# Intelligent Visualisation and Information Presentation for Civil Crisis Management

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## SUMMARY

*This paper describes an ongoing research work on developing methods for effective visualisation support for situation analysis, decision making, and communication in the course of disaster management. The major goals are to reduce the information load of the analyst, decision maker, or information recipient without omission of anything important and to ensure quick and accurate comprehending of the information. The work embraces the issues of selection of the relevant information and defining the appropriate level of detail, data preparation (aggregation and other transformations), and selection of the appropriate methods for visual representation depending on the user's tasks or communication goals, recipient's profile, and the target presentation medium. A practical outcome from the research will be a knowledge base that can be used to support analysis, decision making, and information communication in emergency situations. A great part of the knowledge, specifically, knowledge on data transformation and representation, is generic and can be used for different applications.*

**KEYWORDS:** *Visualisation, visual communication, knowledge-based techniques, decision support*

## INTRODUCTION

This paper describes a research work carried on within the integrated EU-funded project OASIS (IST-2003-004677, coordinated by EADS France, started in September 2004, duration 48 months; see http://www.oasis-fp6.org/). The project as a whole aims at defining a generic crisis management system to support the response and rescue operations in case of large-scale disasters. The research presented here focuses on the use of intelligent visualisation for supporting the crisis management personnel in the analysis of the situation, finding appropriate ways to solve problems, making well-grounded decisions, as well as for informing and instructing the crews, partner organisations, and population.

The objective of intelligent visualisation may be formulated as "give everybody the right information at the right time and in the right way". This statement involves two aspects:

1. A person or organisation (further referred to as "actor") should be timely supplied with the information that is necessary for the adequate behaviour in the current situation or fulfilling this actor's tasks.
2. The information should be presented in a way promoting its rapid perception, proper understanding, and effective use.

The first aspect refers to the problem of the selection of the relevant information, depending on the situation and the needs, goals, and characteristics of the actor. The second part refers to the problem of effective preparation, organisation, and representation of the information. This, again, depends on the goals and characteristics of the intended recipient and should take into account the specific constraints of emergency situations, in particular, the time pressure and stress factor.

The general requirements to intelligent visualisation include:

- Reduce the information load on the recipient: not only irrelevant information should be excluded but also the relevant information should be adequately aggregated and generalised leaving out unnecessary details.
- Choose representation techniques and design the display so as to ensure quick and accurate recognition of the meaning of the information conveyed.
- Take into account the characteristics of the medium used for viewing the presentation.

Intelligent visualisation supposes that both the selection of the relevant information and the subsequent processing, organisation, and representation of the selected information are automated. This is done by applying the knowledge base technology, i.e. incorporating expert knowledge in the visualisation software.

A similarity can be noted between the definition of intelligent visualisation presented above and the notion of decision-centred visualisation (Kohlhammer and Zeltzer 2004), which means the usage of problem-oriented domain knowledge for intelligent data search, processing, analysis, and visualisation in time-critical applications. However, this does not include knowledge-based design of visual displays for communication purposes such as instructing specific addressees how to act or alerting to a danger. Our view of intelligent visualisation embraces the use of visual displays for data analysis, decision support, and information communication.

## RELATED WORK

An established truth concerning the application of knowledge based technologies is that the methods of knowledge representation and automatic inference as well as the architectures are much less important for successful problem solving than the knowledge itself. There is no AI method or tool that could be simply taken and mechanically reused to produce an appropriate result. The lion's share of effort in developing knowledge-based systems is spent on defining and collecting the required expert knowledge. Therefore, the most relevant to the topic of this paper are works on modelling crisis management-related knowledge.

Thus, Gadomski et al. (2001) describe an approach to building an intelligent decision support system for emergency management where a specific emergency domain (e.g. an oil port) is formally represented as a set of objects (e.g. docks, oil tanks, tankers, etc.). The states of the objects are specified by means of attributes. Besides this descriptive knowledge, the system includes procedural knowledge about emergency operations, for example "Foam the top ring of a tank when irradiated or burning or spilled". Such actions are formally represented using a mathematical logic-based notation. The knowledge is used for suggesting the user appropriate actions or plans to overcome crisis situations.

Hoogendoorn et al. (2005) apply formal modelling techniques to disaster response plans. Being represented in a formal language, disaster plans can be analysed, rigorously tested, and compared. A formal model of a disaster plan represents the organisations and teams involved in the disaster management, their roles and responsibilities as well as communications and interactions between them. The formalism allows representing not only static organisational structures but also changes of the structures that may take place under certain condition, for example, if the scale of an event increases.

Eifried (2005) suggests a model describing the major activities involved in a response to a terrorism incident (the author focuses mainly on chemical terrorism incidents). The model represents the operations flow (actions and interrelationships over time) and the information flow involved in a typical response. The model does not appear to be sufficiently formal for utilisation in a knowledge-based system. It is intended mostly for educational purposes, in particular, to assist information system developers in understanding of the activities taking place during an incident response.

Mors et al. (2005) strive at building a mathematical framework that would allow formal representation of response operations for the purpose of building automated decision support systems for emergency response. The research is on a preliminary phase. The major concepts the authors consider are those of *task* and *event*. Incident management consists of various tasks where the execution of one task may depend on the execution of another. Emergency situations are characterised by incoming events such as building collapse, equipment breaks down, alarm call comes in, an emergency response team arrives at the scene, etc. Mors et al. are developing a formal language that would allow one to describe events, tasks, and interrelationships between them.

Kohlhammer (2005) considers emergency management as one of possible applications of the conceptual approach entitled "decision-centred visualisation", or DCV. The essence of DCV is the use of domain ontologies and knowledge to filter and prioritise information and events to be shown to a decision maker, depending on his/her role and current task. The work focuses on defining the conceptual framework and appropriate architecture rather than actual knowledge modelling. According to the framework, the domain ontology of a DCV system consists of four parts, which define

- types of entities existing in the domain and relevant to decision making;
- types of events that may occur and influence decision making;
- user roles;
- types of tasks the users may perform.

Besides the ontology, the framework includes a so called "domain database", which, in fact, is a knowledge base specifying relationships between event types, task types, user roles, and entity types. There are two types of relationships:

- "affects": the event type X affects the task type Y of a user in the role Z;
- "requires presentation of": the task type Y of a user in the role Z requires presentation of the entity type E (or attribute A of the entity type E) .

Hence, if decision-relevant knowledge from a certain domain is represented according to this schema, a DCV system can monitor a situation and, upon an occurrence of any event with accompanying information, determine what items of this information need to be presented to the user, depending on his/her current role and task. The way in which the information is presented depends on the capabilities of the available display system and is mostly out of the scope of Kohlhammer's work.

