MMSL Military Medical Science Letters

Mil. Med. Sci. Lett. (Voj. Zdrav. Listy) 2011, vol. 80, p. 21-27
ISSN 0372-7025
DOI: 10.31482/mmsl.2011.003

ORIGINAL ARTICLE

ONTOLOGICAL MODELS AND EXPERT SYSTEMS IN DECISION SUPPORT OF EMERGENCY SITUATIONS

Pavel Čech[1,2], Vladimír Bureš[1,2]✉, Karel Antoš[2,3], Tereza Otčenášková[1,2], Aleš Macela[2], Petr Musilek[4]

[1]University of Hradec Kralove, Faculty of Informatics and Management, Hradec Králové,
[2]University of Defence, Faculty of Military Health Sciences, Hradec Králové,
[3]University hospital Hradec Králové,
[4]University of Alberta, Faculty of Engineering, Edmonton, Canada

Received 4th October 2010.
Revised 9th March 2011.
Published 6th April 2011.

Summary

During emergency response operations many decisions have to be made. Information technologies provide possibilities for new tools to support decision makers in decisions that comprise of many critical factors and that require specialized knowledge. In these tools the complexity is tackled using modelling and simulations of possible scenarios of response operations. Today, conceptual modelling in the field of information technology is oriented on the ontological approach. Ontology is a shared vocabulary and an unambiguous machine processed specification of terms together with their relationships. The ontology can have the form of a taxonomy or classification, database schema or axiomatic theory. The ontological modelling can be utilized along with expert systems for decision support. Expert systems, in contrast to other approaches such as neural networks for instance, better reflect the domain knowledge and provide justification for the decision. The aim of this paper is to describe prerequisites and design general schema for decision support in response operations during biological incidents including the applicable technology.

Key words: decision; biological incident; decision support systems; ontological model; expert system.

INTRODUCTION

The decision-making during emergency situations represents a specific set of decision cases, which definitely belong to the unstructured ones. Therefore, it is essential to identify important factors that characterize the extent and impact of the incident on protected values (person's life, health, possession, etc.). Moreover, the scenarios of future development should be found and verified. On the basis of accepted scenarios, the measures conducive to the minimisation, possibly elimination of negative consequences of the incident are executed.

The emergency situation for the purposes of this paper is defined as a biological incident, which requires decision exceeding the scope of medical perspective. In this intent the decision-maker, who plays a key role, decides depending on a whole range of incident parameters. The information about the environment, where the infection has occurred; speed, effectiveness and costs of the potential countermeasures (logistic and financial restrictions); or the priorities of individual protected values are assigned to the medical decision parameters.

✉ University of Hradec Kralove,
Faculty of Informatics and Management,
Rokitanského 62, 500 03 Hradec Králové,
Czech Republic
vladimir.bures@uhk.cz

CHARACTERISTICS OF DECISION-MAKING ON BIOLOGICAL INCIDENTS

Firstly, the problem solving of the emerged problem assumes the identification of critical factors for further decision-making on the basis of known information about the incident. Afterwards, the transformation of these data and related knowledge in the scenarios of potential development according to defined criteria and target parameters is made. Information support in form of Decision Support Systems (DSS) can be utilized during this process. At the general level, DSS represent interactive computer systems which help a user to utilize computer communication, data, documents, knowledge and models for problem solving and decision-making (7).

The creation and testing of an incident model becomes a key activity during the preparation for the occurrence of biological incident. Current modelling is based on the gestalt approach to the decision-making process where a human is the key decision factor. Automated system can only support the decision-making process, because it does not bear full responsibility for the final decision. Decision support system, created for the right reaction determination of the crisis situation provoked by the biological agents, should support the whole decision process which consists of the following phases:

a) identification of an incident,

b) characterization of the emerged problem,

c) creation of the potential scenarios,

d) selection of set of the most probable scenarios,

e) determination of the feasible reactions to the incident,

f) selection of the appropriate subset of reactions which will be realized.

The entire process runs in cycle with the iteration count corresponding to the current incident progression. The schema of the decision support system during the crisis situation can be built on the basis of the procedure mentioned above (see also Figure 1).

The entire system is structurally formed from three main parts:

1) subsystem modelling the incident,

2) subsystem supporting the scenario creation,

3) subsystem supporting the selection of measures.

The proposed schema enables to comply the characteristics demanded from the decision support systems - for example applicability to the semi-structured or unstructured problems, support for the decision makers instead of the effort to replace them, support of all phases of the decision-making process, orientation to the effectiveness of the decision-making process rather than to the efficiency; or support of both individual and group decision making (5).

