existence, such as human individuals, hardware or software agents. Finally, a *Position* comprises in a set of roles which is performed by an agent [35]. We say that an agent *occupies* zero or more positions and *plays* zero or more roles. Further, a position is said to *cover* one or more roles [5][12][35].

With respect to goals, Tropos relies on two primitives for goal modeling: hardgoals and softgoals. The language has a general concept Goal which, in its turn is refined into these concepts. A Goal, according to [35], is defined as a condition or state of affairs in the world that the actor would like to achieve.

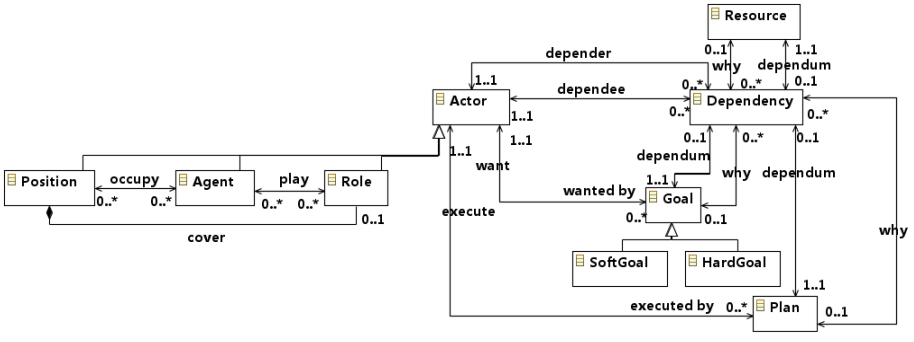

Figure 1. Metamodel of the Actor Diagram [19].

Hardgoals are defined as goals whose satisfaction can be objectively defined [5]. Conversely, softgoals are "subject to interpretation" [35], "imprecise, subjective, context-specific, and ideal" [24] and therefore have no objective satisfaction criteria. This different nature of achievement is denoted in the terms used for stating goal fulfillment: it is said that hardgoals are satisfied while softgoals are *satisficed* [26].

The actor diagram also identifies plans which are executed by agents. The relationship between plans and goals rests on the fact that goals represent "a set of states of affairs (i.e. a set of world states)", while plans "represent, at an abstract level, a way of doing something. The execution of plan can be a means for satisfying a goal or for *satisficing* a softgoal" [5].

Commonly, the actors cannot satisfy their goals in isolation and, as consequence, they engage in dependency relations with other actors. These are relations are also represented in actor diagrams. A dependency represents an agreement between two actors where one actor (the *depender*) depends on another (the *dependee*) to fulfill a goal, perform a plan or deliver a resource (the *dependum*) [12]. Resources [35] are intentional objects (usually obtained as a finished product from a deliberation process).

In the Goal Diagram (whose metamodel is depicted in Figure 2), the central concept of goal is represented by the Goal metaclass [12]. Goals can be analyzed, from the point of view of an Actor, by three types of relationships among them: *means-ends links*, *AND/OR decomposition* and *contribution links*. *Means-end links* aim at capturing which plans and resources provide means for achieving a goal (therefore, a *means-ends link* is a ternary relationship between an Actor, a Goal (the end) and a Plan or Resource (the means) [12]). Further, there are two types of decompositions (specified via an attribute of the metaclass Boolean Decomposition): AND-decomposition and OR-decomposition. An *AND decomposition* supports a goal to be decomposed in a series of sub-goals; while an *OR decomposition* allows modeling alternative ways of achieving a goal. *Contribution links* identify goals that can contribute positively or negatively in the attainment of the goal to be analyzed (thus, it is a ternary relation between An Actor and two goals). As exposed in [12], a contribution can be annotated with a qualitative metric (not shown in of Figure 2).

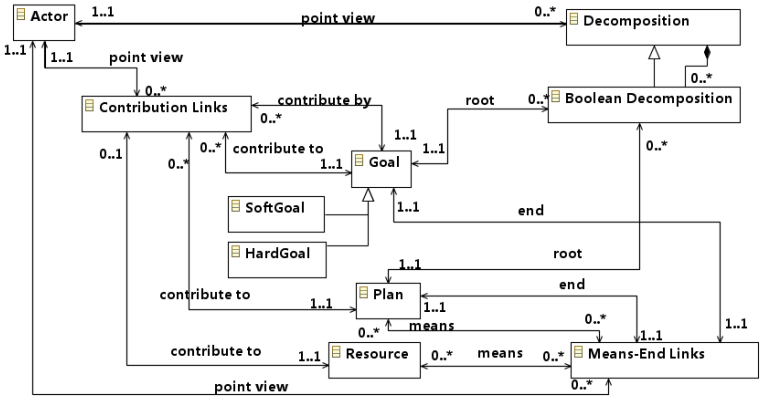

Figure 2. Metamodel of the Goal Diagram [12]

2.2 Metamodels for the ARIS Method

Figure 3 shows a fragment of the metamodel of the business process modeling and goal modeling languages used in the ARIS Method. This fragment was excavated in our earlier work by using the approach described in [29] and defines the abstract syntax of the language as currently supported by the ARIS Toolset. The main metaclasses for business process modeling in this fragment are: *Participant*, *Objective*, *Event*, *Rule* and *Function*. Business processes are modeled in diagrams know as Event-driven Process Chains (EPC). The main metaclasses for objective modeling in this fragment are: *Objective*, *Critical Factor*, *Product/service* and *Function*. These metaclasses are used in an Objective Diagram.

