Crisis designs

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GIS are in growing expansion and changing nature. The third dimension is getting increasingly familiar. The traditional stand-alone, desktop GIS is evolving into a complex system architecture where DBMS plays the critical role of a container of administrative, geometric and multimedia data. These technology advances can be used as a basis for developing a knowledge-based, multi-user and multi-risk emergency response system to increase awareness in crisis situations, and help decision makers, rescue teams and citizens.

Emergency response is the disaster management phase with the highest requirements. Rescue teams, authorities, citizens, press and general public need the most appropriate information, clear instructions, fast responses and timely updates on the development of the disaster. The equipments they use can be numerous: from mobile phones and hand-held devices to virtual environments.

The complexity of decision-making in emergency response is recognised by many authors. Borkulo et al 2005 outline current problems in decision-making and provide examples from the Dutch practice. Cutter et al 2003 discuss the importance of geo-information. Kwam and Lee, 2005, Zlatanova and Holweg 2004, Zlatanova et al 2005 emphasise on the third dimension as compulsory feature for urban areas. Zlatanova et al 2004 present a framework for data integration and address 3D positioning techniques appropriate for tracking and communicating with rescue teams in affected areas. An increasing attention is paid on methods and algorithms for indoor positioning (Torg et al, 2005) and algorithms for evacuation routes calculation (Gillieron and Merminod, 2003, Pu and Zlatanova 2005) and corresponding modelling and data structuring (Verbree et al, 2005, Meijers et al, 2005). First systems that allow a collaboration of information between different users in emergency response are already available, e.g. VNET for use by police, municipality and fire brigade in municipality Arnhem, The Netherlands (Diehl and Heide) and the OGC web services-based system for water management (Grothe et al 2005).

To be able to respond to the diversity of users, environments and situations, a system for emergency response has to be multi-risk, multi-user and knowledge-based. The system has to fulfil the following generic requirements (Zlatanova and Holweg 2004):

- Simple intuitive interfaces. Taking into account work in high stress, fatigue and pain, rescue teams do not have the time to investigate complex graphics, user interfaces, maps overloaded with information, or unclear symbolisation.
- Covering areas unknown to user and providing appropriate guidance. The rescue forces are trained in special environments (particular training

areas) or in areas that are closer to their location. In general, they are not familiar with the specific environment of the disaster occurrence. Very often, they have to access areas (e.g. factories, back yards of public institutions, storage places, give help in neighbouring cities) that are unknown to them. Furthermore, the usual environment might look completely changed due to smoke or damages caused by flooding or earthquake. In such cases, appropriate guidance is especially appealing.

• Able to trace the most appropriate information and provide it to different teams and to the public. Much of geo-information is stored in different information systems (GIS, CAD, geo-DBMS) and all this information should be investigated and, if appropriate, delivered to the rescue teams. For example, a lot of information regarding citizens is available with the municipalities, data about the construction of the buildings might be available with a construction company (responsible for the construction of the building), data about utilities (electricity, gas, water) are hosted with corresponding institutions maintaining the utilities, property data are usually maintained by the cadastral offices. Depending on the type of risk situation, different information might be needed. In case of fire in a multi-store shopping centre, data about the construction will be required, while in case of fire in residential area (e.g. 2-store houses), information about the direction of the wind will be more relevant. The system has to be able to decide which type of information is needed and where to find it (e.g. data discovery).

