Ontological Analysis of Means-End Links

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Abstract. The *i** community has raised several main dialects and dozens of variations in the definition of the *i** language. Differences may be found related not just to the representation of new concepts but to the very core of the *i** language. In previous work we have tackled this issue mainly from a syntactic point of view, using metamodels and syntactic-based model interoperability frameworks. In this paper, we go one step beyond and consider the use of foundational ontologies in general, and UFO in particular, as a way to clarify the meaning of core *i** constructs and as the basis to propose a normative definition. We focus here on one of the most characteristics *i** constructs, namely means-end links.

Keywords: *i**, iStar, means-end links, fundational ontologies, UFO.

1 Introduction

Throughout the years, different research groups have proposed variations to the modelling language proposed in the *i** framework (from now on "the *i** language") [1][2]. Some come from paradigm shifts, others propose some particular type of new construct, and still others issue slight modifications related to the core constructs of the *i** language. This third type of variations mainly appear because the definition of the *i** language is neither fully detailed nor formal, and researchers may have interpreted the same constructs in different ways. The absence of a universally agreed metamodel has accentuated this effect [3].

There are two possible positions. One may argue that due to the social intention behind *i** modelling, a certain degree of freedom is convenient and then these slight changes should be acceptable. On the contrary, a more strict position is to consider necessary the existence of a shared body of knowledge on *i** with a well-defined meaning. In this paper, we align with the second option: our position is that those concepts that form the core of the *i** language shall be well-defined and agreed by the community. This is important to allow a uniform and consistent use of the language,

in a way that the community members are able to understand and communicate well through their models. Moreover, if it is a community objective that *i** gains industrial acceptance, then it is necessary to provide one interpretation of its core concepts.

There may be some discussion about where the boundaries of the *i** language core are, but some constructs like actors, goals and means-end links, to name a few, seem out of discussion. In this paper, we are interested in the analysis of means-end links. Therefore, we search for a proposal that may serve as basis for a community agreement about what a means-end link exactly is. Agreement shall be first at the syntactic level by referencing to some *i** metamodel (e.g., which type of intentional element may be involved in a particular context). But syntax is not enough, still different modelers may interpret syntactic-equivalent models in different ways. We need a deeper understanding of the meaning of means-end link. In this paper, we propose the use of the UFO foundational ontology [4].

With respect to the analysis and (re)design of conceptual modeling languages (i.e. the focus of this particular paper), we must understand ontology as in conceptual modeling, i.e. as a theoretical body of knowledge or foundation (that is why we call it foundational ontology). We propose the use of a foundational ontology as a reference model to which the concepts of the metamodel of an existing modeling language must be mapped into. This approach enables the evaluation of the modeling language, which can further lead to re-design. In other words, UFO is employed here as a well-founded basis for (1) making explicit the ontological commitments of each modeling language; (2) defining (ontological) real-world semantics for their underlying concepts; and (3) providing guidelines for the correct use of these concepts. The adequacy of this ontology for our purposes lies on the fact that UFO includes the concepts that are relevant (i.e. may serve as interpretation) to analyse the *i** framework. In fact, previous works have already analysed some of the concepts of Tropos with the purpose of mapping its metamodel into the metamodel of other modeling languages, namely AORML [5] and ARIS [6]. More about how UFO has been developed may be found in [4][7][8].

2 Objectives of the Research

The general objective of our long-term joint research is to provide an ontological foundation to the *i** language core. In this paper, as a proof-of-concept, we focus on one particular *i** construct that lies in the heart of the language: the means-end link (ME-link). Even thought it may seem that it is not a much controversial construct, it already poses some questions that have not a clear response. Thus, it is a good case as proof of concept of our work. The general objective of understanding the **meaning of a ME-link** can be refined into a series of more concrete research questions:

- Which *i** intentional elements may appear as means and as end of an ME-link?
- Which ontological properties must these elements fulfil?
- Which conditions must be verified to establish an ME-link among two elements?
- Which relationships do exist with other types of links?
- Which are the implications of an ME-link established in one actor A, over another actor B, such that an actor link from B to A is established?