Another class of relevant research includes work on knowledge-based visualisation and modelling of visualisation-related knowledge. Since early 1980-ies, a number of research software systems for automated graphics generation have been created; see the survey (Murray 1994). In the system APT developed by Mackinlay (1986), the approach is adopted that was followed in many later research works. According to this approach, the system partitions the data to be presented into subsets with simpler structure so that it becomes possible to select some visualization primitive for each subset. The visualization primitives include Bertin's visual variables (Bertin 1983) such as position on the display, symbol size, shape, colour, etc. and some established graphical encoding techniques such as bar charts, pie charts, line plots, etc. The visualization primitives selected for the subsets are combined with the use of composition operators. The design process is performed by a planning module capable of backtracking and revision of commitments made earlier.

Selection of primitives is governed by the expressiveness criteria based on the Bertin's principle of correspondence between the properties of data components and the properties of visual variables. When several primitives are expressive for a given data component, the system applies effectiveness criteria to select the best of them. Mackinlay ranks the primitives according to the accuracy of decoding values from graphics but admits that other effectiveness criteria can be used as well.

Composition operators are also ranked: an operator is considered to be more effective if it produces less number of graphical objects.

The work of Mackinlay demonstrated the feasibility of automated graphics design on the basis of generic, domain-independent principles and rules of visualization. Other researchers further developed Mackinlay's approach. In the system VISTA (Senay and Ignatius 1994), more visualization techniques and composition operators were available. This allowed, in particular, building 3D graphics. In the project SAGE (Roth and Mattis 1990), the register of data characteristics to be accounted for in graphics design was significantly extended. The design was also sensitive to the user's information seeking goals expressed as generic tasks of the kind "accurate lookup of separate data values", "comparison of values of two attributes", "study of the distribution of values", or "revealing of functional correlation among attributes". Casner (1991) considered more precisely specified information-processing tasks constructed from predefined primitive logical operators such as a query for a property of an object or arithmetic operations over values.

An attempt to approach the problem of cartographic visualization is described in (Zhan and Buttenfield 1995). The authors built an expert system that consulted a GIS user what visualization technique to select for a given data field. The system did not deal with several attributes and did not perform the visualization. On the basis of this work and the approach of Mackinlay, the system VIZARD was created (Jung 1995) that designed and implemented map visualizations. Like in SAGE, user's information processing tasks are taken into account.

Kohlhammer (2005) criticises these early works on automated graphics design for computational inefficiency, which may be a problem in time-critical applications such as crisis management. Another problem related to the design of graphics from visual primitives is that the appearance of the resulting displays may look unfamiliar to the user and, hence, the displays may be difficult to understand and use. In Kohlhammer's opinion (and this is our opinion as well), an essential requirement to information displays intended for the use in time-critical applications is that the information must be presented in a way familiar to the user. Hence, it seems more appropriate to apply the approach when some previously defined basic designs are adapted to current user needs rather than building new graphics "from scratch".

Sarjakoski et al. (2005) follow this approach (while the application domain is different from crisis management). Their knowledge-based system automatically adapts the content and appearance of a map depending on the context. The context may include such aspects as the purpose for which the map will be used (e.g. hiking, cycling, or skiing), the time (e.g. summer or winter), the user age (e.g. a young or elderly person), the device on which the map must be displayed, etc. The idea is to define the possible use cases, or contexts, and to provide the corresponding map specifications in a knowledge base. A map specification defines what features must be included in a map (this relates both to the geographical background information and to the items of interest) and how these features should be represented. To save the time and effort of knowledge base developers, the authors propose an approach when only one or a few map specifications are fully described while any other specification is introduced as a modification of one of those basic map specifications. In this case, only the deviations from the basic specification need to be described.

The authors of the current paper have also their own experience in developing intelligent software for automated design of interactive maps; see (Andrienko and Andrienko 1998, 1999a, 1999b). However, the former research was focused on the visualisation of geographically related data for the purposes of exploratory data analysis. In OASIS, the focus is different. The major goal is to extract relevant information and to communicate it to crisis managers, stakeholders, and public in the most effective way. Therefore, the current research, which is described in the remainder of the paper, is quite different from the previous work while the experience in knowledge-based map design is certainly a valuable asset.

## TWO MODES OF USING INTELLIGENT VISUALISATION

The intelligent visualisation is used for two different purposes:

- Build an interactive display to support the work of an analyst, planner, or decision maker.
- Build an information presentation for sending to a specific recipient.

The first type of use supposes that the information is presented directly to the user of the system. The display is shown on the screen of the same computer where the system runs and remains linked to the system, i.e. may be further controlled and updated by the system when needed.

The second type of use supposes that the presentation is intended for another person or group of people. The display must be standalone so that the addressee could view it independently of the system and not necessarily on a high-end computer screen. Thus, performers on site may be informed and instructed by means of hand-held or head-mounted devices but also on paper (e.g. by fax). People in the danger zone can be alarmed, warned, and instructed through their mobile phones and electronic information boards while information kiosks may provide additional information when appropriate. General public (observers) is usually informed by means of TV and newspapers. Each type of media imposes its specific constraints on how information can be presented and further dealt with. The intelligent visualisation support system must take these constraints into proper account.

## THE KNOWLEDGE FOR INTELLIGENT VISUALISATION

The following types of expert knowledge are needed for the intelligent visualisation:

- Emergency management domain ontology: a system of general notions relevant to the domain of emergency management and the relations between those notions. This includes
    - Various types of events such as fire, flood, or chemical contamination, their elements (agents) such as flame, heat, water, or hazardous substances, and the effects that may be produced by these agents such as ignition, detonation, destruction, or contamination;
    - Types of objects entailing latent dangers and the agents that may activate those dangers. For example, petrol facilities are hazardous in case of ignition while an electric transformer station is a source of risk in case of leakage of a flammable gas;
    - Various groups of population that may require help, their special needs, and types of places where these population groups may be present, such as schools, hospitals, or shopping centres;
    - Generic tasks that are often involved in emergency management, such as evacuation of people, animals, and valuable objects from the danger zone;
    - Types of resources and infrastructure that may be needed for managing emergency situations, including people, teams, and organisations (e.g. a fire brigade or a bus company), transportation means, roads, sources of power, fuel, and water, and so on.
- Generic actors (roles) involved in an emergency situation and their typical information needs. The following generic roles are considered:
    - Analyst: a person (typically in the situation control room) that needs to understand the current situation and its development, identify problems, and find proper ways of solving the problems.
    - Decision maker: a person who chooses a specific way of solving a problem from the possible variants defined by the analyst (which may be, in particular, the same person as the decision maker).
    - Planner: a person who builds a plan for realising a chosen way of solving a problem or achieving a specific goal, assigns tasks to performers and allocates available resources to the tasks. Again, this may be the same person as the analyst and/or decision maker.