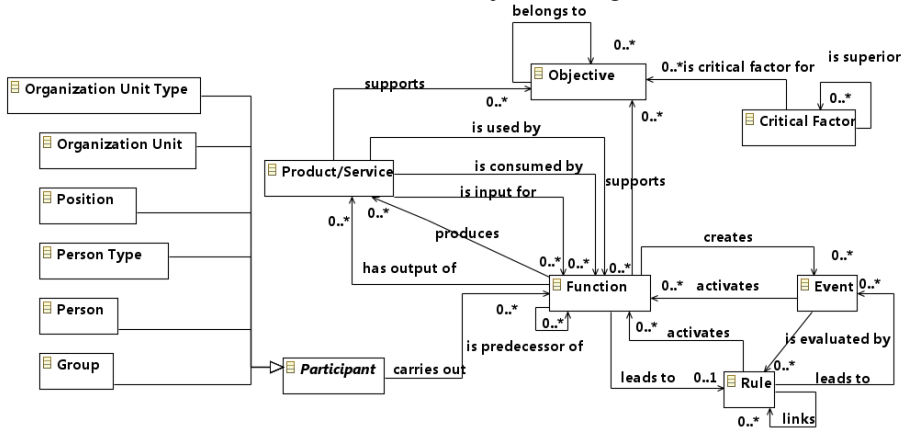

Figure 3. Fragment of the metamodel for Business Processes and Goals in ARIS

The *Participant* abstract metaclass subsumes the following metaclasses: *Organization Unit Type*, *Organization Unit, Position*, *Person Type*, *Person*, *Group* and *Employee Variable*. These organization elements belong to the ARIS Organizational diagram and are referenced in an EPC to describe participants in organizational activities. According to [32], the *Organization Unit* metaclass represents an entity that is responsible for achieving organizational goals. The *Position* metaclass represents the smallest organizational unit possible (a particular job position). The *Person* metaclass is used to represent a person who is assigned to organization. The *Person Type* metaclass represents a role performed by one or more persons, positions, groups or organizational units [30][32]. The *Group* represents a group of employees (*Person*) or a group of organizational unit (*Organizational Unit*) that work together to achieve a goal.

The *Function* metaclass is a basic element for EPC process modeling. According to the ARIS documentation, the Function concept represents either a human task or a task performed on some object (hardware or software), with the purpose of achieving one or more business goals [32]. A function can be performed by either a person or an application system [32], and has inputs – such as information or raw material – and outputs, such as new information or products. Furthermore, functions can consume and create organizational resources during their execution [1]. The *carries out* meta-association between the *Participant* and *Function* elements indicates that one or more

participants of the business process will be responsible for performing the task. Due to space constraints we refer the reader to [30] for a full treatment of the *Event* and *Rule* metaclasses as well as the *is predecessor of, activates, creates* meta-associations. For the purposes of this paper, it is sufficient to assume that these modeling elements enable different types of specification of behavior.

An objective diagram "models a hierarchy of business *objectives* along with their *critical success factors* and the *Functions* and *Products* that support achievement of these objectives" [9]. According to the ARIS documentation, "a *product/service* is performed in the course of a value-added process. It is the result of a human act or a technical process. A product/service can represent either a service or a product" [10][32]. The *Critical Factor* metaclass represents the aspects which need to be considered in order to reach a particular objective [32] (and follows the Critical Success Factor definition by Rockart [28]).

The language has opted for modeling the relationship between goals (represented by the *Objective* metaclass) and *Functions* since the execution of functions can be seen as operations applied to objects for the purpose of supporting one or more goals [32]. This relationship is denominated as "*supports of*" relationship. Goals (*Objectives*) and their relationships are also modeled in this view. Goals can be linked with one another with a subordinate goal supporting several overriding goals (through the "*belongs to*" relationship).

3 ONTOLOGICAL FOUNDATIONS

In the sequel, we discuss a fragment of UFO in line with the purposes of this article. For a full discussion regarding this foundational ontology, one should refer to [17][15].

We start with the fundamental distinction between universals and individuals. The notion of universal underlies the most basic and widespread constructs in conceptual modeling. Universals are predicative terms that can possibly be applied to a multitude of individuals, capturing the general aspects of such individuals. Individuals are entities that exist instantiating a number of universals and possessing a unique identity.

Further, UFO makes a distinction between the concepts of Endurants and Events (also known as Perdurants). Endurants are individuals said to be wholly present whenever they are present, i.e., they are in time, in the sense that if we say that in circumstance c1 an endurant e has a property P1 and in circumstance c2 the property P2 (possibly incompatible with P1), it is the very same endurant e that we refer to in each of these situations. Examples of endurants are a house, a person, the moon, a hole, an amount of sand. For instance, we can say that an individual John weights 80kg at c1 but 68kg at c2. Nonetheless, we are in these two cases referring to the same individual John. Events (Perdurants), in contrast, are individuals composed by temporal parts, they happen in time in the sense that they extend in time accumulating temporal parts. An example of an Event is a business process. Whenever an Event occurs, it is not the case that all of its temporal parts also occur. For instance, if we consider a business process "Buy a product" at different time instants when it occurs, at each of these time instants only some of its temporal parts are occurring.

