Using a Foundational Ontology to Investigate the Semantics Behind the Concepts of the *i** Language

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Abstract. In the past few years, the community that develops *i** has become aware of the problem of having so many variants, since it makes it difficult for newcomers to learn how to use the language and even to experts to efficiently exchange knowledge and disseminate their proposals. Moreover, this problem also delays the transfer of the *i** framework to industrial settings. Our work is one of the current attempts to promote interoperability among the existing variants, and it does that by investigating the semantics behind the *i** core concepts. For that, we apply a foundational ontology named UFO, which is used as a semantically coherent reference model to which the language should be isomorphic. In this paper, we report on the steps we have pursued, what we have accomplished so far, also setting the context for the work ahead.

Keywords: iStar, language interoperability, semantics, foundational ontology, UFO

1 Introduction

Nowadays, the community that develops *i** is relatively big and these developers, who are geographically dispersed, tend to ascribe different (and sometimes conflicting) meanings to its constructs. It is argued that this flexibility is part of the framework's own nature, and in fact may be considered one of its key success features. But on the other hand, it is our belief that this represents a clear risk in terms of promoting the framework, creating serious issues, such as: a) hampering the efficient communication of knowledge among experts of the community [1]; b) increasing the learning curve of newcomers; and c) inhibiting the adoption of the framework by practitioners. We refer to [1][2][3] for a more detailed state of the art on the different uses and ascribed semantics of the *i** language constructs.

In the past few years, the community has become aware of this problem and several attempts have been made for facilitating the access and uniform use of the *i** language. One of these initiatives is the creation of a common repository and collaborative environment, namely the *i** wiki (http://istar.rwth-aachen.de/tiki-view_articles.php). In particular, there is a session in the wiki called *Guidelines*, aimed at collecting and making explicit the different approaches to the language. Works on metamodeling have also tried to make it clear the meaning ascribed to the distinct constructs [3][4]. Although we recognize there are significant outcomes of these works (e.g. pointing out the applied concepts in particular variations; showing the author's view on how concepts relate), these attempts did not quite succeed in providing interoperability, simply because metamodels are powerful structures to define a language's syntax while being very limited in terms of clarifying its semantics. Cares [5] has proposed an interoperability method that considers a supermetamodel [6], which facilitates the translation from an *i** variant to another, and an XML-based mark-up language, named iStarML [7], which triggers existing tools to interoperate as much as their underlying metamodel allows. This approach has advanced the state of the art, by providing a standard interoperability format that facilitates model translation, but we are afraid that iStarML only makes syntactic checks, leaving the semantic interoperability issues still untouched.

Going beyond syntactic issues, since 2006, we are involved in an attempt to define a common ontology for the core concepts of the *i** language. We believe this may assist in clarifying the semantics of the language's concepts, thus generating a number of modeling guidelines targeted at enhancing the language's usability. We do this by applying the UFO foundational ontology as a reference model and our approach prescribes that the *i** metamodel reflects such model [8]. For that, at times, we propose some of the *i** constructs may be left aside, as they have the same semantics, thus being excessive in the language [9]. To diminish ambiguity, other times, we perform some language extensions, avoiding a single concept to be overloaded with two or more different semantics. However we attempt to do that with extra care, as it is undesirable to end up with a language with too many constructs as it would require even more effort to be learned and used.

This paper reports on what we have accomplished so far and also presents what lies ahead of us. For that, the remainder of the paper is structured in three sections besides this introduction: section 2 presents the objectives and methodology of our research, also pointing at which stage we currently are; section 3 describes the main contributions and challenges involved in this initiative; section 4 discusses some conclusions and presents our future research agenda.