PROPOSAL OF THE APPROACH TO PROBLEM SOLVING

The following characteristics are assumed for decision support during solving the emergency situation. Input parameters are heretofore known information about the incident, domain knowledge from the area of epidemiology (especially causal relationship between agents and their impact on the protected values) and emergency management, parameters determining the protection level of protected values, potentially strategy of the impact minimisation. Therefore, it is necessary to combine up-to-date information and knowledge into appropriate solution alternative during the entire problem solving process. The mentioned above allow to evaluate the appropriateness of the approaches.

All three mention parts of the problem solving process can be realized while using various methods and techniques. For example, cybernetic modelling is based on the assumption of knowledge of the causal or at least functional relationships represented through the mathematical formulations (6). Cybernetic modelling also assumes the presence of agent performing a certain activity (for example managing, monitoring, predicting) on the examined process. This way of modelling is therefore focused on the modelling of functional knowledge within the examined system.

Along with the cybernetic modelling, it is possible to utilize also its specific alternative - mathematical and qualitative modelling (3). This type of modelling is based on the functional dependencies represented in more or less exact form. Qualitative modelling originates in idea of mathematical models comprised from differential equations which include constant values. These constants can be replaced by the symbolic names. Afterwards, functional dependencies between two characteristics are specified as monotonically increasing or decreasing function. All other details are not necessarily known.

Neural networks, as a tool utilizable in the second subsystem of the proposed schema, are related to the model types mentioned above. Neural networks transform the input parameters into the output ones on the basis of the multilevel multicriterial selection according to the defined rules for next level transition. The advantage of neural networks is the possibility to "learn" how to determine the output parameters on the basis of the input ones (10). However, the neural networks are utilized within the area of biology and chemistry (for example (2)), the problem solving with their utilization seems not to be suitable in this context, because of two reasons:

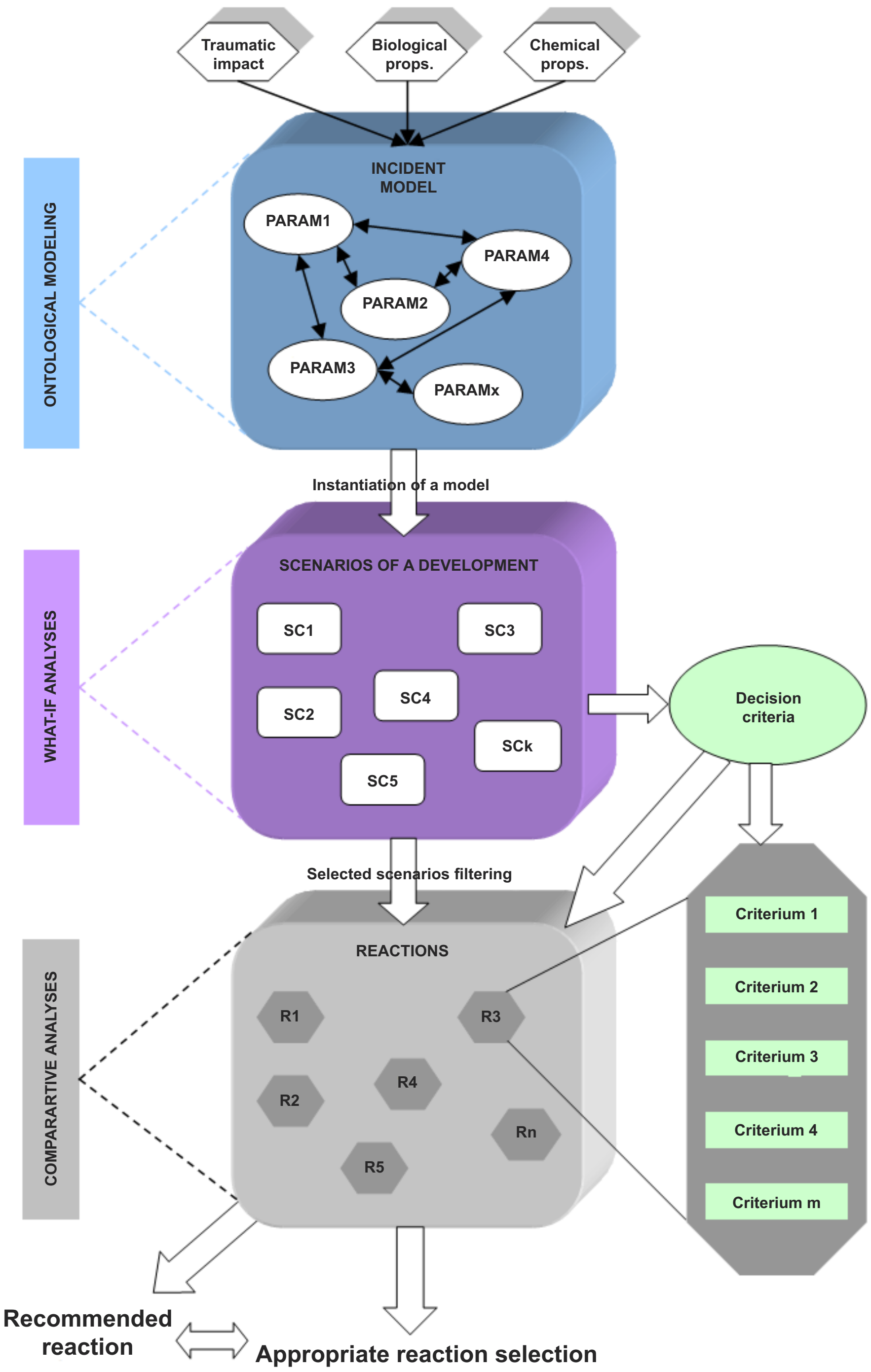

Fig. 1. General schema of the system

1. First of all, the transformation of the domain knowledge to the internal neural network structure is considerably problematic. The right "training" of neural network would require wide training set of incidents, possibly input parameters identified on the individual incident and its expected solution alternatives.

2. Apart from this fact, the internal structure and the determination process of the result in context of neural networks are perceived as a black box. Therefore, the solution finding using neural networks would not provide required justification in individual parts of decision process.

The latter mentioned would influence both the transparency of the result and the possibility to perform what-if analysis. Rather than scenarios of certain problem solving, the neural network would offer only the solution which would be either accepted or rejected. The neural network itself would not contribute with any data for this acceptance or rejection.

Although qualitative models (for example a system of differential equations describing the virus spread (1)) are employed within the realm of biological agents, according to the mentioned above it is appropriate to apply the ontological modelling. This is based on the knowledge structuring according to diverse abstraction levels and with the usage of the taxonomical and mereological relations. The basis of the ontological modelling is the explicit conceptualization represented in a formal language.

Ontological models differ according to the following classification (6):

- Domain Ontology - conceptual knowledge base from the domain (for example Galen - medical terminology, or Enterprise Ontology - business structure and operation).
- Task Ontology - problem solving methods, diagnostics, monitoring, designing, planning (for example task ontology library of iBROW project).
- Upper-level Ontology - similar to the domain ontology with difference in broader focus on the common-sense knowledge - general concepts present in any ontology such as time ontology. For example Cyc or SUMO (Suggested Upper Merged Ontology) ontology.
- Application Ontology - part of a particular application which is comprised of domain as well as task component (for example medical ontology of project GAMES-II).
- Representation Ontology - language definition for the knowledge representation, so-called metaontology (definition of programming languages).

The following list summarizes the reasons why ontological modelling was chosen for the purposes of the incident modelling:

- Ease of communication among people/organisations thanks to the unambiguous specification of terms.
- Ease of cooperation of the computer systems (ontology as an exchange format for knowledge).
- Ease of knowledge application development (ontology as a basic, conceptual layer of the knowledge base, ontology as an on-line documentation).
- Domain connection (molecular biology, decision-making).

The ontology describes concepts and relations important within the chosen problem area. In this way for instance, the concept of an agent can be specified together with concepts of its characteristics such as infectability, transmission, fatality, etc. and put into a relation with an appropriate treatment and response operation. Hence, ontology provides a shared vocabulary and unambiguous computer processed specification of terms together with their relationships. The ontology can have the form of taxonomy or classification, database schema or axiomatic theory. The main reasons for ontology employment include capturing, sharing and reutilizing knowledge within the certain area; as well as computer processing of captured domain knowledge.

The consecutive steps should be followed during the entire process of problem solving while creating the ontology. These are:

1. Defining the ontology extent and domain fields.
2. Informal/semiformal knowledge accumulation
   – Relevant terminology determination
   – Terminology organisation
   – Concept definition
   – Informal representation.
3. Specification of both information needs for decision-making process, and criteria for testing.
4. Implementation - creation of normalized schema and framework - prototype implementation and model extension (control of functioning).
5. Quality assessment (considering the targets) and improvement in tests for further development and change tracking.