A Substantial is an Endurant that does not depend existentially on other Endurants, roughly corresponding to what is referred by the common sense term "Object". In contrast with Substantials, we have Moments (also known as particularized properties, objectified properties and Tropes). Moments are existentially dependent entities, i.e., for a Moment x to exist, another individual must exist, named is bearer. Examples of Substantials include a person, a house, a planet, and the Rolling Stones; examples of Moments include the electric charge in a conductor, a marriage, a covalent bond as well as mental states such as individual Beliefs, Desires and Intentions (or internal commitments). The last three examples fall in the subcategory of Mental Moments.

UFO also adds distinctions concerning the intentionality of events to this basic core. Examples include the concepts of Action, Action Universal, Intentional Participation and Agent.

Actions are intentional events, i.e., events which instantiate a Plan (Action Universal) with the specific purpose of satisfying (the propositional content of) some Intention of an Agent. The propositional content of an intention is termed a Goal. Only agents (entities capable of bearing intentional moments) can perform Actions. As events, actions can be atomic (Atomic Action) or complex (Complex Action). While an Atomic Action is an action event that is not composed by other action events, a Complex Action is a composition of at least two basic actions or Participations (that can themselves be atomic or complex).

Participations can themselves be intentional (i.e., Actions) or non-intentional Events. For example, the stabbing of Caesar by Brutus includes the intentional participation of Brutus and the non-intentional participation of the knife. In other words, we take that it is not the case that any participation of an agent is considered an action, but only those intentional participations called Intentional Participations. Figure 4 shows a fragment of UFO with emphasis on the events and intentional aspects.

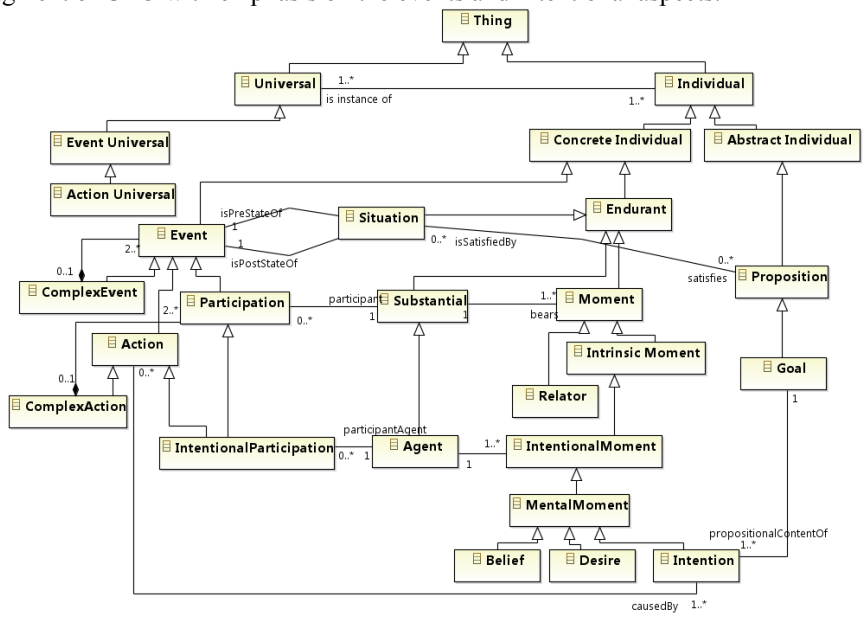

Figure 4. Fragment of UFO with events and intentional aspects.

The category of agents further specializes in Physical Agents (e.g., a person) and Social Agents (e.g., an organization, a society). In an analogous manner, objects can also be categorized as Physical Objects (e.g., cars, rocks and threes) or Social Objects (e.g., a currency, a language, the Brazilian constitution). Agents can also be further specialized into Human Agent, Artificial Agent and Institutional Agent, which can be represented, respectively, by human beings, computationally-based agents and organization or organizational unit (departments, areas and divisions). Institutional Agents are composed by a number of other agents, which can themselves be Human Agents, Artificial Agents or other Institutional Agents.

We should now briefly elaborate on what is meant by stating that "Institutional Agents are composed of other agents". An Institutional Agent exemplifies what is named a Functional Complex in [17], i.e., a mereologically complex entity whose parts play different roles with respect to the whole. By instantiating each of these roles defined in the characterization of that Functional Complex Universal, each part contributes in a different way to the integral behavior of the whole. In the case of a social functional complex such as an Institutional Agent, the characterization of the universal instantiated by that agent is made via what is termed in the literature a Normative Description [17].

