CONCEPTUAL MODELLING FOR MANAGEMENT OF PUBLIC HEALTH IN CASE OF EMERGENCY SITUATIONS

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Abstract: Emergency situations such as biological or chemical incidents require prompt decision making. There are however only a limited set of formally declared procedures and principles of how to tackle such incidents. The aim of the paper is to introduce specific techniques of conceptual modelling that form a framework of decision making during emergency situations. The paper will present an ongoing research that is focused on identification of proper response procedures and responsible authorities during the incident and unification of knowledge from do-main experts on bio-terrorism, epidemiology and medicine as well as procedures that are given in national and regional recovery plans.

1 INTRODUCTION

Emergency situations such as biological or chemical incidents require prompt decision making. There are however only a limited set of formally declared procedures and principles of how to tackle such incidents. The disaster and recovery plans usually focus on natural disaster or pandemic. The immediate actions are focused primarily on casualties, however, comprehensive response operation need to address other aspects. The knowledge necessary to properly conduct the response operation is mainly in the heads of experts and could be difficult to get quickly enough in a form that can be used by the decision maker. Next, experts are usually focused on a narrow view of a problem lacking the overall picture. Therefore, the decision support framework that would overcome such difficulties would be fruitful. The aim of the paper is to introduce specific techniques of conceptual modelling that form a framework of decision making during emergency situations. The paper addresses the gap between the knowledge from particular domains, discusses the conceptual modelling framework of its closure, and presents an ongoing research that is focused on identification of proper response procedures and responsible authorities during the incident and unification of knowledge from domain experts on bio-terrorism, epidemiology and medicine as well as procedures that are given in national and regional recovery plans.

2 PROBLEM STATEMENT

To conduct response operations effectively and efficiently, information from various sources and experience from different domains needs to be processed. This is not a problem from the technological point of view due to recent developments in computer science (Panuš, 2010) and successful application of various systems supporting decision-making processes in particular situations (e.g. Čech and Bureš, 2007). The challenge is that decisions are required taking into account not only the health issues but also economical, political, environmental aspects with often contradictory priorities. The authorized decision maker is often not specializing on these areas but rather relies on advices from different experts. Experts are usually looking from their own perspectives and immersed in detail knowledge they often disregard other aspects. The decision maker should be able to unite all the aspects and coordinate response operations holistically. Achieving holistic view in decision making would require the knowledge of the expert to be shared with the

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decision maker. However, Liou (1992) states that as people are becoming more experienced in performing a certain task, they are becoming less aware of cognitive processes involved in accomplishing that task. Since knowledge engineering methods and techniques have already been successfully applied in various areas (e.g. water resources management (Mikulecký, Ponce and Toman, 2003) or tourism (Čech and Bureš, 2009)), the abovementioned problem can also be treated with the help of these. Therefore, knowledge acquisition needs to be performed in order to capture and share the reasoning processes of an expert.

3 METHOD

The paper explores the use of various conceptual modelling techniques for knowledge acquisition. The task is to find a framework that will serve two purposes. First, it will be used to offer a way how to conceptualize knowledge from the different domains acquainted from different experts. Second, the framework would offer the decision maker a comprehensive pattern for decisions during biochemical incidents taking into account various aspects, stakeholders and responsible authorities. The paper will be divided into two parts. First, conceptual modelling will be reviewed and selected conceptual modelling techniques will be presented in order to find an appropriate tool for transferring domain knowledge from experts to decision maker that is responsible for coordinating response operations. The techniques will be reviewed with respect to application in knowledge sharing as a part of knowledge acquisition task. Also, the possibility to create conceptual models of decision making in emergency situations caused by biochemical agents will be considered. Second, the approach taken during the research dealing with decision support tools in emergency situations will be presented.

4 CONCEPTUAL MODELLING

As stated by Robinson (2006) conceptual modelling is concerned with appropriate simplification of a reality or of a proposed system. Although, there is not a common consensus of how to define conceptual modelling, the researchers such as Luo and Yoshida (2007) or Mandl and Levin (1989) regard conceptual modelling as a mental tool that helps to convey thoughts and ideas and thus is often denoted as a knowledge sharing technique. The central idea of a conceptual modelling is an identification of relevant concepts denoted as entities, objects, things or similar constructs and their mutual associations known as relations. The conceptual model is stripped from technological and implementation details. The purpose of the modelling and the approach determines logical pattern and thus what is relevant and what might be abstracted. The conceptual modelling is often connected with visualisation techniques. It is argued for instance by Kosslyn (1980), Mandl and Levin (1989), or Shepard and Cooper (1982) that visual representation makes for easier recognition and recall then merely textual representation.