- Performer: a person, group, or organisation fulfilling a particular task or sequence of tasks. A performer may need to make various tactical decisions depending on the specifics of the situation and its changes.
    - Sufferer: a person, group, or organisation that is exposed or may be exposed to some of the danger factors of the emergency situation.
    - Observer: a person or organisation that is not directly involved in the emergency situation but is interested in receiving information about it. This includes, in particular, the mass media, which broadcast information about the situation to the general population.
- Techniques and methods to manipulate, organise, and present various types of data, which include:
    - Methods for data aggregation, smoothing, interpolation, transformation from absolute values to relative, change computation, etc.
    - Principles of choosing display types and graphical primitives according to data characteristics.
    - Principles of representing data according to the tasks they are supposed to be used for.
    - Methods for combining several displays providing complementary information.
    - Methods for controlling the level of detail and the visual prominence of information depending to the degree of relevance.

The knowledge on data manipulation and representation is independent of the emergency management domain unlike the former two categories of knowledge, which are domain-specific. It is therefore reasonable to separate the domain-independent and domain-specific knowledge. This approach allows the visualisation knowledge to be reused for other applications.

The entire intelligent visualisation system can be viewed as consisting of two cooperating expert subsystems, which may be called “emergency management expert” and “visualisation expert”. The emergency management expert selects the necessary information depending on the needs of the intended recipient determined by recipient’s role and the current status of the situation. Then the visualisation expert finds appropriate methods for transformation and presentation of the selected information.

A critical issue in building any expert system is the acquisition of the necessary knowledge. The success or failure of the endeavour depends chiefly on the quality and comprehensiveness of the knowledge that can be collected and adequately represented. To solve this challenging problem, we take an incremental approach. We start with a few selected types of emergency events and their agents, a subset of actors, and a limited set of data types dealt with. We also do not try to build at once a full knowledge base on data manipulation and visualisation but choose a subset of methods to address. In case of success of the pilot prototype, it will be gradually extended and elaborated.

As the source of domain-specific knowledge, we use the literature on crisis management (e.g. Rosenthal et al. 1989, Rosenthal and Pijnenburg 1991) and available reports about real incidents. Much information concerning the management of real disasters can be found in the news reports from various news agencies available, in particular, on the Web. Thus, using the Web, we have compiled a rather detailed description of the course and management of the flood in Czech and Germany in August 2002.

The domain-independent knowledge on data preparation and visualisation comes from the extensive literature on information visualisation, geographic visualisation, data analysis, and graphics design. We have recently summarised the current state-of-the-art in these areas with the focus on techniques and tools supporting data exploration and analysis (Andrienko and Andrienko 2006). Additionally to this, we need the knowledge concerning effective information presentation according to the intended communication goals. The relevant literature includes exposition of general principles (e.g. Tufte 1997) and reviews of techniques suitable for specific purposes such as increasing the visual prominence of the most relevant information (e.g. Reichenbacher 2005). Our orientation to various types of output media necessitates the use of knowledge concerning the possible ways of presenting information on these media. In particular, we can use the recent research results concerning information visualisation on mobile devices (e.g. Gartner and Uhlirz 2001).

## PUTTING THE KNOWLEDGE IN OPERATION

The organisation and functioning of the intelligent visualisation system can be schematically represented as is shown in Figure 1.

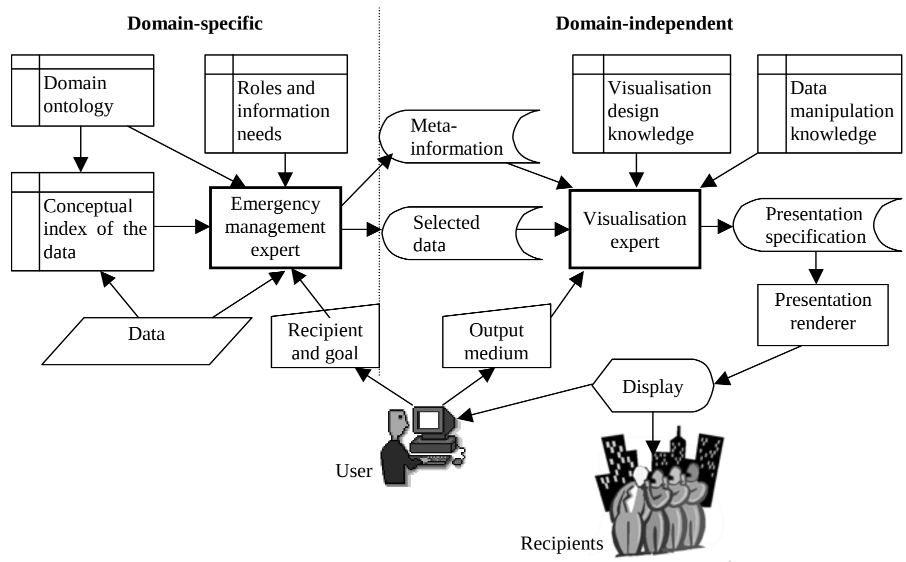


***Figure 1:*** A schematic representation of the structure and functioning of the intelligent visualisation system for emergency management.

According to the approach adopted, the emergency management expert uses the domain-specific knowledge in order to find and retrieve the addressee-relevant information and to supply it with meta-information that allows the visualisation expert to interpret, process, and present this information adequately. The meta-information includes the following items:

- Type of the entities the information refers to: movable or unmovable objects, places, processes, actions, or relations.
- Structure of the data and types of the components they consist of: spatial, temporal, numeric, ordinal, or categorical.
- Quality and certainty of the information: does the information result from actual measurements or observations or from prediction or estimation? What is its degree of accuracy or certainty?
- The goal of providing the information to the addressee:
  - alert, attract attention to something unexpected like an impending threat;
  - inform: what, where, when happens and how evolves;
  - suggest, e.g. some action to take or additional information to consider;
  - enable: analysis, reasoning, decision making, or action planning;
  - instruct: what, where, when, how to do or to avoid;
  - explain or justify, e.g. a proposed solution or a decision made.

- Degree of relevance to the goal: information of primary importance or supporting information (e.g. orientation clues).
- Degree of novelty to the addressee: new or known.
- Criticality, i.e. whether an information item requires immediate attention of the addressee.
- The expected level of addressee's knowledge concerning the topic of the information and the geographical area the information refers to.