Each Institutional Agent has a Normative Description associated to it. Moreover, this Institutional Agent defines a context in which a normative description is recognized. We can state then that Normative Descriptions are social objects that create social entities recognized in that context. Examples include Social Roles (e.g., president, manager, sales representative), Social Role Mixins (whose instances are played by entities of different kinds, e.g., customer, which can be played by persons and organizations), Social Agent Universals (e.g., a political party, an education institution), Social Agents (e.g., the Brazilian Labour Party, the University of Twente), Social Object Universals and other Social Objects (e.g., a piece of legislation, a currency) or other Normative Descriptions [1]. A Normative Description that defines social individuals in the context of an institutional agent is termed a Constitutive Normative Description.Figure 5 shows a fragment of UFO focusing on the social aspect.

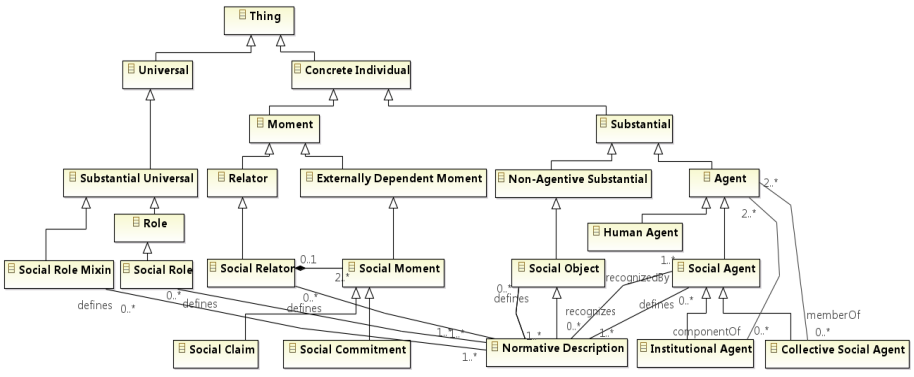

Figure 5. Fragment of UFO with the social aspect.

4 INTERPRETATION OF ARIS AND TROPOS

4.1 Ontological Analysis of the Tropos Metamodels

We start our ontological analysis with the fragment which considers the specializations of the metaclass *Actor* (the interpretation of this part of the metamodel is based on the interpretation discussed in [19]).

We interpret the metaclasses *Agent* and *Role* in Tropos as the concepts of Agent and Social Role in UFO (respectively). The metaclass *Position* is also interpreted as a Social Role. This interpretation is supported by the fact that Tropos positions are defined solely with the purpose of aggregating different roles. Since an agent role is defined by the set of social moment universals (commitments and claims implied by the role), an aggregation of roles is also a role in itself, i.e., a universal capturing a set of social moment universals [19]. The abstract metaclass *Actor* is introduced to capture general relations between *Agent*, *Roles*, *Positions* and other modeling elements and, thus, it has no specific interpretation in itself.

We interpret Tropos goals as Goals in UFO. Goals in UFO are sets of intended states of affairs of an agent. The relation between an Actor in Tropos and a Goal (through the meta-association *wants*) is interpreted indirectly by making use of the concept of Intention (or Internal Commitment) in UFO, which is a Mental Moment of an Agent. As previously discussed, UFO contemplates a relation between Situations and Goals such that a Situation (or possibly a number of Situations) may satisfy a Goal. In other words, since a Goal is a proposition (the propositional content of an Intention), we have that a particular state of affairs can be the truthmaker of that proposition. This interpretation choice seems to model directly the intention behind the concept of *hardgoal* in Tropos. For the case of *softgoals*, a different analysis must be conducted.

The concept of softgoals does not have a uniform treatment in the Tropos community. Sometimes, softgoals are taken to represent non-functional requirements [7]. In other times, a softgoal is considered as a fuzzy proposition, i.e., one which can be partially satisfied (or satisfied to a certain degree, or yet, *satisficed*) by Situations [14]. We here take a different stance, namely, that a softgoal is one "subjective to interpretation" and "context-specific".

As a consequence of this conception, for the case of softgoals, it seems to be impossible to eliminate a judging agent (collective or individual) from the loop. Thus, instead of considering in the ontology a new *satisfices* relation between Situation and Goal which perhaps should contemplate a fuzzy threshold of satisfaction, we take a different approach. We consider the relation of satisfaction as a ternary relation that can hold between an agent, a goal and situation. An instance of this relation is derived from the belief of an agent that *a particular situation satisfies the goal at hand*. Now, in this view, different agents can have different beliefs about which sets of situations satisfy a given goal. In fact, it is exactly this criterion which seems to capture the aforementioned notion of softgoals and its differentiae w.r.t. hardgoals: (i) a goal G is said to be a hardgoal iff the set of situations that satisfy that goal is necessarily shared by all rational agents; (ii) a goal G is said to be a softgoal iff it is possible that two rational agents X and Y differ in their beliefs to which situations satisfy that goal.

Seeing the distinction between these subcategories of goals under this light, allows us to talk about different levels of "softness" between different formulations of a goal. In one end of the spectrum, each individual agent would have a different belief about which situations satisfy a goal. In the opposite end, we have a hardgoal. In between, we can have communities of agents (or collective agents) of different sizes which share a common belief regarding this set of situations. In the last case, this collective agreement can be captured by a Normative Description.

The mapping of the Plan concept from Tropos to some UFO concept is established in a direct manner. In section 2.1, we stated that a Plan in Tropos is a specific way of doing something to satisfy some Goal (or *satisfacing* some Softgoal). From the UFO ontology (section 3), we have that an Action (instance of an Action Universal) is an intentional event performed by agents with the purpose of achieving goals. Consequently, the Tropos *Plan* construct can be interpreted as an Action Universal.

