Logical inference mechanism in situational awareness systems

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***Abstract* – In the article are described problems related to creation and maintenance of situational awareness systems. An approach based on situational knowledge representation with ontological models is selected for attaining situational awareness in complex intelligent enterprise systems, where objects can be in several situations in the same time and some situations are defined imprecisely. Granular computing approach is used for reduction of situational knowledge management complexity.**

Keywords – situation assessment, situational awareness, ontology, logical inference, granular computing.

I. Introduction

The main task of modern intellectual decision support systems is to release from intervention human-operator in systems operation, that is, fully automated integration of sensor data without practicing direct interaction with the user. Such systems should interact and exchange information with the external environment. Today, this area of research is very promising, as various applications (smart building, systems for public transport, etc.) are being developed to improve the everyday life of a person.

The development and maintenance of situational awareness is a necessary condition for such systems [1].

Situational awareness (SAW) as an understanding of system's environment state is a mandatory part of any decision-making system. The process of situational awareness formation and maintenance is a complex one, including the stages of gathering data from sensors, interpreting those data and updating knowledge about the current situation in order to make the correct decisions.

For operation of the system that performs the functions of SAW, is necessary to be based on a specific domain model. One way of building this model is the using of ontologies. Before using ontology models were built for each domain separately. It was inconvenient to modify the system and re-use knowledge of the situation. This caused the feasibility of using ontologies [2].

II. The main results of the research

Situation awareness is based on representation and analysis of situations. It is impossible to achieve situational awareness without the preliminary analysis of the situation [3].

Sometimes situational awareness is defined as a situational assessment and certain sources frame it as a same unit. However, it must be understood that these concepts have some differences. While situation assessment is focused on system interaction, the notion of situational awareness (SAW) is centered on the interaction of system with the users (in this case, "awareness" refers to the awareness of the final user of the current system state for forecasting and prediction its next states) [4].

Using knowledge of the subject area presented in the form of ontology and ontology-based models to identify situations has important advantages in comparison with using decision tables, trees or rule sets [5]. In particular, it allows storing and using knowledge of the subject area and the possible situations in it in a coherent form, taking into account dependencies between objects and situations presented in the form of relations. Moreover, the use of ontologies to identify situations provide additional possibilities for situation definition and processing using structural features of ontology and logical inference mechanisms.

Ontology defines a common vocabulary for researchers who need to share information in the subject area. It includes machine-interpreted the wording of the basic concepts of the domain and the relationships between them [6].

Formally, situational knowledge within the ontology is encoded as descendants of a separate class *Situation*. The description of the situation (attribute *DefinedFor*) contains a reference to the class for which this situation is determined. It simplifies finding situations in the process of solving practical problems, when there is a need to find a situation for a particular object of certain class.

If $\bar{S} = \{S_1, S_2, ..., S_n\}$ – is set of situations. We define function, which maps the set of classes in the ontology to the set of situations:

$$F_{TS} : T \to \bar{S} . \quad (1)$$

This function allows to divide the set of situations into subsets corresponding to ontology classes:

$$\bar{S} = \bigcup_{i=1}^{nt} S_{Ti} . \quad (2)$$

Sets S_{Ti} can overlap, because the object of a certain class can be in several situations simultaneously.

A promising approach to simplification of situational knowledge management is using the paradigm of granular computing [7], creating default situation definitions for large groups of objects.

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Granular computing is an umbrella term to cover any theories, methodologies, techniques, and tools that make use of granules in problem solving. Basic ingredients of granular computing are granules such as subsets, classes, and clusters of a universe [8, 9].

The use of granules generally leads to simplification of practical problems resolution. In case of ontological modeling, when classes form a hierarchy and attributes of classes are inherited by subclasses, using an approach of granular computing can be translated to situation definition, when possible, for classes of higher levels of the hierarchy.

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The definition of situation S_j contains an attribute $SDefinition - At_{def}$, which stores Boolean expression CS_j (signature), which takes a value "true" for objects of given class that reside in certain situation. That is, object $t_{ij} \in T_i$ reside in S_{Ti} if $Cs_{STi}(t_{ij}) = True$.

In the simplest case, when the situation is defined by the state of an object of a given class T_i, the signature CS_j contains only attributes of this class:

$$CS_j = BooleanExpression(a_1, a_2, ..., a_n), \quad (3)$$

where: $\forall i : a_i \in At_i \in T_i$, $BooleanExpression(a_1, a_2, ..., a_n)$ – is Boolean expression with arguments $(a_1, a_2, ..., a_n)$.

In the basis of logical inference mechanisms in ontological modeling is the description logic. It uses a set theory to form axioms and to construct new classes of ontology based on existing classes.

Ontology modelling presents a good base to definition of *situationally-oriented concepts*. These concepts and the corresponding classes of ontology are determined by situation definitions. Therefore, they are subclasses of ontology classes for which such situation applies. Examples of situationally-oriented concepts are the concepts of "meeting attendee" or "traffic rules violator". The definition of ontology concepts through the situations allows not only to justify their creation, but also to find all necessary attributes and relations used by these concepts.

A set of all objects (population) of situational class T_s, specified for class T_i by situation S_{Ti} is a subset of objects of class T_i for which axiom CS_{STi} in situation S_{Ti} is a class constructor.

$$\forall t_S : Cs_{STS}(t_S) = True, T_S \subseteq T_i \quad (4)$$

In addition to the attributes and relations inherited from the higher levels of hierarchy, such situationally-oriented ontology classes have their own attributes and relationship identified in the situation model. Using situational concepts allows us to enrich the ontological model of subject area and use logical inference to obtain and use new knowledge about the situation.

On the other hand, using the mechanisms of logical inference based on description logic allows us to build complex situational concepts with basic operations of set theory and therefore consider and find objects which, for example, simultaneously reside in several different situations.

Conclusion

Development and implementation of systems with situational awareness is a relatively new and popular area of research due to the growing interest in autonomous intellectual systems. The decision-making process in such systems is based on information about current domain state and general knowledge about domain dependencies and rules. There are many different methods for knowledge representation and processing in situational awareness systems each having their flaws and use cases. Thus, there is a need to build a unifying framework allowing using different reasoning and decision-making methods for a single set of input data and knowledge about domain.

The usage of logical reasoning is an important part of any knowledge-based system because it helps to maintain the logical consistency of domain model and the correctness of data.

An approach based on situational knowledge representation with ontological models is selected for attaining situational awareness in complex intelligent enterprise systems, where objects can be in several situations in the same time and some situations are defined imprecisely. Granular computing approach is used for reduction of situational knowledge management complexity.

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