The meta-information concerning the character, structure, and properties of the information comes from the indexing of the information items in terms of the domain ontology. The emergency management expert must specify this meta-information in a domain-independent manner so that the visualisation expert could use it without having any domain knowledge.

In the use cases when the intelligent system generates an interactive display directly for its user to support situation analysis or decision making, the goal of providing information is typically clear from the current context of the system use as well as the information needs of the user. In the cases when the user wants to send some information to a different actor, the user is expected to specify the addressee's role and geographical location and the goal for which the information will be used. On this basis, the emergency management expert can estimate the degree of relevance, novelty, and criticality of each information item for the recipient. For this purpose, it uses the domain knowledge concerning the actors (roles) and their typical information needs. The same knowledge allows the expert to estimate the probable level of addressee's thematic and geographic knowledge. Thus, an analyst may be qualified as an expert in emergency management issues but the level of knowledge concerning the area of the incident may be low. In opposite, the local population to be alerted may know the area quite well but be unaware of the character of the particular threat and the possible consequences.

Since the information is selected and supplied with the meta-information, the visualisation expert can apply its domain-independent knowledge to prepare the data (aggregate, transform, classify, etc.), choose adequate display types and graphical primitives, provide an appropriate level of detail and degree of visual prominence for each information component depending on its relevance and criticality, arrange components in a composite display, and so on. If the user requests a standalone display for sending to another actor, he/she is expected to specify the intended output medium: a standard desktop or laptop computer, a small-size mobile computer, a mobile phone, a head-mounted display device, television, or paper. The visualisation expert will take into account the typical characteristics of this medium specified in its knowledge base: size, resolution, available colours, possibilities for dynamic output and user interaction, memory capacity, individual or public use. If the characteristics of the output medium permit, the visualisation expert may design a dynamic (animated) display and/or include appropriate interaction controls, for example, for zooming or switching between pages.

The design produced by the visualisation expert is implemented by a rendering component, which generates a corresponding information display on the screen of the user's computer. If the presentation is intended for a different recipient, the display serves as a preview and allows the user to edit the presentation, e.g. to change colours or symbol sizes. After user's approval, the rendering component generates either a static image or a presentation in SVG (Scalable Vector Graphics) format, which may be dynamic and include some interactive controls.

## PROGRESS TO DATE

This paper describes a work in progress. Not all ideas presented above have been already implemented. At the moment of writing this paper, the domain-specific part of the system is quite developed. This includes the emergency management expert and a problem-specific user interface. The domain-independent part, which consists of the visualisation expert and the presentation renderer, is on an early phase of development. In this section, we describe the currently available functionality and present a roadmap for the implementation of the visualisation expert.

## Situation Manager

We use the name "Situation Manager" for the software module that includes the emergency management expert, the user interface, and various service routines such as data loading. The main functionality of Situation Manager is intelligent search for various types of relevant information.

As a prerequisite of any search, the system needs information about the current crisis situation and the territory affected by the situation. The information about the situation may come from another OASIS component or from the network or may be entered by the user in a dialog. The system needs to know what event(s) has (have) occurred and where. Besides the location of each event, an approximate perimeter of its impact zone must be defined. If this information is not supplied, the system builds the outline of the impact zone by itself under user's supervision. For this purpose, it utilizes the information about the effect distances of the hazardous agents involved in the events, which is specified in the knowledge base. Information about the crisis-affected territory is loaded upon demand from a database or from files.

As soon as information about an event is received, Situation Manager identifies the hazardous agents involved in it. This information comes from the description of the respective event type in the knowledge base. Although the list of currently active hazardous agents is shown to the user, it is mainly intended for internal use. In particular, it plays an important role in the search for potential dangers: the system looks for objects situated in the impact zones of the active hazardous agents and containing, in turn, other hazardous agents. For each such object, the system checks whether the hazardous agent contained in it can interact with any of the active agents so that this can produce an undesirable effect. For example, sparks contained in a transformer station can interact with an explosive gas spreading over the territory and produce an explosion. The system also checks whether the hazardous agent can escape from the object. This may happen in one of two cases:

- Some of the active agents can destroy the container. If this happens, the hazardous substance will not be confined any more. For example, a blow involved in an explosion may ruin a container of toxic chemicals; hence, there is a risk of those chemicals being released.
- Some of the active agents may act as carriers of the agent (in particular, substance) contained inside the object while the object is not protected from those agents. For example, water involved in a flood may carry liquid or solid wastes contained in a purification plant or a waste treatment factory.

The search procedure works on a generic level using information about classes of objects and types of agents available in the knowledge base; see example definitions in Figure 2. However, the system needs to recognise the class of each specific object present in the database of objects. For this purpose, the system checks whether the name of the object or the value contained in the database field denoting object type includes any of the keywords specified in the definitions of the object classes in the knowledge base. For example, a territory-specific database of objects may contain a record about an object AGIP with the value "gas station" in the field "type". This allows the system to associate this object (and all other objects with the same value in the field "type") with the concept "petrol station", which is defined in the knowledge base as is shown in Figure 2.

```xml
<ObjectClass id="petrol_facilities" local="true" >
    <Name>
        <Default>petrol facilities</Default>
        <Keyword>petrol</Keyword>
        <Keyword>gasoline</Keyword>
        <Keyword lang="German">Benzin</Keyword>
    </Name>
    <Content category="Substance" type="petrol" presenceTime="continuous"
             storageType="hermetic" />
</ObjectClass>

<ObjectClass id="petrol_station" isA="petrol_facilities" >
    <Name>
        <Default>petrol station</Default>
        <Synonym>gas station</Synonym>
        <Synonym>gasoline station</Synonym>
        <Synonym lang="German">Tankstelle</Synonym>
    </Name>
</ObjectClass>

<ObjectClass id="school" local="true" >
    <Name>
        <Default>school</Default>
        <Keyword lang="German">Schule</Keyword>
    </Name>
    <Content category="People" type="children employees"
             presenceTime="recurrent" >
        <TimeLimits>
            <WeekDay from="Monday" to="Friday" />
            <DayTime from="7" to="15" />
            <Excluded>holidays vacations</Excluded>
        </TimeLimits>
    </Content>
</ObjectClass>
```

***Figure 2:*** Examples of definitions of object classes in the crisis knowledge base.

If, after the recognition of the object class, the system finds out that this object contains an agent that can interact with the active agents or can escape from the container, this object is treated as a source of potential risk. On the basis of the knowledge base, the system generates an appropriate explanation concerning the risk. A list of potentially dangerous objects with the corresponding explanations is shown in the user interface of Situation Manager (Figure 3). Simultaneously, the locations of the objects are displayed on a map, where the objects are represented by iconic symbols (Figure 4).