There are several conceptual modelling techniques each following a slightly different purpose and defining special principles and perspectives that are to be focused on. The techniques define also the visual representation with its own notation. However, the majority of visual representations are based on graphs with nodes and arcs. The core of the modelling consists of constructing the visual representation along the given principles. The simple techniques concentrate only on specifying names to nodes and arranging links in between. The advanced conceptual modelling approaches such as object or ontological modelling enhance the model by further specification of nodes and arcs.

In the scope of the research the focus were aimed at mind mapping, cognitive maps, entity relationship (ER) modelling, object modelling, ontological modelling and decision trees.

Mind maps consist of arranging related concepts around a central key concept. According to Luo and Yoshida (2007) mind mapping is often used for learning and brainstorming. Mind maps offer a structural view of concepts in a certain domain. The technique is useful in cases when one central concept can be defined and where there are not many overlapping and duplications of concepts and their relations.

Cognitive maps are used for the mental representation of concepts and causal assertions. Spicer (1998) reminds that cognitive maps were originally developed by psychologists and can be used to support transition of knowledge and promotion of understand and shared thinking about a certain problem domain.

ER modelling is primarily employed in logical design of databases. The technique deals with entities that can be further extended with attributes and relations. The relations are interesting especially

due to a so called multiplicity or cardinality. The purpose is to capture the structure of the data that will be later transformed into platform dependant physical data schema. Object modelling is often used for conceptualisation of functional systems rather than just for arranging concepts in a certain domain.

Object oriented approach breaks down a complex system into a set of mutually interlinked cooperating objects. The arrangement of concepts or objects obeys fairly strict principles to achieve flexibility and reuse. The creation as well as interpretation of the model requires knowledge of these principles.

Ontological modelling is based on the concept structuring according to diverse abstraction levels and with the usage of the taxonomical and meteorological relations. The purpose of the ontological modelling is the explicit conceptualisation represented in a formal language. Ontological modelling is similar to object oriented one. However, ontological modelling offers a richer specification of relations and constraints that can be used for simple inferences.

Decision trees represent a simple conceptual model of a decision. In general decision trees are used to describe and classify data and are known to offer a simple interpretability and also possibility for validation. In connection to decision making decision trees model the sequence of tasks together with possible outcomes and consequences (Esmeir and Markovitch, 2007), (Podgorelec, Kokol, Stiglic and Rozman, 2002). The resulting structure can serve as a basis for automation of given tasks or decisions.

5 KNOWLEDGE ACQUISITION EXERCISED

With reference to the selected method described above the set of sessions with experts were arranged. During the sessions various knowledge elicitation techniques were applied. These techniques include structured interview, brainstorming, observation, learning rules from examples, model based rule learning (Agarwal and Tanniru, 1990); (Lavrac and Mozetic, 1989); (Liou, 1992).

In the first stage of the research the brainstorming method was used to determine the context and to create the basic conceptual model of the whole system. The brainstorming was conducted with experts on biology, epidemiology, military health operations and software engineering. The basic conceptual model contains the definition of the core functionality, components of the whole solution and input and outputs. The basic conceptual model also determines the specific approaches taken in various stages of further research.

The next stage of the research was aimed at knowledge acquisition with the use of interviews and semi-structured interviews with experts. The preliminary session with the experts confirms the difficulty of experts to articulate the cognitive processes used during performing certain tasks (as described by Liou (1992)). The experts considered most of the knowledge as obvious. The problem was addressed by structuring the interviews along the predefined questions. Thus the experts were confronted with questions extracted from the national and regional pandemic plan. Based on the answers the responsible authorities and institutions were identified and conceptual model in the form of a cognitive map was created. The model contains involved authorities that were identified together with systems being used expected inputs and outputs in form of information that should be given or processed. The model was created using the CMAP tools. The appropriateness of using CMAP tools was discussed by Miertschin and Willis (2007) in connection curriculum modelling. The resulting cognitive map (see its partial illustration in figure 1.) is going to be used for further review and validation by experts.

Next, experts were interviewed in order to gain knowledge about properly conducting response operations for various biochemical agents. The key decision parameters (e.g. transmission, infectiousness, incubation) were identified and prioritized and the responsibility for providing specific information was ascertained. The result is the set of questions that should be answered to determine appropriate response operation. The decision tree was used to model the sequence of questions and possible outcomes. In the next round of the interviews the model will be reviewed and further extended by assigning probabilities to given outcomes and by determining known constraints.