3 Scientific Contributions

3.1 State of the Art on the use of Means-end Links

Different *i** variants/approaches/dialects [9], whilst respecting the main idea of the ME-link as "a means to attain an end", state their own (if any) restrictions (see Table 1). In his seminal proposal, Yu stated about ME-links: "the end can be a goal, task, resource or softgoal, whereas the means is *usually* a task". The term "usually" was dropped in the evolution of this variant, the *i** wiki version, where not just the means were completely restricted to tasks (i.e., not *usually* but *always*) but also the end was restricted to goals. The guidelines in the wiki state that other types of links are available for different combinations of intentional element's types. Whilst being clear in terms of what types are permitted, this definition is very restrictive.

Another issue to remark is the relationship to the concept of "OR-decomposition". The concept of ME-link is close to that of OR-decomposition, in the sense that the source elements of the link (either "means" or "sub-elements") are interpreted in a kind of logical OR relationship with respect to the target. In fact, several proposals seem to not distinguish these two concepts, e.g. GRL has eliminated means-end links and just OR-decomposition (in addition to AND- and XOR-decomposition) is offered. On the contrary, some Tropos definitions are using both constructs in its language, like in the following quotations: "in an OR decomposition the sub-goals represent alternative ways to achieve the root goal", and "the means/end relationship specifies a means (in terms of a goal, a plan or a resource) to satisfy the goal"; whilst others Tropos' papers are closer to the classical Yu's proposal or even whilst providing both constructs, it is not clear which is the real difference.

It is also worth to remark that existing works do not seem to address much the relationship between ME-links and actor links. In our ongoing work analysing the meaning of the is-a actor link (follow-up of our previous work in [10]), we have mainly investigated if new means can be added to an end that is inherited in a subactor. To do so, a question need to be answered: is a means-end relation always complete, is it always incomplete, or if none of the former, is it possible to distinguish an incomplete relation from a complete one?

Last, a final issue is whether the means for an end are to be considered exclusive or not (XOR vs. OR). For instance, Yu's thesis does not explicitly state this interpretation, but from the examples the means seem to be always exclusive. Just one analysed proposal (GRL) allows explicitly declaring the type of logical operator, but we remind that GRL is not distinguishing among ME-links and OR-/XOR-decompositions.

Approach	Link	Intentional types (means->end)	OR/XOR/not stated
Yu's thesis	Means-end link	(usually) T -> G | SG | T | R	Not stated
*i** wiki	Means-end link	T -> G	Not stated
Tropos	Means-end link	G | T | R -> G	Not stated
	OR-decomposition	G -> G	Not stated
GRL	OR-decomposition	G | SG | T | R -> G | SG | T | R	Explicitly declared

Figure 1. Summary of the state of the art.

3.2 Means-end Links from an Ontological Point of View

Before analysing *i** ME-links, it is important to provide an ontological view of the language intentional elements. Reading this section requires some basic knowledge about UFO [4][7].

We interpret the *i* Agent* and *Role* as the concepts of Agent and Social Role in UFO (respectively). *Position* is also interpreted as a complex Social Role, since this *i** concept is defined solely with the purpose of aggregating different roles. The abstract *Actor* concept only captures general relations between *Agent*, *Roles*, *Positions* and other modeling elements and, thus, it has no specific interpretation in itself.

We interpret *i* Goals* as Goals in UFO. Goals in UFO are sets of intended states of affairs of an agent. The relationship between an *Agent* in *i** and a *Goal* 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.

The concept of *Softgoal* does not have a uniform treatment in the *i** community. Sometimes, softgoals are taken to represent non-functional requirements. In other places, 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 [5]. We here take a different stance, namely, that a *Softgoal* is one "subjective to interpretation" and "context-specific". Hence, for 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.

The mapping of the *Task* concept from *i** to some UFO concept is established in a direct manner. *Task* in *i** is a specific way of doing something to satisfy some *Goal* (or satisfacing some *Softgoal*). From the UFO ontology, 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 *i* Task* construct can be interpreted as an Action Universal.

