Ontology-Driven Knowledge Integration from Heterogeneous Sources for Operational Decision Making Support

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Abstract

The paper discusses a methodology for integration of heterogeneous knowledge to support an operational decision making during coalition operations in a network-centric environment. The idea is based on managing context of two types: *abstract* and *operational*. The former is structured knowledge relevant to a task (problem) or a situation, the latter is an instantiation of the abstract context. The abstract context describes generally a problem or a situation, the operational context is used to solve the current problem or to clearly represent the current situation to the decision maker.

1 Introduction

The goal of the project is to develop a methodology and technology for integration of heterogeneous information and knowledge to support an operational decision making during coalition operations in a network-centric environment. The examples of coalition operations include logistics, supply chain, war avoidance, etc. The approach proposed is mainly based on technologies of *ontology* and *context management*, and *constraint programming.*

The approach developed is aimed at situation description or problem solving. A situation is regarded as the current state of a model, its objects, and objects' relations; a problem is considered as a task to be solved in the current situation. The problem and situation are generally represented by an abstract context incorporating integrated knowledge relevant to these problem or situation. As a problem (situation) similar to one described in the abstract context arises the context is activated. Knowledge sources including humans whose knowledge is integrated into the activated context instantiate it by imposing constraints. The instantiated context is thought of as an operational context.

2 Methodology

The approach is based on the following methodology.

Description of the area of interests. The approach is based on the availability of domain knowledge described by an adopted formalism. Domain knowledge is represented by domain and task ontologies. The domain ontology describes conceptual knowledge about the given domain. The task ontology describes a set of tasks and a set of methods to solve them. The ontologies are interrelated in a way that indicates what kind of conceptual knowledge is used by a certain task. The context-oriented approach assumes that knowledge constituting a context accumulates data and information provided by the environment. To take this into account the domain and task ontologies have to clearly indicate what kind of source is responsible for data, information, and knowledge included in the ontology.

Abstract context composition. Abstract context is formed automatically (or reused) applying ontology slicing and merging techniques based on information about ontology relations. The purpose of it is to collect and integrate knowledge relevant to the current task (situation) into a context. Since at the previous stage sources responsible for data, information, and knowledge are indicated only sources relevant to the context knowledge are used when a problem or situation is represented by the context.

Operational context composition. Sources related to the abstract context provide the required information instantiating the context. As the result of that a concrete description of the current situation is formed or the problem at hand is specified by data values.

Generation and presentation of results. Depending on the problem definition introduced by the decision maker an operational context either formalizes the problem or describes the current situation. In the former case, the problem is solved by a solver as a constraint satisfaction problem, and the result is displayed to the decision maker. In the latter case, the current situation is presented in a human readable and understandable form (Figure 1).

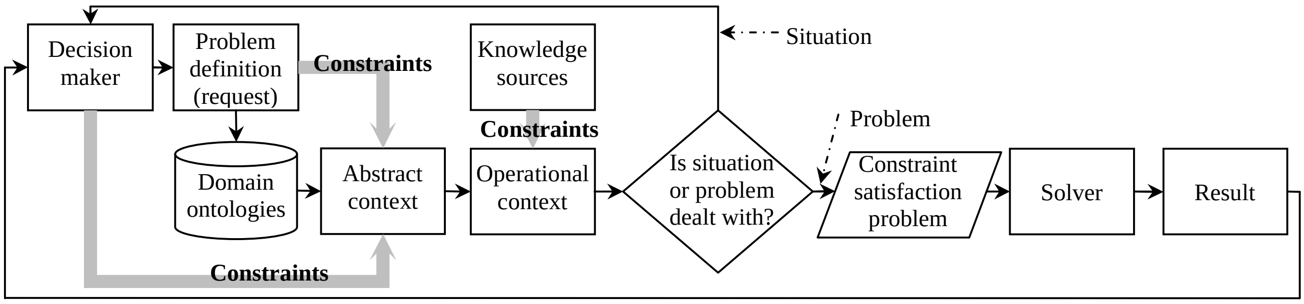

Figure 1. Methodology scheme

The methodology intends the following levels of knowledge integration.

Domain level. This level is responsible for the creation and maintenance of the domain ontology, and it is focused on the integration of information and knowledge provided by heterogeneous sources.

Task level. This level deals with the creation and maintenance of the task ontology. It concerns the integration of task-solving methods pertinent to the domain under consideration or other domains, if required, through reveal of such methods from experts and other knowledge sources and their formalization.

Due to the common formalism and vocabulary, the domain and task levels unify the knowledge provided by heterogeneous sources. This ensures that the next (context) level deals with the integration of uniform knowledge.

Context level. This level manages the integration and presentation of knowledge relevant to a particular problem (situation). Since the level deals with the uniform knowledge the automated integration is the most probable here.

The proposed methodology is oriented to the constraint programming techniques. These techniques combine a natural way of defining problems with the intelligent search and ability to assess the impact of decisions. The proposed approach offers the formalism of object-oriented constraint networks (OOCN) for the knowledge description. The formalism deals with a knowledge represented by the sets of classes, classes' attributes, attributes' domains, and the set of hierarchical, associative, compatibility, and functional constraints. This representation is in compliance with the internal representations of solvers. As the common vocabulary lexical system WordNet has been adopted.

Unlike widely used ontology representation languages such as OWL, DAML+OIL, RDF, XML, etc., OOCN formalism supports functional constraints allowing representation of functional dependencies between domain objects. This facilitates representation of complex axioms and relations of formal theories. On the other hand, the proposed formalism is compatible with the formats listed above, that enables conversion of knowledge described by them into knowledge represented by the OOCN formalism.

The main ideas behind this approach have been published and tested by a case study for health service logistics [Smirnov et al., 2003; Smirnov et al., 2004].

Conclusion

The presented methodology has a number of potential advantages in the decision making support: (1) contexts contain information relevant to a particular task or situation, that allows selecting source types responsible for observation constraints relevant to the area of interests; (2) due to ontology use, information provided by sources is transformed into knowledge at the level of description of the area of interests therefore an ontology-driven context at the decision making level provides the decision maker with the knowledge; (3) context management technique enables generation of alternative contexts representing alternative situations or alternative ways of problem solving. Emphasizing Semantic Web topics the methodology makes a contribution on domain ontologies creation issue since it is based on domain ontologies built by domain experts and contexts derived from these ontologies underlie applications tested on a set of case studies; the way contexts are formed allows to say about semantic integration of knowledge; the contexts essentially are ontology-based modules.

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