6 FURTHER RESEARCH

The resulting conceptual model in form of the decision tree is going to be used in the further stages of the research for automation of information gathering procedures. Hence, the next round of interviews will serve as a basis for ontological modelling and developing ontology covering the

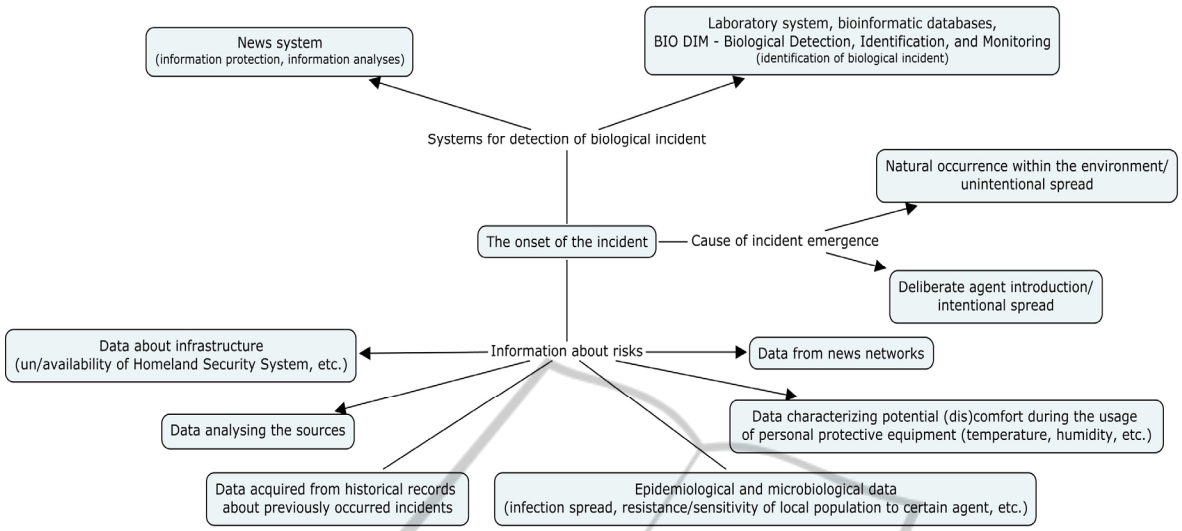

Figure 1: The Illustration of the Cognitive Maps Utilisation - the Onset of the Incident and the Following Phases (Source: authors).

concepts, their relations and constraints from given domains. The specification of concepts and relations together with inference engine would enable the identification of implicit relations that were not given explicitly during the knowledge acquisition phase of the research.

Although, the ontology would enable simple inferences, the implementation of procedures modelled using the decision trees will require translation to the form of rules. The discovered rules will be processed by a rule based engine incorporated in the designated prototype. The prototype that would test the overall functionality of the framework will be designed using the object oriented modelling. However, since the translation of rules into an object oriented system is not straightforward, projects like Hammurapi rules would need to be explored (Čech, Bureš, Antoš and Ponce, 2010). Moreover, the real challenge with disaster modelling is to test the procedures without ever having a disaster event. Therefore coping with this type of problem represents the main focus of further research.

7 CONCLUSIONS

In case of biological or chemical incidents the knowledge necessary to properly conduct the response operation is usually hidden in general disaster and recovery plans, or is locked in the heads of experts and could be difficult to get quickly enough in a form that can be used by the decision maker. Moreover, experts are usually focused on a narrow view of a problem lacking the overall picture. Therefore, the paper bridges the gap between theoretical and real-world risk management. The described research was focused on the selection and consequent application of appropriate methods or techniques, which would help to solve this issue. During the arranged set of sessions with experts various knowledge elicitation techniques were applied. The suggested framework enables knowledge conceptualization across multiple domains and facilitates robust decision support tools for emergency situations.

The results of this initial stage are key decision parameters (e.g. transmission, infectiousness, incubation), which were identified and prioritized. Furthermore, the responsibility for providing specific information was ascertained. The main output, which will be used as an input to the next stage, is the set of questions that should be answered to determine appropriate response operation. The decision tree was used to model the sequence of questions and possible outcomes. The overall result of the research should have the form of a prototype, which will support decision makers in the effort to minimize casualties during selected intended (biological or chemical weapons) and unintended (biological or chemical accidents) incidents.

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