Decision support can be linked with the ontological modelling based on expert systems. Expert systems, in contrast to other approaches such as neural networks for instance, better reflect the domain knowledge and provide better mechanisms for justification of the final decision. The expert systems capture domain knowledge in knowledge base, mostly in form of defined rules and statements

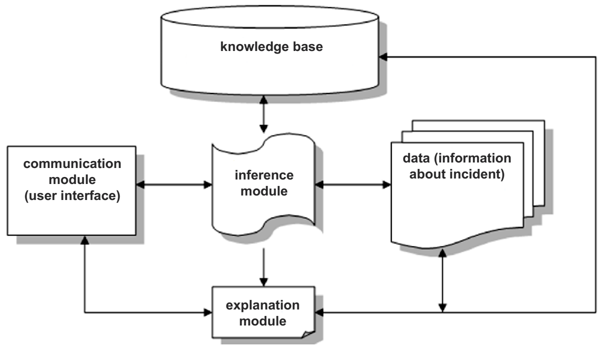

Fig. 2. Structure of the expert system (adapted from (9))

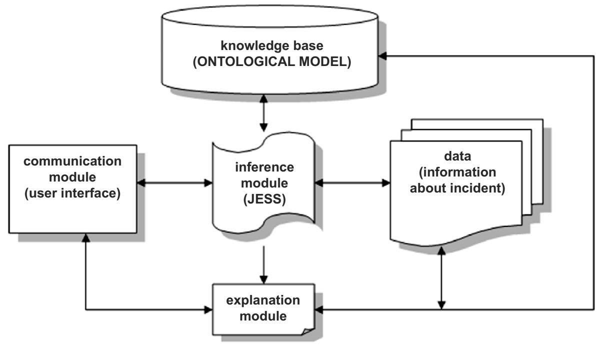

Fig. 3. Applied expert system schema for decision support in emergency situations

An illustrative example of the expert system generating a possible scenario for response operation could be as follows. Let us assume for the purpose of this example that the agent causing the incident is anthrax. Based on the domain knowledge in the form of ontology the important characteristics would be determined. Thus the authorized personnel commanding the response operations would be able to found out that anthrax is transmissible through air and a contact with infected animals. Thus it is important to know for example the wind speed and wind direction and also whether there are infected animals or contaminated food. Once these environmental characteristics and other data about the incident would be supplied the expert system would be able to suggest some actions based on the defined rules and inferred facts. In this way the expert system would suggest to provide for protective mask supply or animal kill off in a particular area.

The knowledge base is created on the basis of structured and semi-structured interviews with experts and analysis of available sources. Knowledge capturing is therefore more explicit than in case of neural networks.

Furthermore, verification and possibly inconsistency detection are easier, and the entire process of problem solving is more transparent. The expert system structure is provided in the Figure 2.

The major parts of an expert system are:

- **Knowledge base** - in form of rules or facts.
- **Inference engine** - mechanism determining the appropriate rule for the incident and deriving new facts which lead to the application of further rules, etc.
- **Explanation module** - module elucidating the process of the rule application based on the given data about the incident and the derived facts.
- **Communication module** - user interface for data entry.

ONTOLOGY CREATION METHODOLOGY

The following tools and environments are suitable for creation of the ontological model of the incident. These are for example VOEditor, DUET, Visual Ontology Modeler (VOM), OILed, OBO-Edit or OntoEdit. Regarding the previous experience and availability of the environment, **PROTÉGÉ** environment can be recommended.

Protégé is an open-source platform of tools for the domain models and knowledge systems creation based on ontologies. The Protégé's core includes a wide range of constructs and techniques for support of activities such as: ontology creation, visualization and manipulation in different forms of representation. Protégé provides adjustable environment for construction of domain-based knowledge models and also communication tools for data entry. Protégé can be extended while using modular architecture and Java-based application-programming interface (API). Thereby Protégé can be incorporated within more complex ontology-based specialized systems.

Protégé platform provides two main ways of ontology modelling (8):

- **Protégé-Frames** editor provides construction and storage of frame-based ontologies compatible with Open Knowledge Base Connectivity protocol (OKBC). In this model, ontology consists of:

  a) set of classes organized into hierarchy to represent distinctive concepts within a certain domain,

  b) set of slots associated with classes to describe their properties and relationships,

  c) set of instances of modelled classes to represent individual conceptual instances with specific values for given slots.