• Easy to combine various data for a variety of clients. As it is described in the next section, several different groups (with different equipment) might be involved in the response phase. Different equipments should

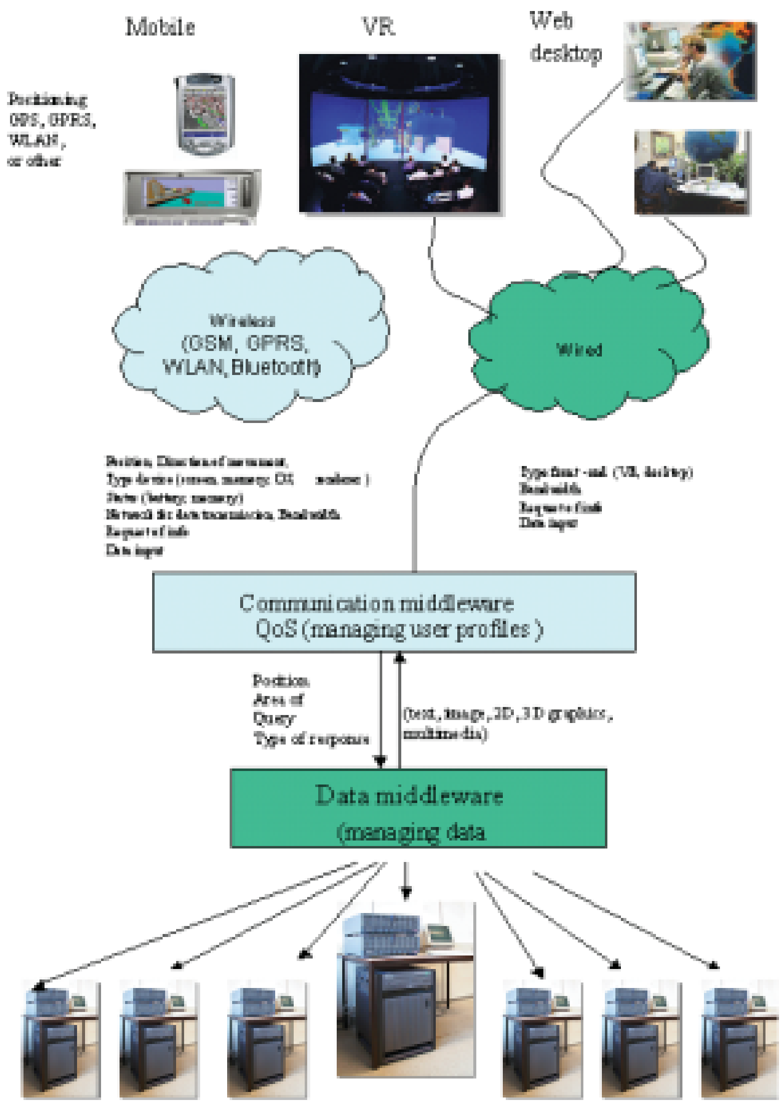

Figure 1: Overall architecture of a proposed system (Zlatanova and Holweg, 2004)

not create delivery problems. The data has to be scalable and adaptable for the type of the equipment.

• Integrated automated quality control of data. Very important aspect of management in the response phase is the input of field data. Updated information about the development of the disaster will greatly improve the decision-making process. However, the quality of supplied field data has to be strictly controlled. Apparently, new data will be expected and delivered by all the groups in the affected areas. All these inputs have to be estimated and evaluated (prior to combining with other data) in order to be used as supplementary and not contradictory sources.

• Real-time, fast at all levels. A very important aspect of systems for emergency support is the speed of communication (sending requests and delivering responses). The clients, especially on the field, hardly have sufficient waiting time. Investigations amongst Internet users (in stress situations) show that acceptable waiting time (for displaying of a web page) is less than 15 sec. In case of emergency, the information has to be supplied within 5 seconds and even less.

Such a system should be seen as a modular, dynamic, extensible network of different sub-systems that can be easily connected and adapted for all kind of situations. If an expert opinion on a particular aspect is needed, then the systems should be able to search and provide link/connection to the specific problem. The type of connection can vary from a person (particular specialist) to another network (information system in a particular organisation)

Figure 1 shows the overall architecture for an efficient emergency management. The components of a particular interest in this paper can be separated into three general levels: users, middleware and database.

The users

To address all users in emergency management, they can be classified according to the environment they are working in: virtual reality clients, mobile clients, desktop clients and web clients.

