EXPLOITATION OF ONTOLOGY-BASED RECOMMENDATION SYSTEM WITH MULTI-AGENT SIMULATIONS

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Abstract: The paper investigates the usage of ontology engineering-based techniques for recommendation system development. The potential of ontology containing SWRL rules is studied with relation to the generation of scenarios (recommendations). These scenarios are the basis for the creation of multi-agent models and simulations. The multi-agent systems offer dynamic view on implications of recommendations that are suggested by the ontology-based recommendation system.

1 INTRODUCTION

The nature of response operation during the biochemical incidents asks for a clear set of actions that follow the generic goal of minimizing the casualties and loss of protected assets. There are strategic documents covering the response operation in general but the specificity of agents, uniqueness, and relative rareness of such incidents requires response operation to be more tailored in detail depending on the type of agent and its characteristics. However, most of the knowledge that needs to be processed is in the form of declarative assertions and atoms of actions such as simple rules resident in heads of experts. The aim of the paper is to design automated support for decision making during biochemical incidents. The comprehensive framework for decision support during emergency situation caused by biochemical agent is proposed. This framework should cover the whole decision making process and enable for elicitation, translation, integration of knowledge and imitation the decision making processes of human expert. Traditionally, the expert system with knowledge base and inference engine would be deployed. However, we suggest to use ontology for knowledge representation about biochemical incidents and extend the expert system with simulation engine to provide better justification for recommendation. Thus, the recommended set of actions will be assessed against the assumed impact modelled in the simulation. The focus is on technological aspects so that particular solution can be designed and tested.

The structure of the paper consists of two parts. First, the conceptual level of the framework is outlined. Second, the technological and implementation aspects of the solution are being designed and discussed. The solutions will include the integration of recommendation with simulation for better justification of the recommended actions.

2 SOLUTION

The conceptual level is used to define basic requirements and goals of the system. Also the system architecture is being delineated and the decomposition of the system into particular subsystems together with interfaces is being designed. The technological level deals with possible technological platform. The particular methods and techniques are determined and aligned along the goals given in conceptual level. The implementation level focuses on realizing the model in a particular environment using particular specification or language.

The conceptual level has already been described in (Čech, 2011). The system was decomposed into three subsystems:

- subsystem modelling the incident,
- subsystem for scenario generation,

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▪ subsystem supporting the selection of action.

Subsystem modelling the incident is used for capturing the domain knowledge and current data about the incident. The input into this subsystem consists of the domain knowledge that is predominantly in the heads of expert on a particular area being medicine, epidemiology, biology, chemistry etc. There are also information in the form of documents, books and similar resources that contain already formalized knowledge, see “Fig. 1a”. The output of the subsystem that is at the same time input into the subsystem for scenario generation are the characteristics of agent together with relevant characteristics of the environment that are important relative to the agent.

Subsystem for scenario generation is based on an inference engine and corresponding causality models in form of rules, see “Fig. 1b”. Declarative domain knowledge about the agent and current data about the incident will be processed against the rules and the recommended set of action or scenario of response operations will be generated. It is necessary to receive the feedback from the expert(s) for ensuring the correctness of SWRL rules representation, see “Fig. 1c”.

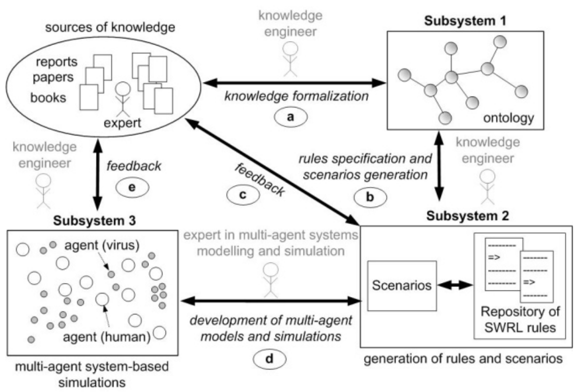

Figure 1: Ontology-based framework.

Subsystem supporting the selection of actions is based on a simulation engine. The simulation takes the characteristics of the agent and environment as parameters and examines the impact of a particular set of actions. The particular set of actions represents alternatives that are to be considered. The resulting estimations of casualties and impact on the protected assets form the output of this subsystem, see “Fig. 1d”. Outputs of multi-agent simulations have to be compared with the outputs presented the reality. Expert is able to give us the information if the multi-agent system behaves correctly or not, see “Fig. 1e”.

2.1 Ontology and Rules

The principles of ontological modelling are applied in formalizing the captured knowledge. According to Gruber (1993), ontology is regarded as “an explicit specification of a conceptualization”. This definition was slightly extended (Borst, 1997). Ontology is “formal specification of shared conceptualization”. Ontology should be formalized for machine-processing and reflect consensus between people for knowledge sharing.

There are several widely used languages for ontology modelling. The OWL ontology, based on the interviews with experts and relevant documents, has been built during the course of the project. The open-source Java-based environment Protégé 4.1.0. has been used for the ontology modelling. Logic of the ontology was verified with the aid of the open-source Java-based Pellet reasoner in ver. 2.0.0. Important classes with explanation of their meaning are mentioned in “Tab. 1”.

In the course of the framework development also the alternative languages were considered. Especially, the attention was focused to UML (Unified Modelling Language). UML is not primarily oriented to modelling ontologies though; there might be sound reasons to use UML also for describing concepts and relations in a knowledge base. UML is a de facto standard modelling language in software industry. UML serves as modelling tool for development of computer information systems. The UML is designed to be general enough so that it can serve also other purposes than it was originally intended to. UML offers specification together with graphical notation for describing models.