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. A Complex Action is a composition of at least two basic Actions or Participations. Participations can themselves be intentional (i.e., Actions) or non-intentional Events.

3.2.1. Ontological Analysis of the *i** Means-end Relation

We first analyse *ME-links* between a *Task* and a *Goal*. In *i**, the *ME-link* is a ternary relation indexed to an *Agent*'s (subjective) point of view. However, as stated above, we consider in UFO that all agents have a consensual opinion regarding the satisfaction of a hardgoal. In this sense, we can exclude the agent's point of view from the definition of this *ME-link*, simply interpreting it as: a Task T is a means to a Goal G (G being the end) iff one or more executions of T (i.e., action instances of type T) produce a post-situation which satisfies G.

Similarly, the *ME-link* can also be defined between a *Resource* type and a *Task*, or between a *Resource* type and a *Goal*. The former mode of this relation can be interpreted as follows: a Resource type R is a means to a Goal G (G being end) iff every Action which satisfies that Goal has as part a Participation of a Resource of that type. In contrast, the *ME-link* between a *Resource* and a *Task* should be interpreted as: a Resource type is a means to a Task (end) iff every Action instance of that Task has as part a Participation of a Resource of that type.

In the case of a *Softgoal*, we should in fact consider the perspective (i.e. belief) of a particular agent, since its satisfaction set is not a consensus. Thus, we define the ME-link between a *Task* and a *Softgoal* as follows: a Task T is a means to a Softgoal S (S being the end) in the point of view of Agent A iff one or more executions of T produce a post-situation which A believes to satisfy S.

3.2.2. Resolving the Dispute Regarding Means-end and OR-decomposition

As already mentioned in section 3.1, the *i** dialects do not agree on the use of the ME-link and the OR-decomposition. Having two distinct relations that model the same phenomenon in the world is usually not a good practice, because, in general, the modeler will attempt to ascribe different meanings to each of them, or else randomly chose one or another when modeling such phenomenon. Thus, we believe it is in the interest of the *i** community to reach an agreement, having one uniform view in this regard. In this paper, instead of taking a stand, we prefer to present two possibilities to be debated with other *i** community members.

A first option (Fig. 2, left) is having only one relation, namely the ME-link, excluding the OR-decomposition from the *i** core. This option favors a cleaner language, which may lead to a simpler use of the framework. In this case, the ontological definitions in section 3.2.2 are applied, along with the following: i) Goal G2 is a means to a Goal G1 iff satisfying G2 produces a post-situation that satisfies G1, and ii) Task T2 is a means to a Task T1 iff executing an Action instance of T2 causes the execution of an Action instance of T1.

A second option (Fig. 2, right) is having both ME-link and OR-decomposition relations as part of the *i** core. Although leading to a more complex language, one can argue that this may add expressivity. In this case, the ontological definitions in section 3.2.1 are applied if we consider means and ends of **distinct types**. Among intentional elements of the **same type** we consider OR-decomposition only, e.g. an OR-decomposition of goal G_0 into subgoals $G_1 \ldots G_n$ should be interpreted as: $(G_0 \leftrightarrow (G_1 \vee G_2 \vee \ldots \vee G_n))$. Thus, these relations reflect logical relations between propositions.

		End			
Means		T	R	G	SG
	T	ME	---	ME	---
	R	ME	---	ME	---
	G	---	---	ME	---
	SG	ME	ME	---	---

	End			
	T	R	G	SG
T	Or-D	---	ME	---
R	ME	---	ME	---
G	---	---	Or-D	---
SG	---	---	---	Or-D

Figure 2. Two tables summaring the two options considered in this section.

4 Conclusions

In this paper, the ontological underpinnings of the means-end link have been analysed and two different positions for further discussion, identified. We think that this is a first step of a long-term goal about providing an ontological foundation to the *i** language core with the aim of obtaining a shared definition of that core fostering standardization and thus eventually boosting industrial adoption.

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