The metamodel includes a relation of *means-end* between a Plan and a Goal. We call attention to the *point of view* relation in the metamodel of Figure.2. As one can observe, in the Tropos metamodel, the means-end relation is a ternary relation indexed to an Agent's (subjective) point of view. The form of this relation in the metamodel seems to corroborate our interpretation of goals just discussed. Thus, in general, the *means-end* relation between a *Plan* and a *Goal* can be interpreted in the following manner: a *Plan* P is a *means-end* to a *Goal* G in the point of view of *Agent* A iff one or more executions of that *Plan* produce a post-situation which A believes to satisfy G.

The concept of *Resource* has been interpreted as a resource in UFO, i.e., as a Non-agentive Substantial (or Object) which participates in a Complex Action. The relation of *means-end* can also be defined between a Resource type, a Plan and an Agent, or between a Resource type, a Goal and an Agent. The former mode of this relation can be interpreted as follows: a Resource type R is a means-end to a Goal G in the point of view of Agent A iff every Action which satisfies that Goal (according to A) has as part a participation of a resource of that type. In contrast, the means-end relation between Resource type and Plan should be interpreted as: a Resource type is a means-end to a Plan iff every Action instance of that Plan has as part a participation of a resource of that type. Now, notice that the latter rendering of relation is actually Agent-independent! If a Plan is taken to be an Action universal, this relation reflects the structure of Plan and not the belief of a particular agent regarding the structure of a Plan. In (apparent) opposition to this idea, one could argue that a Plan should not then be interpreted as an Action universal but as an Intention to execute a particular Action universal. Even if this view is taken, the correct alternative interpretation would be that a Plan is an intention to instantiate a particular specialization of that Action Universal in which resources of that type are essential participants. Still, this would only refine the reference to a particular subtype of that Action universal. The participation of that resource in instances of that (now more specific) Action universal would still reflect the structure of those actions, not an Agent's subjective point of view.

In Tropos, goals can be further structured by using different types of relations, namely, AND-decomposition and OR-decomposition. Since Goals are taken here to be propositions, if we have that goals $G_1 \ldots G_n$ AND-decompose goal G_0, this relation

should be interpreted as: ($G_0 \leftrightarrow (G_1 \wedge G_2 \wedge \ldots \wedge G_n)$). In an analogous manner, and OR-decomposition $G_1 \ldots G_n$ of goal G_0 should be interpreted as: ($G_0 \leftrightarrow (G_1 \vee G_2 \vee \ldots \vee G_n)$). Here once more, these relations reflect logical relations between propositions and, accordingly, are independent of an Agent's point of view (contra Figure.2).

We have offered an ontological analysis of the relation of Dependency in Tropos elsewhere [40]. In that paper, we show that Tropos overloads in the same construct the two different (ontological) relations of Dependency and Delegation, which constitutes another case of construct overload in the language. As discussed in depth there, these relations belong to different ontological categories: whilst the former is an example of a formal relation, the latter is one a material relation. To put it baldly, agent X *depends on* agent Y for goal G iff G is a goal of X, X cannot achieve G, and Y can achieve G. Notice that in this case, agents X and Y do not even have to be aware of this dependency. In contrast, if agent X delegates goal G to agent Y then: there is a social commitment c from Y to X; G is the propositional content of c.

Finally, Tropos includes a relation of *contribution* that can be defined between a hardgoal and a softgoal, or between a plan and a softgoal. The idea is that a hard-goal or plan can positively or negatively *"contribute to"* a soft-goal. Since soft-goals involve subjective judgments of agents, the relation of contribution must be agent-indexed. Thus, one should not state that *G' contributes positively to G"* but that *Agent X believes that G' contributes positively to G*. One should notice that the Tropos metamodel (Fig.2) takes this relation as a ternary one indexed to an Agent's point of view. Further, the contribution relation can be used between a Resource and a Goal, in the sense that the Resource is a *means* to a plan that the Agent believes that contributes positively to the Goal. A fuller interpretation of this relation requires an elaboration of the propositional content of beliefs, which is outside the scope of this paper.

4.2 Ontological Analysis of the ARIS Metamodels[2]

According to [18] and [33], a business process can be defined as a collection of interrelated organizational tasks, initiated in a response to an event, which aim at achieving one or more organizational goals. In other words, a business process describes a type of organizational task that must be performed to achieve one or more organizational goals. Since EPCs are used for business process modeling, we can say that, collectively, the elements of an EPC diagram can be interpreted as a Complex Action Universal of UFO [15]. According to [16][32], a *Function* can be defined in several abstraction and refinement levels. Therefore, in [30] the *Function* element was interpreted as Action Universal.

[2] This is part of our larger effort in the ontological analysis of the ARIS method. We focus here on the elements which are most relevant for the relations between ARIS Objective Diagrams, Organizational Charts and EPCs. For further information on the ontological analysis of ARIS EPCs, please refer to [30], and for further information on the ontological analysis of the organizational elements please refer to [31]. These works also discuss the relation between our approach to ontological analysis and that of Green and Rosemann [13] who have performed ontological analysis of ARIS in terms of the BWW ontology (not addressing the intentional aspects).