Virtual reality users can be high-level decision-makers. They are responsible for technical, strategic or information management and have to coordinate all the arrangements necessary to handle the situation. Depending on the practice, which differs from country to country, they can be mayors, fire brigade officers, heads of civil protections institutions, Red Cross, etc. These decision-makers usually stay outside the disaster location, at a centre containing advanced equipment and often provided with elaborated VR environments (e.g. virtual auditoriums, large 'touch' screens), in which they will be able to observe latest developments, discuss possibilities and give orders to the rescue teams.

Figure 2: 3-D visualisation of important power switch (courtesy FORTHnet, Greece)

Other specialists from the variety of organisations contributing to the handling of the situation by providing special data and expertise usually use desktop clients. In case of small-size disasters, high-level decision-makers also may work only with desktop systems.

Mobile clients include

- rescue teams (police, fire brigade, ambulance, army, special forces, Red Cross),
- lower level decision-makers that have to give information to people that are on the way, into the area or in the vicinity of the area of emergency; and
- ordinary people with hand-held devices (that can receive directions on their own).

The fourth type of client is the web client. This is the general public and media that seek information regarding the disaster. The information can be diverse: from location of victims to last developing of the disaster in picture and text. In general they are also using desktop systems.

These four groups of clients are represented at the top of Figure 1. The variations in the needed technology are apparent. While mobile users have small devices with limited characteristics (screen, power, memory, hardware acceleration), wireless connection need to be located in space, web/desktop users have power computers, wired connection and their location is not of interest. In contrast to these two, VR environments require several computers for parallel processing to be able to render several images at once (e.g. in case of a five-wall CAVE, five parallel computers are required). Mobile users demand a quick response and pose high requirements to the provided information.

The geo-data

Numerous types of data with different formats (CAD, GIS, DBMS, modelling data acquisition software), dimensions and representations are currently available and in use. It is often discussed that the major bottleneck is not lack of data but finding the most appropriate of them. Most challenging is the third dimension (Zlatanova and Prosperi, 2005) especially when urban areas are regarded. Data from 3-D CAD models (very detailed 3-D data but in many cases lacking topology) has to be integrated with GIS data (usually smaller scale, less details and organised in 2-D or simple 3-D topological models).

In case of an emergency, 'mountains' of such data have to be analysed if they are useful/necessary. Analysing such volumes of data clearly overwhelms the traditional methods of data analysis such as ad-hoc queries and dedicated scripts. These methods can create informative reports from data but cannot analyse the contents of these reports. New methods and tools are needed that can intelligently and automatically transform data into information. There are at least three distinct cases in which information may be lost when communicating between different groups or information communities:

- In the first case, definitions and concepts are shared but there is no common language between the two groups, or the groups share a common language but use dramatically different dialects. This problem is corrected through simple translation using a bi-directional mapping between the two languages. As long as the languages themselves are stable and there is a 1:1 relationship between relevant terms, this mapping solution supports effective communication. For instance, if A and B want to talk about urban areas, they can agree that the mapping of 'house' = 'building' will be used to communicate this concept.

- In the second, a somewhat more abstract case, a stable base of definitions for terms is not shared between the communities. Correcting for this requires a direct mapping of shared definitions plus a set of interpretations for terms that cannot be mapped. Where there is a 1:1M mapping of definitions between communities, generalisation and a consequent loss of information will occur when mapping multiple, specific definitions to one more general definition.

- Finally, there is the case in which basic concepts are not shared between the communities, i.e. when the two communities have strongly different worldviews. For instance, consider the real world features 'snow' and 'electrical cables'. Suppose one information community recognises only the first, and the second recognises only the second. Attempting to address the effects of snow on electrical cables would be difficult or impossible in either community.