- **Protégé-OWL** editor enables ontology creation along with the Semantic Web concept, specifically according to the W3C Web Ontology Language (OWL). Ontology comprises description of classes, properties and individual instances. The formal semantic rules specify derivation of further facts not explicitly included in the ontology, but implied from the meaning of other domain concepts.

The support of scenario construction is ensured by the expert system. Its operation should follow steps listed below:

1) Information about incident are entered into the system.

2) Inference mechanism applies the appropriate rules according to the identified information, furthered to the detection of information necessary to be determined.

3) Explanation module enables examination of the sequence of the applied rules and potential readjustment of priorities during derivation.

The core of the entire problem solving is the ontology describing the agents and the mutual causal relationships, specifically the knowledge base embracing knowledge in epidemiology field and the interference mechanism. Actual implementation of the interference mechanism might be realized by the **JESS** platform. JESS represents java-based development environment for creation of knowledge-based systems. This environment was constructed in late nineties of the last century in Sandia National Laboratories in Livermore, California. JESS was inspired by the CLIPS expert systems which are (on the contrary) related to rule-based systems like OPS5 or ART. JESS provides a rule engine as well as the scripting language. The rule engine uses the improved Rete algorithm for the evaluation of appropriate set of rules. Scripting language syntax corresponds to the declarative programming languages like LIPS (4). The JESS platform enables creation of knowledge-based systems founded on the declarative knowledge specified for example by the ontology.

Figure 3 depicts the structure of the mentioned relation between the ontological modelling and the expert system.

CONCLUSION

Emergency management comprises processes of planning and managing activities during the preparation for the occurrence of incidents as well as during the elimination of their consequences. There are a lot of aspects of a emergency situation. One of the most important is the protection of population health. These issues become nowadays more and more complex due to the character of potential sources of these situations.

Information technologies provide possibilities for new tools for decision support including the realm of biological incidents. This problem is not linked only with the questions of decision support discussed above. It embraces also the application of basic knowledge resulting from research of biological agents to systems utilizable in praxis, i.e. initial identification of unique biomolecular properties of examined systems, their functional characteristics as well as construction of tools for detection, identification or modulation (prophylaxis, therapy) of real processes within live systems. The fundamental knowledge enables the systematic creation of new knowledge, its storage in specialized databases, classification and utilization for emergency situation solving with the employment of decision support systems.

The ontology creation in such complex system provides both a shared vocabulary and unambiguous computer processed specification of terms used in vocabulary. The certain processing of ontology can have different forms, including a taxonomy or classification, database schema, and complete axiomatic theory. The ontological modelling can be linked with the decision support based on the expert systems, which reflect the users' demands on domain knowledge more appropriately than neural networks. Moreover, these also provide more suitable mechanism for justification of the final decision.

In addition to the theoretical development of the discussed issues, the authors emphasise the contribution of decision support systems for solving of biological incidents for the model application as a component of medical subsystem in general information system.

ACKNOWLEDGEMENT

This paper was created with the help of the project MO0FVZ0000604.

REFERENCES

1. COLIZZA, V. – BARRAT, A. – BARTHELEMY, M – VALLERON, AJ – VESPIGNANI, A. Modeling the Worldwide Spread of Pandemic Influenza: Baseline Case and Containment Interventions. PLoS Med. 2007, vol. 4, iss. 1, p. 13.
2. DOHNAL, V. – SLÁDKOVÁ, A. – KUČA, K. – JUN, D. Artificial Noses in Detection of Moulds and Mycotoxins, Vojenské zdravotnické listy, 2008, vol. 77, no. 2, p. 66-70 (in Czech).
3. FORBUS, K. D. Qualitative Process Theory, Artificial Intelligence 24, pp. 85-168, 1984.
4. FRIEDMAN-HILL, E. Jess in Action, Manning, New York, 2003.
5. MARAKAS, G. M. Decision Support Systems in the 21st Century, Prentice Hall, Upper Saddle River, NJ, 1999.
6. PONCE, D. Slow Processes, dissertation thesis, Economic University in Bratislava, 2006.
7. POWER, D. J. Decision Support Systems: Concepts and Resources for Managers, Quorum Books, London, 2002.
8. PROTÉGE: The official website, available: http://protege.stanford.edu, 2009.
9. SKLENÁK, V. et al. Data, information, knowledge and Internet, C.H.Beck, Praha, 2001(in Czech).
10. VASANT, D. - STEIN, R.: Intelligent Decision Support Methods. Prentice Hall, New Jersey, 1997.