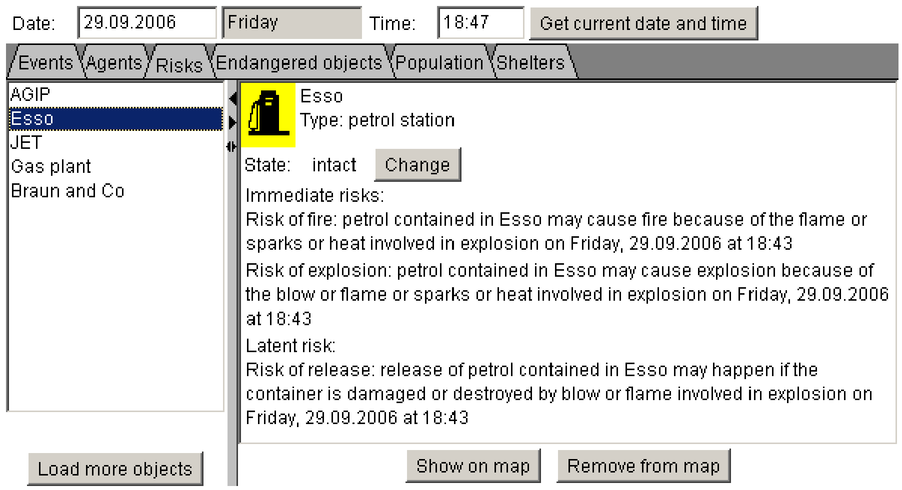


***Figure 3:*** Presentation of the list of potentially dangerous objects and explanation of the risks.

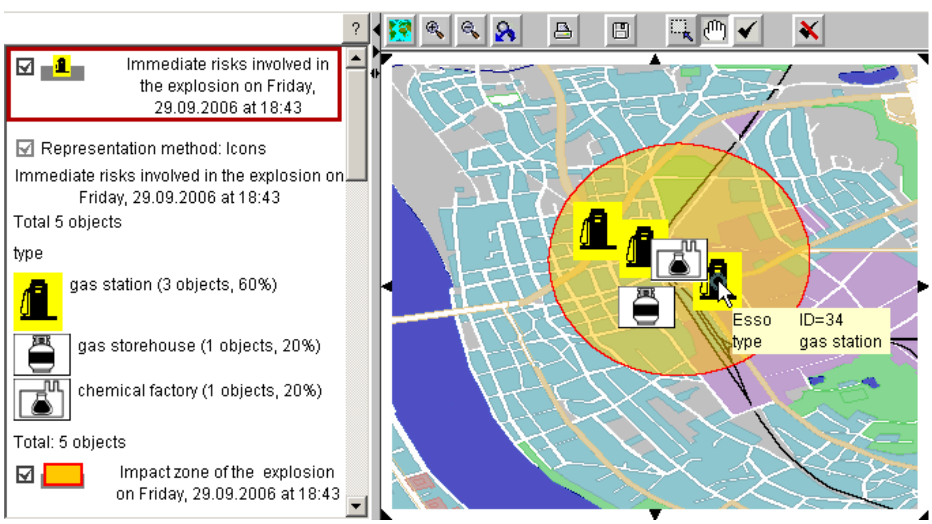


***Figure 4:*** The positions of the potentially dangerous objects are shown on a map display using iconic symbols.

Furthermore, Situation Manager displays a list of possible secondary hazardous events that may be caused by the risks detected. For each event, an explanation is generated on the basis of the content of the knowledge base (Figure 5). Whenever possible, the system automatically estimates the impact zones of the potential events, which can be displayed on the map upon user's request.

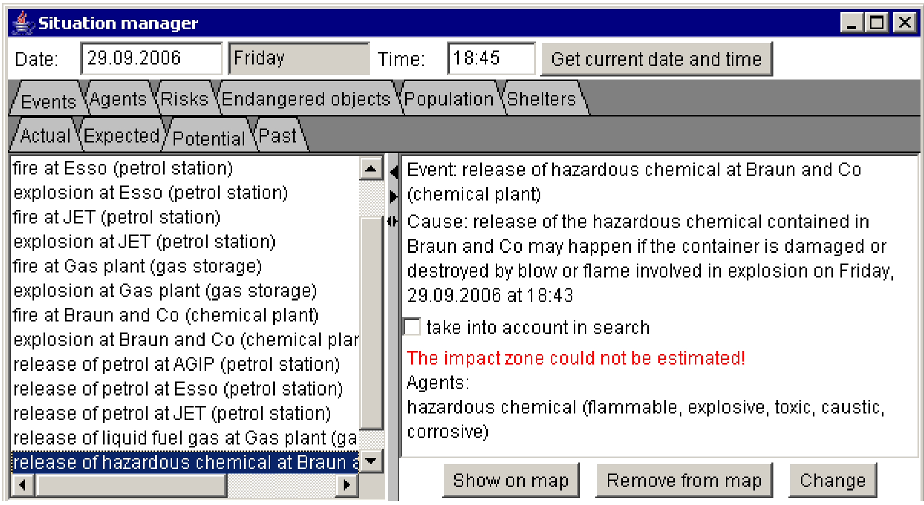


***Figure 5:*** A list of possible secondary events that may occur in the current situation as a result of interaction of the active agents with the dangerous objects present in the crisis area.

The search for objects that need to be saved or protected is done in the following way. The system, again, looks for objects situated in the impact zone of any of the active hazardous agents. After recognizing the class of an object on the basis of the keywords, the system looks in the knowledge base whether this kind of object may contain people or valuable items at the current time (see the definition of the object class "school" in Figure 2). However, even if the items are not likely to be present inside the object at this time, the system does not discard the object but marks it as having low probability of containing the items. The idea behind is that the user should anyway check if the items are there to be sure that nobody and nothing is forgotten. Thus, a school normally does not contain people in the evening; however, there may be a special event (e.g. a party or a concert of the school chorus) when people come to school in an unusual time.

If an object may contain people (whatever the probability is), the system checks if the people can escape the danger on their own. This is possible when the following conditions are fulfilled:

- The people are not present inside the object continuously (i.e. do not live there);
- The danger approaches rather slowly so that the people have enough time to move away;
- The people have no special needs for enabling their movement.