Since organizational units can be decomposed recursively into smaller organizational units [32], we interpret the *Organizational Unit* metaclass representing a particular kind of substantial, namely, an Institutional Agent. Similarly, the *Organization Unit Type* metaclass has been interpreted as an Institutional Agent Universal. The *Position* metaclass does not represent an organization unit, but a Social Role instantiated by a Human Agent (*Person*) [1].

Person Type is an element to represent a type which can be instantiated by different entities (persons, and, despite the name suggesting the contrary, organizational units). Thus, the *Person Type* element has been interpreted as a Social Role, Social Role Mixin or a Social Mixin. It is often used in the scope of a business process to avoid tying specific agents to business processes, differently from *Position* which is a social role defined in the organizational structure.

The *Group* metaclass can be interpreted as a Collective Social Agent or as an Institutional Agent. The first interpretation occurs when *Group* represents a collection of agents playing the same role. An example of this situation occurs when we model a parliamentary inquiry committee in which all congressmen play the same role.The second interpretation occurs when *Group* represents a collection of agents each of which with a different role in this collection [17]. An example of this situation occurs when we model a parliamentary inquiry committee in which some of the congressmen play different roles, for example, if one of them is the chairman of the committee.

The *Objective* element is used to represent a business objective associated with a business process (*Function*) or business product/service (*Product/Service*). While the element's name would suggest a correspondence to the Goal concept in UFO, this interpretation is far from trivial. This is because UFO Goals are necessarily associated with a particular Agent (they are the propositional content of an agent's intention). A viable interpretation is that the (Institutional) Agent which has the Goal is the owner of the business process (*Function*) which *supports* the *Objective* such as, for instance, the Organization (Unit) which (partial) behavior is described by that process universals or, alternatively, a Social Role within an organizational structure which contains that behavior specification as part of its definition. This notion of "owner", however, is not directly modeled in ARIS, although it is implied by Scheer [32] when referring to "corporate goals", which are necessarily present at an organization whenever a business process exists.

The *belongs to* relation between *Objectives* defies a precise definition, since it may refer to a number of different relations, not distinguishing conjunctions or disjunctions of propositions. Further, there is very little explanation in the ARIS literature concerning the role of *Product/Service* in an ARIS objective diagram. Thus, we will refrain from providing a complete interpretation here; instead of adopting the relations in the ARIS Object Diagram metamodel, we will use the richer relations between Tropos *Goals, Agents, Plans* and *Resources* as discussed in the next section.

Having clarified the semantics of the modeling constructs through interpretation in terms of UFO, we establish the correspondence between the constructs in each of the identified fragments of Tropos and ARIS in Table 1.

Table 1. Interpretation ARIS and Tropos.

Tropos	Ontological concept (from UFO)	ARIS
Agent	Agent	*Person*
	Institutional Agent	*Organization Unit* and *Group*
	Collective Social Agent	*Group*
Role or Position	Social Role	*Position* and *Person Type*
Goal	Goal	*Objectives*
HardGoal	A Goal such that the set of situations that satisfy that goal is necessarily shared by all rational agents;	
SoftGoal	A Goal such that Agents can differ in their beliefs to which situations satisfy it.	
Plan	Action Universal	*Function*
Resource	Non-Agentive Substantial	*Product/Service*
Dependency	Dependency or Delegation	N/A
Means-ends (Plan and *Goal)*	One or more executions of that Plan produce a post-situation that satisfies the Goal.	Included in the scope of *supports* relation between *Function* and *Objective*
Means-ends (Resource and *Goals)*	Every Action which satisfies that Goal has as part a participation of a Resource of that type	Included in the scope of *supports* relation between *Product/Service* and *Objective*
Means-ends (Resource and *Plan)*	Every Action instance of the Plan has as part a participation of a Resource of that type.	Included in the scope of *input for* and *is consumed by* relationship between *Product/Service* and *Function*
Negative Contribution (Plan, SoftGoal)	Agent believes that an execution of the Plan contributes negatively to Goal	N/A
Positive Contribution (Plan, SoftGoal)	Agent believes that an execution of the Plan contributes positively to Goal	Included in the scope of *supports* relation between *Function* and *Objective*
Negative Contribution (Resource, SoftGoal)	The Resource is a means to a Plan that the Agent believes contributes negatively to Goal	N/A
Positive Contribution (Resource, SoftGoal)	The Resource is a means to a Plan that the Agent believes contributes positively to Goal	Included in the scope of *supports* relation between *Product/Service* and *Objective*
Negative Contribution (Goal G1, SoftGoal G2)	Agent believes that the Goal G1 contributes negatively to Goal G2	N/A
Positive Contribution (Goal G1, SoftGoal G2)	Agent believes that the Goal G1 contributes positively to Goal G2	Included in the scope of *belongs* relation between Objectives
AND decomposition	The propositional content of the composed Goal is the conjunction of the component Goals	
OR decomposition	The propositional content of the composed Goals is the disjunction of the component Goals	

5 CONCLUSIONS AND FUTURE WORK

Although Zachman's framework has recognized the importance of the goal domain in its "motivation" column, Zachman did not define basic concepts for this column, justifying that "there is a scarcity of good examples in the people, time, and motivation columns" and stating that "the *why* column would be comprised of the descriptive representations that depict the motivation of the enterprise, and the basic columnar model would likely be ends-means-ends, where ends are objectives (or goals) and means are strategies (or methods)" [34]. So far (18 years later), few comprehensive enterprise modeling approach have addressed the why column (see, e.g., the work described in [38] on the integration of CIMOSA, i* and Albert II, and the recent ARMOR extensions of ArchiMate [27]). Further, most approaches can be criticized for their lack of expressiveness with respect to the strategic dimension, while some can be criticized for having poor (or no) semantic underpinnings.