Both OWL and UML are based on common principles coming from object oriented thinking and modelling. However, OWL conforms to the principles of declarative programming paradigm, the UML follows the imperative programming paradigm. The declarative formalism is closer to the nature of knowledge that was to be captured. The imperative formalism was closer to what should be recommended since the result of the recommendation should be an imperative set of actions. The major difference with respect to the goal is that OWL enables to use existing inference engines. In case of UML the inference engine has to be implemented separately.

Currently, ontologies have been widely used in semantic web applications in order to recommend web pages or multimedia resources (Middleton, 2006); (Lops, 2011).

Table 1: Important classes of the ontology.

Classes	Meaning
Agent	This class represents a biochemical agent. The agent is characterized by its occurrence, reservoir, infectivity, transmission, fatality, symptoms, incubation period and prevention. The particular agents are modelled as individuals with specific values of given characteristics represented as well as individuals. The following individuals are represented: Anthrax, Brucellosis, Cholera, Glanders, Melioidosis, Bubonic plague and Tularemia.
Environment	This class describes the important characteristics of the scene of the incident. The environment is characterized by wind speed, direction, temperature, humidity, animal occurrence, density of population in the area, and also number of infected persons, number of infected animals, number of dead persons, number of dead animals, time from first symptom observed, occurrence in public transport, etc.
Response Operation	This class describes particular response operation mainly with its impact to protected assets. The following individuals are represented: Vaccination, Water reservoir decontamination, Area quarantine Animal kill off, Water supply, Food supply, Insect repellent supply, Protective mask supply, Army power utilization, Soil reservoir decontamination, Human quarantine, Animal quarantine, Vaccine buying, Laboratory analysis of sample, Air decontamination
Recommendation	This class is going to be associated with individuals of Response operation class. The individuals associated will be inferred based on the domain knowledge in form of the rules.
Incident	This class is used to associate Agent, Environment and Recommendation class. Individual belonging to this class would represent a current incident and would be associated with individuals of Agent class that caused the incident, individual describing the current environment setting and would be linked to particular response operations inferred as a recommendation to tackle the incident.
Protected Asset	This class represents the protected assets that are threatened during the incident by the agent. The protected assets are also impact by recommended response operations. Currently, there are three types of subclasses and that is the tangible property, intangible property or financial assets of humans. Particular protected assets will be represented as individuals belonging to one of these subclasses.

The ontology describes user preferences and particular items of interest and based on the principles of content or collaborative filtering the similarity was computed. In such cases the ontology based inferences can be utilized since the description of an item or user preferences can be enriched by implicit classification based on the defined properties and relations. However, there are some limitations of ontology based reasoning. First, it regards only classes and thus is not able to handle individual. Modelling particular instances of certain events and elements, however, better reflect the reality. Second, it is not able to reason based on expressed causality that is an evident part of knowledge need during response operations. That is why it was necessary to employ add into the ontology another level of expressivity using rules. OWL comes with extension including Horn-like rules that is called SWRL (Semantic Web Rule Language). There are six core classes in the paper, see “Tab. 1”.

These classes with their individuals are basis for the implementation of SWRL-based rules. These rules represent knowledge of experts that were elicited during interviews. SWRL editor of Protégé 4.1.0 tool was used. SWRL-based rules are the inputs for the inference engine. We use the open-Pellet reasoner in ver. 2.0.0. It is able to infer new relations between classes and individuals or between individuals only (Sirin, 2007).

2.2 Simulation

The subsystem for modelling the incident is linked to the subsystem responsible for simulation. The main goal of the simulation is to estimate the impact of these actions to people and protected assets as the time develops. The recommended set of actions together with the description of the environment represents the input into the simulation subsystem. The simulation model is based on the domain knowledge gained from experts and other resources such as papers, reports, etc. In particular, data from Committee on Toxicology (1997) and U. S. Department of the Army (1990) were used for the compiling of the document with chemical agent characteristics (NBC, 2011). This document was used in our ontology development.

Simulation is based on multi-agent technology. Multi-agent simulation appropriately reflects the emergency situation during biochemical incident in which there are many heterogeneous elements characterized by given properties and with its own behaviour. Agents represent infected persons (individuals), dangerous object (virus, bacteria, etc.) as well as protected assets. Currently the model simulating the spread of Anthrax in an environment is prepared in order to test the technology and the possibility of integration with the subsystem for modelling the incident. The model reflects the characteristics of the Anthrax and simulates the spread in an environment based on the wind speed and wind direction and the corresponding effect of the contaminated cloud on population.

The subsystem for simulation is implemented in the open source environment called NetLogo. NetLogo enables to study systems that change in time. The connection to subsystem modelling the incident is realized using the NetLogo API (Application Programming Interface).

Using the simulation the person responsible for commanding the response operations can better predict the outcomes of performed activities. The simulations are useful also in situations in which alternative set of actions is being recommended.

3 CONCLUSIONS

The response operation during emergency situation caused by biochemical agent requires to process huge amount of domain knowledge from various areas. Ontology represents a possibility how to capture domain knowledge and enable recommendation inferred based on the rules imitating expert decision making. Presented ontology together with rule based reasoning and simulation is a part of a proposed decision support framework. The paper points to technical and implementation aspects of the framework development.

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