The information about the presence time comes from the description of the object class in the knowledge base. The information about the speed of the approach of the danger comes from the description of the event and of the agents involved (attribute "approach" with the possible values "instant", "rapid", and "prolonged"; the latter value indicates that people have enough time to escape). The information about the special needs comes from the description of the people class in the knowledge base. However, even if the system finds that the people can escape the danger without help, it does not discard the object but marks it as having low probability of containing people. As in the search for potential risks, the system generates explanations about the objects found, which include the types of items they may contain, the dangers these items are exposed to, and the special needs they have (Figure 6). The positions of the objects are shown on the map display. The degree of criticality is reflected in the sizes of the symbols representing the objects: smaller symbols are used for the objects that are less likely to contain endangered items at the current time (Figure 7).

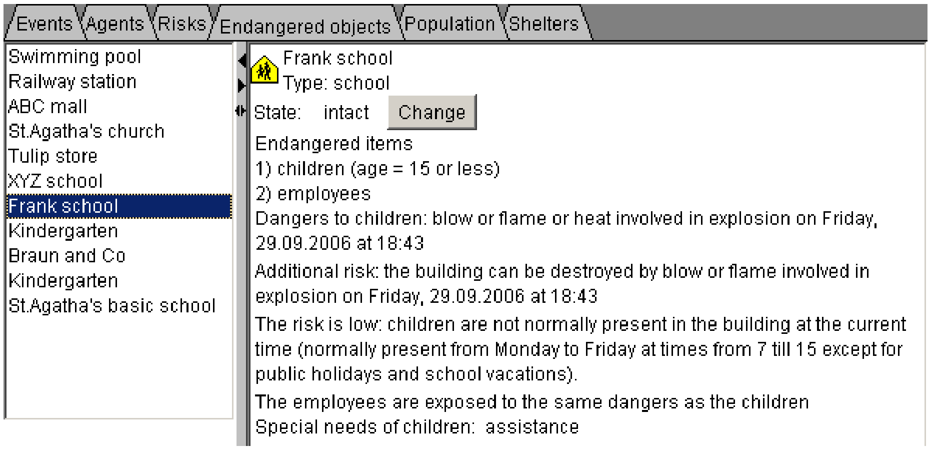


***Figure 6:*** A list of endangered objects with explanations.

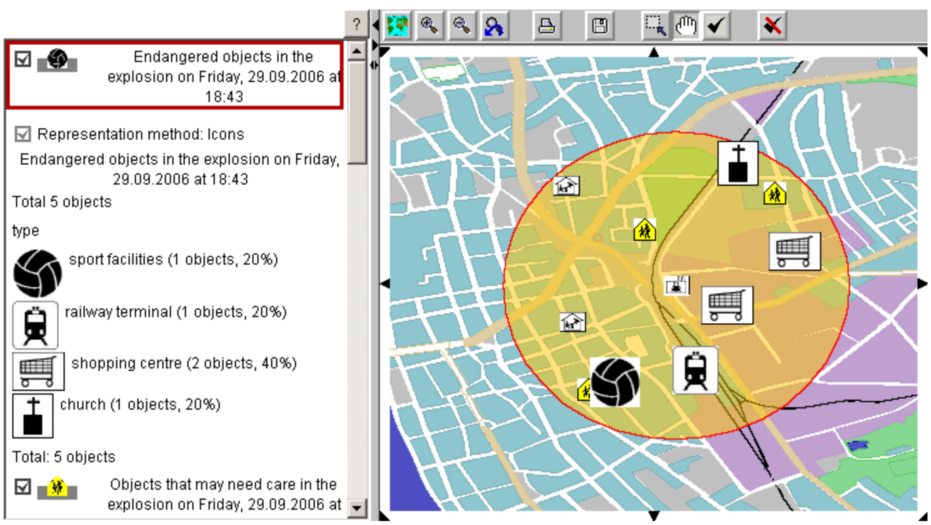


***Figure 7:*** Positions of the endangered objects are shown on a map display. Smaller symbols are used for objects that are less likely to contain endangered items at the current time.

The user can also check what objects will be in danger or entail potential risks in case of occurrence of any of the potential events, which have been defined by the system (see Figure 5). For this purpose, the user should select the checkbox “take into account in search” in the description of the event. If the system was not able to estimate the impact zone of the event automatically, it asks the user to specify the expected zone. This may be, in particular, a circle or an ellipse generated by the system according to user-specified parameters. The example map in Figure 8 shows what objects will be affected in case of release of a hazardous substance from the chemical plant if it spreads in the south-western direction on the distance of 1500m.

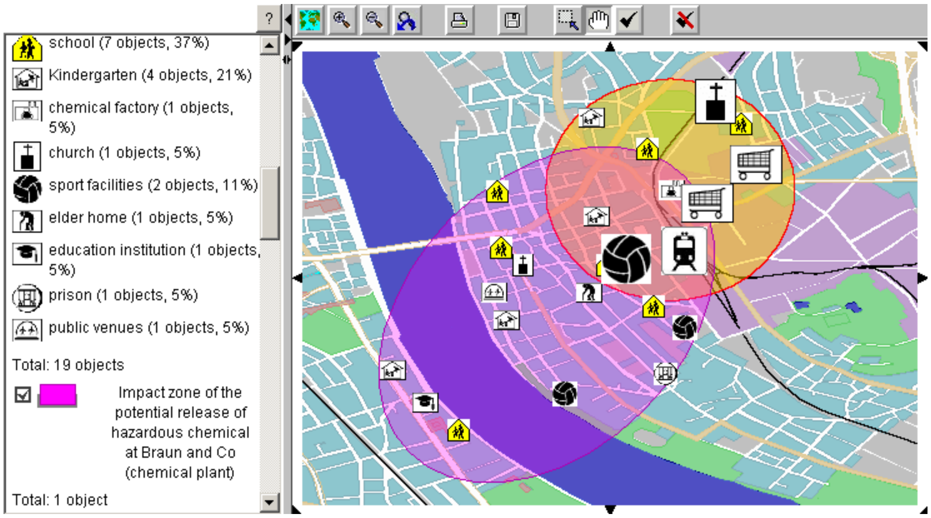


***Figure 8:*** The map display shows what objects will be affected in case of occurrence of one of the potential events, specifically, release of a hazardous chemical from a chemical factory.

Similarly to the search of risk objects and endangered objects, Situation Manager can also search for objects that could be used as shelters. The classes of objects suitable for this purpose are specified in the knowledge base. It is also specified for what categories of people they can be used. On this basis, the system looks for objects of the suitable classes that are situated outside of the danger zone (the minimum distance to the danger zone is specified by the user) and groups the objects found according to the people categories they are suitable for (Figure 9).