This work has contributed towards filling this gap by proposing a semantic integration between the Tropos goal modeling language and the ARIS framework. As an outcome of the semantic analysis, we were able to provide a correspondence between subsets of these languages, in addition to clarifying the semantics of the main goal-related constructs of these languages. We have concluded that the relations between goals and between the goal domain and the business process domains as currently addressed in the ARIS method are overly simplistic and have opted to employ the Tropos concepts to address this deficiency. The use of the ontology has influenced heavily the definition of correspondences between the elements of both approaches and also has revealed a significant difference in the notions of *Objective* (ARIS) and *Goal* (Tropos), and their relations with respect to *Functions* (ARIS) and *Agents* (Tropos). Further, we have been able to provide an initial account for the notions of hard- and softgoals as well as for the relations between goals.

While we have addressed semantic integration, an issue for further investigation concerns integration at the abstract syntax level with the development of an integrated Tropos+ARIS meta-model. This requires the development of prescriptive modeling guidelines to be followed when using (in tandem) goal models in Tropos and business process models in ARIS EPCs. Tool support for this integrated metamodel would enable one to assess how changes in a process model impact respective goals or alternatively, how changes in business goals are reflected at the operational level.

As future work, we intend to analyze the ARMOR language which extends ArchiMate with i*/Tropos concepts [27]. We also intend to enrich the semantic foundation with other goal relations to provide a precise account for the notion of goal conflicts. We will address the relations between goals and other elements of an enterprise architecture which are currently not covered in Tropos (nor ARMOR). In a case study that we have conducted at a Hospital (in which Tropos and ARIS have been used in tandem), we have concluded that goals have complex relations with a number of domains in enterprise modeling beyond the business process and resource aspects as addressed in Tropos [6]. For example, there are relations between goals and organizational norms (business rules, business policies as identified in the Business Motivation Model (BMM)), goals and the organizational structure, goals and agent's skills/capabilities, goals and agent's beliefs, goals and properties of resources, etc.

REFERENCES

1. Almeida, J. P. A., Guizzardi, G., Santos, P. S., Applying and Extending a Semantic Foundation for Role-Related Concepts in Enterprise Modelling, Enterprise Information Systems, v3, pp. 253-277 (2009)
2. Andersson, B., Bergholtz, M., Edirisuriya, A., Ilayperuma, T., Johannesson, P., Zdravkovic, J., Using Strategic Goal Analysis for Enhancing Value-based Business Models. Andersson, 2th International Workshop on Business/IT Alignment and Interoperability (BUSITAL'07). Workshop at CAiSE'07 (2007)
3. Bottazzi, E. and Ferrario, R., Preliminaries to a DOLCE Ontology of Organizations, Int'l Journal of Business Process Integration and Management, Vol. 1, pp.64–74 (2006)
4. Bresciani, P. and Sannicolo, F., Requirements Analysis in Tropos: a self referencing example. Technical Report DIT-02-105, University of Trento (2002)
5. Bresciani, P., Perini, A., Giorgini, P., Giunchiglia, F., Mylopoulos, J., Tropos: An Agent-Oriented Software Development Methodology, Autonomous Agents and Multi-Agent Systems (2004)
6. Cardoso, E.C.S., On the Alignment between Goals Models and Enterprise Models with an Ontological Account, Master Thesis, Federal University of Espírito Santo, Brazil (2009) (http://nemo.inf.ufes.br/ecardoso)
7. Chung, L., Nixon, B., Yu, E. and Mylopoulos, J., Non-functional requirements in software engineering. Kluwer Academic Publishers (2000)
8. Davenport, T., Process Innovation: Reengineering work through Information Technology. Harvard Business School (1992)
9. Davis, R., Brabander, E., ARIS Design Platform – Advanced Process Modelling and Administration, Springer-Verlag (2008)
10. Davis, R., Business Process Modeling with ARIS - A Pratical Guide, Springer (2001)
11. Eclipse Foundation "Eclipse Modeling - EMF - Home", http://www.eclipse.org/modeling/emf/ (2008)
12. Giorgini, P., Mylopoulos, J., Perini, A., Susi, A., The Tropos Metamodel and its Use, Informatical journal (2005)
13. Green, P., Rosemann, M., Integrated process modeling: An ontological evaluation, Information Systems, Volume 25, Issue 2, Elsevier, pp. 73-87 (2000)
14. Guizzardi, G. and Wagner, G., On A Unified Foundational Ontology and some Applications of it in Business Modeling, In 16th International Conference on Advances in Information Systems Engineering (Latvia), CAiSE 2004, Open INTEROP Workshop on Enterprise Modelling and Ontologies for Interoperability (2004)
15. Guizzardi, G., Falbo, R. A., and Guizzardi, R. S. S., Grounding Software Domain Ontologies in the Unified Foundational Ontology (UFO): The case of the ODE Software Process Ontology, In XI Iberoamerican Workshop on Requirements Engineering and Software Environments (IDEAS'2008), Brazil (2008)
16. Guizzardi, G., Ferreira Pires, L., and Van Sinderen, M., An Ontology-Based Approach for Evaluating the Domain Appropriateness and Comprehensibility Appropriateness of Modeling Languages, In ACM/IEEE 8th Int'l Conf. on Model Driven Engineering Languages and Systems, Lecture Notes in Computer Science Vol. 3713. Springer (2005)
17. Guizzardi, G., Ontological Foundations for Structural Conceptual Models, Ph.D. Thesis, CTIT PhD-thesis, University of Twente, The Netherlands (2005)
18. Guizzardi, R,, Guizzardi, G., Perini, A., Mylopoulos, J., Towards an Ontological Account of Agent Oriented Goals. Software Engineering for Multi-Agent Systems 5, Springer (2007)
19. Guizzardi, R., Agent-oriented Constructivist Knowledge Management. PhD Thesis, Twente University, The Netherlands (2006)