2 Objectives and Methodology

The general objective of our long-term joint research is to provide an ontological foundation to the *i** language core. In the current research stage, we are clarifying the semantics of *i** intentional element links: means-end, decomposition and contribution. In this context, it is necessary not only to determine accurately the meaning of these constructs, but also to provide methodological advice on their use, since in some cases differences may be a bit subtle. To sum up, the general objective of understanding the **meaning of *i** intentional element links** can be refined into a series of more concrete research questions: 1) For every type of intentional element link: Which are the logical conditions and implications of a link established from an intentional element to another? 2) In particular, which *i** intentional elements may appear as root and target of such an intentional element link? 3) Which ontological properties must these elements fulfil? 4) Which are the methodological guidelines that drive to the application of a particular type of intentional element link? 5) What is the modeler's agreement on the aspects above? The rest of the paper reports the current results obtained so far and outlines the most immediate future work in relation to these research questions.

3 Scientific Contributions and Challenges

Our work has started with the semantics analysis of the core *i** intentional elements, such as ***actor, goal, task*** and ***resource***[1]. The results of this analysis are reported in [9]. This initial analysis has also taken into consideration the concepts of ***agent, role*** and ***position***, along with the ***dependence*** relation. More recently, our attempts shifted to the remaining relations of the language. In [8][10], we propose some modeling guidelines for the means-end link and OR-decomposition, based on UFO's semantic interpretation. According to UFO, a `goal` is the `propositional content` of an `agent's intention`. Thus, ontologically, a ***goal*** is in itself a *proposition* and ***decomposition relations*** reflect logical relations between propositions. Table 1 formally describe the And and OR decomposition of goal G in four subgoals G1-G4

Table 1. Formal Description of And and OR-decomposition according to UFO

AND-decomposition	$G \leftrightarrow G1 \wedge \mathrm{G2} \wedge G3 \wedge G4$
OR-decomposition	$G \leftrightarrow G1 \vee \mathrm{G2} \vee G3 \vee G4$

The *i** literature shows that modelers sometimes use ***OR-decomposition*** and ***means-end*** to express the same phenomenon. This is also reflected in some dialects. For instance, GRL does not allow ***OR-decomposition***, thus only means-end links are applied [11]. On the other hand, it is also very common to find two diagrams of the same modeler in which the same relation express distinct semantics [8].

In our work, we see the ***means-end link*** and ***OR-decomposition*** as two different relations. For example, a goal is as mentioned, a proposition, thus it is not possible to decompose a goal into tasks or resources. A goal may be only decomposed into subgoals. The ***means-end link***, on the other hand, is generally applied between ***tasks*** and ***goals***, for example. But how can we formally define the ***means-end link***? To understand that, one must first review the ontological meaning of intention. `Intentions` are mental states of `Agents` which refer to (are about) certain `Situations` in reality (i.e. states of affairs the `agent` aims at achieving). Now, we may define the notion of `deliberately achieving` a goal as follows:

$$task(a) \wedge goal(G) \wedge deliberately\text{-}achieves(a, G) \leftrightarrow$$
$$achieves(a, G) \wedge (\exists i: intention(i) \wedge is\text{-}reason\text{-}for(i, a) \wedge implies(propositional\text{-}content(i), G))$$

[1] From now on, we use different font to highlight *i** and UFO elements. For i* elements, we use bold and italic ***arial*** while for UFO elements, we apply `courier new`

In other words, a task *(*action in UFO*) a* deliberately achieves a goal *G* iff this task achieves *G* (i.e., causes the world to be in a state which makes *G* true) but also this task must be motivated by an intention (intention *i* is the reason for task *a*) whose propositional content implies *G*. Informally, we can state that *a* is performed with the intention of achieving *G*. Now, we are able to define the ***means-end link*** as:

$$task(a) \wedge goal(G) \wedge ME(a, G) \rightarrow deliberately\text{-}achieves(a, G)$$

In other words, a means-end link between a task *a* and a goal *g* holds if the execution of such task leads to goal achievement and is deliberately performed by the agent in whose perspective the relation is defined. Please note that this definition makes a clear distinction between the ***means-end link*** and the ***OR-decomposition*** relation, previously defined.

Another common case of *construct overload* in *i** is given by the indistinct use of the ***means-end*** and ***contribution links***. For instance, let us make us focus on a make contribution example (Fig.1).