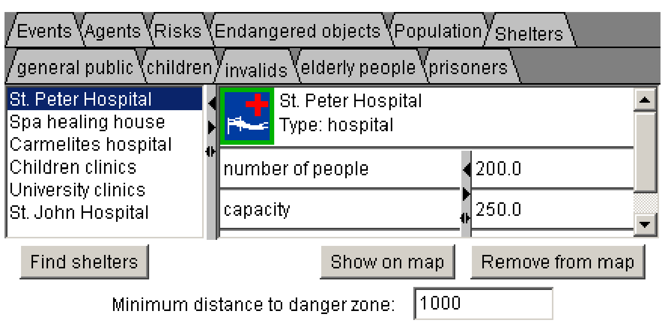


***Figure 9:*** The potential shelters are grouped by the people categories they are suitable for.

One more intelligent function of Situation Manager is the estimation of the number of population living in the danger zone. For this purpose, census data can be used where population counts are specified for some territory compartments such as enumeration districts or administrative districts. To fulfil the function, Situation Manager needs to know the meanings of the attributes present in the census data. More specifically, the system needs to know which attribute denotes the number of the population as a whole and which attributes correspond to population groups having special needs, such as children, elderly people, or invalids. The system tries to infer this information automatically from the attribute names or from metadata, if provided. For this purpose, it uses the keywords specified in the definitions of the people categories in the knowledge base. Additionally, the system uses the information about the properties of the people categories, which are also specified in the knowledge base. Thus, some people categories are defined in terms of age; for example, elderly people are people whose age is 65 years or more. To find attributes that may refer to elderly people, the system looks for occurrences of numbers 65 or greater. If there are several such attributes, for example, p65-75 and p75-99, the system assumes that the number of elderly people is the sum of values of these attributes. Figure 10 shows that system's guesses about the semantics of census attributes may not always be valid (thus, the system mistakenly ascribed the attributes nHouse96 and nHouse95 to the category of elderly people); therefore, the user is always asked to check and correct them when necessary.

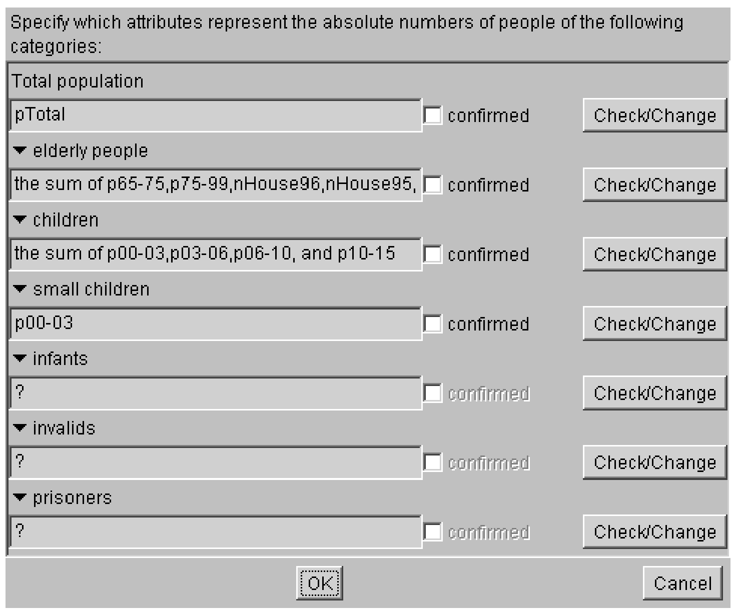


***Figure 10:*** The system asks the user to check and correct its guesses concerning the semantics of the attributes available in the census data.

After establishing the meanings of the relevant census attributes, the system looks through the census data and extracts the values of these attributes associated with the districts that fit in the cumulative danger zone of all events or overlap with it. For the districts that are not fully covered by the danger zone, the system computes the proportion of the coverage and multiplies the attribute values by this fraction (of course, this is a rough estimation assuming that the people are evenly distributed within the district). The numbers for different districts are summed up, and the resulting estimations are presented to the user in a form of table.

As we have mentioned, the "visualisation expert" capable of building information presentations for various actors and various media is not available yet. Still, the user has an opportunity not only to see the results of intelligent search on the screen of his/her computer but also to communicate this information in a visual form to others. For this purpose, the system builds an SVG (scalable vector graphics) presentation with the same content as the current map display. This is not just an image but an interactive presentation with facilities for zooming and panning, switching map layers on and off, and viewing information about objects (the information is shown in popup windows as the mouse cursor points on the objects). The SVG display can be viewed in a Web browser with the use of a standard plug-in; hence, it can be sent to another actor, who does not need to have the OASIS system for reading the visual message.

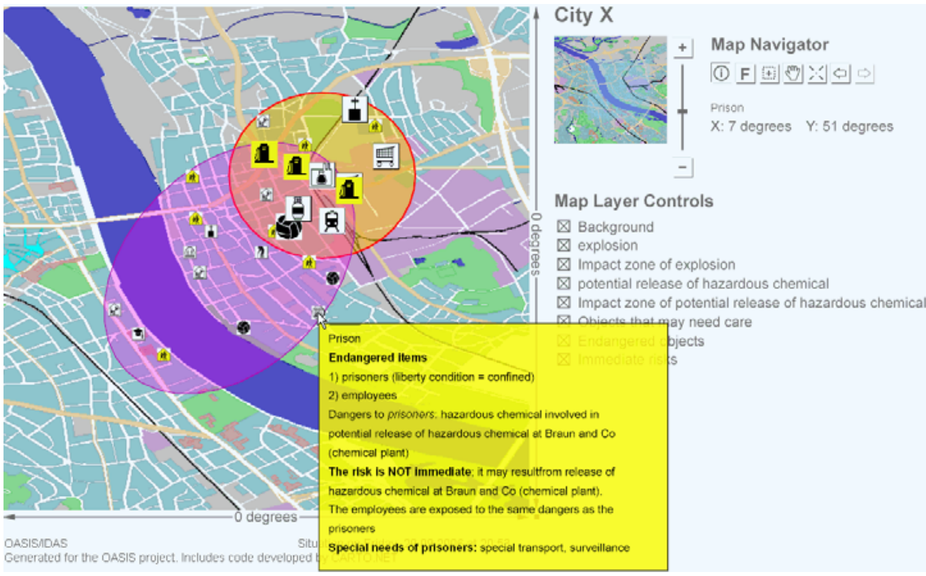


***Figure 11:*** An interactive presentation in SVG, which can be used for communication of relevant information to various actors.

## A roadmap for implementing the visualisation expert

Stated on a very general level, the approach is to produce visual displays by adapting some prototypical designs rather than by designing “from scratch”. A prototypical design specifies the information content of the display in terms of information categories, the structure of the display in terms of the visualisation modalities involved (that is, what components it consists of, e.g. a map and a table), and the choice of visualisation techniques and visual variables. The challenge is to define prototypical designs in a generic, domain-independent way.