20. Halleux, P., Mathieu, L., Andersson, B., A Method to Support the Alignment of Business Models and Goal Models, In Proc. 3rd Workshop on Business/IT-Alignment and Interoperability (BUSITAL'08), CEUR Workshop Proceedings, Vol. 336 (2008)
21. Hammer, M., Reengineering Work: Don't Automate, Obliterate, Harvard Business Review (1990)
22. Harrington, H. J., Business Process Improvement: The Breakthrough Strategy for Total Quality, Productivity and Competetiveness. MacGraw-Hill, New York (1991)
23. Jonkers, H. et al, Concepts for Modelling Enterprise Architectures. International Journal of Cooperative Information Systems (2004)
24. Jureta, I. J., Faulkner, S., Schobbens P. Y., A More Expressive Softgoal Conceptualization for Quality Requirements Analysis, In Conceptual Modeling - ER, 25th International Conference on Conceptual Modeling, Arizona (2006)
25. Letier, E., van Laamsweerde, A Reasoning about Partial Goal Satisfaction for Requirements and Design Engineering, ACM SIGSOFT SEN. Vol. 29, Issue 6 (2004)
26. Mylopoulos, J., Chung, L., Yu, E., Nixon, B., Representing and Using Non-functional Requirements: A Process-Oriented Approach, IEEE Trans. on Software Engineering, 18(6), pp. 483- 497 (1992)
27. Quartel, D., Engelsman, W. and Jonkers, H., A Goal-Oriented Requirements Modelling Language for Enterprise Architecture. Proceedings of the 13th IEEE International Enterprise Distributed Object Computing Conference, EDOC 2009, New Zealand (2009)
28. Rockart J., Chief executives define their own data needs, Harvard Business Review, 57(2), pp 81-93 http://www.ncbi.nlm.nih.gov/pubmed/10297607 (1979)
29. Santos Jr., P. S., Almeida, J. P. A., and Pianissolla, T. L., Uncovering the Organizational Modelling and Business Process Modelling Languages in the ARIS Method, International Journal of Business Process Integration and Management (IJBPIM), in press
30. Santos Jr., P. S., Almeida, J. P. A., Guizzardi, G., An Ontology-Based Semantic Foundation for ARIS EPCs, In: 25th ACM Symposium on Applied Computing (Enterprise Engineering Track), Switzerland (2010)
31. Santos Jr., P. S., Almeida, J. P. A. and Guizzardi, G., An Ontology-Based Semantic Foundation for Organizational Structure Modeling in the ARIS Method, In: 5th International Workshop on Vocabularies, Ontologies and Rules for The Enterprise (VORTE) (at EDOC 2010), IEEE Computer Society (2010).
32. Scheer, A.W., ARIS – Business Process Modeling. Third Edition. Springer (1999)
33. Sharp, A. and McDermott, P., Workflow Modeling-Tools for Process Improvement and Application Development. Artech House (2001)
34. Sowa, F., Zachman, J., Extending and formalizing the framework for information systems architecture, IBM Systems Journal, v.31, p 590-616 (1992)
35. Yu, E., Modelling Strategic Relationships for Process Reengineering, PhD Thesis, University of Toronto, Canada (1995)
36. Yu, E., Strohmaier, M. and Deng, X., Exploring Intentional Modeling and Analysis for Enterprise Architecture, In Proc. EDOC 2006 Conference Workshop on Trends in Enterprise Architecture Research (TEAR 2006). IEEE Computer Society (2006)
37. Zachman, J., A Framework for Information Systems Architecture, IBM Systems Journal. pp. 276-292 (1987)
38. Petit, M., Formal Requirements Engineering of Manufacturing Systems: A Multi-Formalism and Component-Based Approach, PhD Thesis, University of Namur, Belgium (1999).