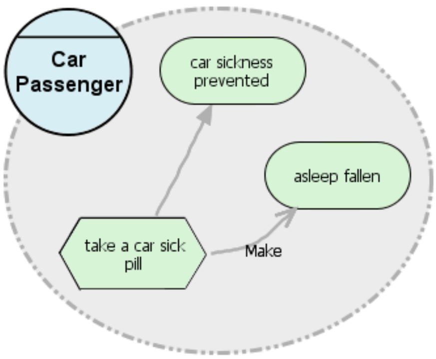

Fig. 1. The case of the passenger (Means-end link vs. Make Contribution link)

In it, a Car Passenger agent executes the take a car sick pill task in order to prevent himself from being sick during the journey he is making (Means-end link to car sickness prevented goal). As a side effect of this medication, the Car Passenger also goes to sleep (Make Contribution link to asleep fallen goal). Let us now carefully analyze this example. Both goals depicted in the model are equally accomplished: following the proposal in [8], we here assume that the ***means-end link*** leads to full accomplishment and the ***contribution link*** value is Make, which also indicates the goal is completely fulfilled. So then, what is the distinction among these two links? Do the ***means-end link*** and the ***make contribution link*** have the same semantics? If so, it would be best that the *i** framework only offered one of them to avoid construct redundancy [8], which may undermine the understanding and proper use of the language. However, it is our claim that these links are not the same. The difference here is given by the Intention behind the execution of the task.

As result of the mapping from i* tasks into UFO `actions`, every task is associated with a causing `intention` whose `propositional content` is a `goal`. In other words, we execute a particular task in order to accomplish a specific goal. In *i**, the association between the task and the goal in this case is made by a ***means-end link*** (e.g. take a car sick pill task as means to car sickness prevented goal). On the other hand, this same task can also generate some other goals to be accomplished, without however, being intended by the choice of this particular task. In this case, a ***make contribution link*** is established (e.g. take a car sick pill task as means to asleep fallen goal). By using the notion of *deliberately-achieves* previously defined, we may also make clear the distinction between the ***means-end link*** and the ***make contribution link*** (MakeCont).

$$\begin{aligned} &action(a) \wedge goal(G) \wedge MakeCont(a, G) \rightarrow \\ &\qquad achieves(a, G) \wedge \neg deliberately\text{-}achieves(a, G) \end{aligned}$$

As can be noted by the above definition in comparison with the means-end definition described a few paragraphs before, the only distinction between the two links is given by the causing intention. Table 2 summarizes some guidelines resulting from the analyses presented in this subsection for the use of the OR-decomposition relation, means-end link and make contribution link.

Table 2. Guidelines: OR-Decomposition, Means-end link and Make Contribution link

Hardgoals G ---***OR-decompostion***-→ hardgoals G1,G2 for an actor A iff 1. By accomplishing either G1or G2, G is accomplished
Action *a* ---***means-end***-→ hardgoal G for an actor A iff 1. By choosing to perform *a*, it was A’s intention to achieve goal G, 2. Performing *a* causes situation S and 3. Situation S satisfies G
Action a ---***make contribution***-→ hardgoal G for an actor A iff 1. By choosing to perform a, it was NOT A’s intention to achieve goal G, 2. Performing a causes situation S and 3. Situation S satisfies G

For reasons of lack of space, we refrain ourselves from presenting the results of the analysis of the break, help and hurt contribution links.

3 Conclusions and Future Work

In this paper, we have presented the long-term objectives and main results of our effort to provide an ontological foundation to the *i** language core. Our work so far has been conceptual, providing a clear formalizations to ensure that the semantics of the *i** constructs can be well understood and properly used. This work is not finished because i* is a powerful language allowing the expression of actor’s theories about effects, side-effects and obstacles of actions. However, to move forward, we now need to do empirical work to validate the usability of our ontology, measured in for example ease of learning and effort to use, and to validate the utility of the ontology for particular stakeholder purposes.

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