Each prototypical design is associated with a certain generic task, for example, “give an overview of the current situation” or “show the development of the situation over time”, where the situation is not necessarily a crisis situation. The list of appropriate generic tasks is yet to be defined. We do not expect to be able to enumerate all possible generic tasks during the time of the OASIS project. Instead, we are going to consider examples of visualisation tasks that may occur in the course of crisis management and generalise these examples so as to receive domain-independent task formulations. It should be noted that a generic task is not only a name but also a description of the supposed content and purpose of use.

The generic tasks and corresponding prototypical designs are utilised in the following way. For a specific task on visualising a certain collection of information, a matching generic task is found. Then, the prototypical design associated with this generic task is chosen. This design is instantiated with the specific information that needs to be visualised, which results in a specific design to be implemented by a display generation module.

Besides the generic tasks and the prototypical designs, the knowledge base on visualisation design contains constructs that may be called "design modifiers". This is similar to the approach suggested by Sarjakoski et al. (2005). A design modifier specifies how a prototypical design should be modified depending on certain aspects of the context in which the visualisation will be used. The aspects include the rhetoric goal of the visualisation (alert, inform, suggest, enable, instruct, or explain), degree of novelty to the addressee, criticality, addressee's location and expected level of knowledge of the information topic and the geographical area, and characteristics of the target output medium. Modifiers may also be related to the characteristics of the information, such as the size of the territory to be shown, the number of geographical objects or database records, the number of different object categories (e.g. types of vehicles), the quality of the information (e.g. does the data result from actual measurements or observations or this is a forecast or estimation), and so on.

The possible modifications of a prototypical design may include:

- Addition of a display component, e.g. an overview map showing the position of the area represented on the main map display or a table with summary information;
- Addition of an information item, e.g. a map layer with roads, landmarks, or land cover data;
- Transformation of the information or some part of it: generalisation, aggregation, interpolation, normalisation, etc;
- Replacement of one representation method by another, e.g. area painting by graduated symbols;
- The choice of a particular colour scale or palette, symbol library, sizes of symbols, line widths, opacity levels, etc;
- Inclusion of specific techniques for user interaction.

One and the same modifier may be associated with several prototypical scenarios.

The generation of a visual display proceeds as follows. The data to be visualised are supplied to the visualisation system together with metadata describing the data semantics, the goal (e.g. general informing or supporting orientation and navigation) or intended focus of the display (e.g. situation as a whole or particular objects or events), and the contextual information. All this together is called *specific visualisation task*. The visualisation system must be able to recognise this visualisation task, i.e. classify it as one of the known generic tasks. On this basis, the system picks up the prototypical design corresponding to this generic task. A prototypical design can be imagined as a structure with slots. It is instantiated (i.e. turned into a specific design) by filling references to specific information components and characteristics in the slots. In reality, the procedure may be more complex. Thus, there may be dependencies between the slots, which must be taken into account when the slots are filled in. The dependencies can be specified using rules or other appropriate ways of representing procedural knowledge.

As soon as the prototypical design has been instantiated, the system checks if any of the modifiers available in the knowledge base are applicable to the prototypical design chosen and to the information given. For this purpose, the metadata are analysed. The applicable modifiers are applied to the design. After that, the completed design is sent to the display generation module. The design contains a full specification of the display: the display components and how they linked, what information components (layers) are shown and what representation method is used for each layer, how the individual data items from each layer are encoded into visual features of the display, titles, labels, comments, and legend items, and what user interaction mechanisms are provided. The process of visualisation design and display generation is schematically represented in Figure 12.

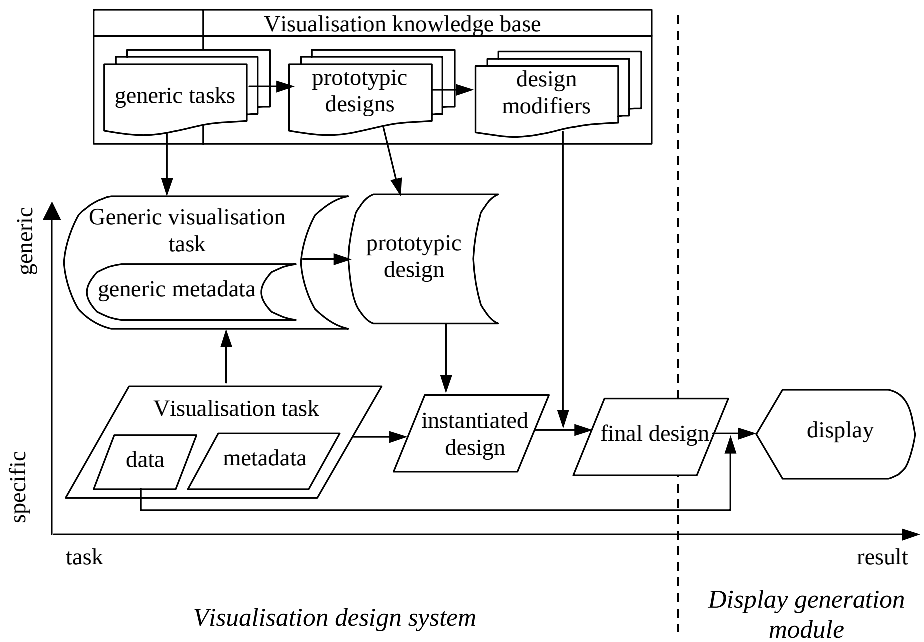


***Figure 12:*** The process of visualisation design and display generation.

## CONCLUSION

The paper describes an ongoing work where the objectives have been only partly attained and much is yet to be done. We are encouraged by positive reactions of potential users, employees of the civil protection services, during the recent trials of the OASIS system. Unfortunately, there were no possibilities for detailed testing and evaluation of each component of the whole large system. However, the intelligent search and visualisation component attracted the attention of the users. They acknowledged that this kind of functionality was new for them and that such tools would be useful in their practice. It is also important that the user interface of the component was quite simple and clear for the users.

During the next phase of the project, we shall put our focus mostly on the intelligent visualisation design, according to the roadmap presented in this paper. We hope to achieve results that will be applicable in a wide range of domains.


## ACKNOWLEDGEMENTS

In the work on producing interactive SVG displays, the resources available at http://www.carto.net/ served us as examples, and some source codes provided on this Web site were reused. The authors appreciate the assistance from Andreas Neumann (ETH Zurich, Switzerland) and thank Ivan Denisovich (University Bonn, Germany) for the implementation of the SVG generator.

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