This semantic gap has to be first closed, and then a model has to be developed to allow appropriate management of the information. Different software (CAD, GIS, DBMS based) can be of interest for emergency coordination institutions. Recently, almost all large vendors (dealing with spatial information) provide numerous mechanisms for managing information from distributed environments (e.g. ProjectWise, Bentley, http://www.bentley.com/en-US/Products/ProjectWise). In this paper however we will draw the attention to the utilisation of geoDBMS.

There are a lot of reasons to use geoDBMS: reliable management of large data sets, multi-user control on shared data and crash recovery, automatic locks of single objects while using database transactions for updates, advanced database protocol mechanisms to prevent the loss of data, data security, data integrity and (standardised) operations that comfortably retrieve, insert and update data. Nowadays, several commercial and non-commercial DBMS are available with support for spatial data types: Ingres, Oracle, Informix, IBM DB2, MySQL, PostGIS. The support of 2-D objects with 3-D coordinates is already almost a standard (Oosterom et al 2002, Zlatanova et al 2002). Some DBMS (e.g. Oracle) even support several different spatial models (geometry, topology, network). Still developments toward the third dimension are needed. The offered functions and operations are predominantly in the 2-D domain (Stoter and Zlatanova 2003). Concepts for 3-D objects and prototype implementations are already reported (Arens et al 2003, Stoter and Oosterom, 2003). Furthermore, no 3-D topological structure is currently available in any of the commercial software (Oosterom et al 2002) but a lot of research is done (Coors and Flick 1998, Lee 2001, Zlatanova and Heuvel 2002). Recent experiments and benchmarking have also clearly shown a significant progress in geoDBMS performance (Oosterom et al., 2002). We firmly believe, for efficient management, a geo-DBMS has to be considered as a basic component of the system.

Semantic gap should be first closed, and then a model has to be developed to allow appropriate management of the information

The major responsibility of database in a crisis centre is to manage 1) own data and 2) include data from, or connect to other data sources. Practice shows that crisis centres are usually a part of municipality systems (or connected to them) and thus hosts already a lot of data. In addition, there are ongoing discussions on agreeing on and creating a basic set of data that should be permanently stored and available to everyone in any kind of disaster (Diehl and Heide, 2005). Indeed, it is impossible having all data necessary (or useful) for managing emergency within one system all the time. Usually, one does not know the point in time when a case of emergency comes up or what data will be useful or even necessary during the next case of emergency. Therefore, the system should provide different ways of accessing or integrating data to the system. All incoming data has to be structured with respect to well-known models and standards (based on ISO/TC211, Open GIS, W3D, etc) and made analysable by all parts of the system.

Special attention has to be paid to the update of data. Approaches are provided for maintaining temporal data, but the third dimension is not supported. A solution would be maintaining a temporal 3D model of the current situations that would be available to all the users of the system and accessible for updates. The update of the temporal model should be strictly controlled. Different priorities of access have to be created for different users.

Communicating data to users

Discovering the right information and providing it to the end users is a complex process requiring a high-level of intelligence. Two types of middleware levels can be distinguished to materialise the request with respect to the situation, find and deliver the information:

Communication Middleware: As shown in Figure 1, two types of profiles are to be supported by communication middleware, i.e. wireless and wired. The wireless profile has to contain information about:

- Position of the mobile client and the direction of movement (tracking)
- Type of the mobile device, including screen resolution, memory capacity, operation system, rendering engine (if 3-D rendering available), etc.
- Status of the mobile device (charge level of battery, available memory)
- Network for data transmission (GSM, GPRS, WLAN, Bluetooth, others) and the corresponding bandwidth
- Requested data with an indication about emergency of the case and considering data input of field data into the system.
- Human factors (age, gender, disability, injuries, etc.)

The profile has to initiate a separate connection to the data middleware that will decide on required and delivered data.

The wired profile is relatively simple compared to the wireless since position and mobile parameters are not of interest. The wired profile has to maintain data about:

- The front-end, i.e. desktop or VR. As it was mentioned above, VR environments may require two or more parallel processes to be run at once.
- The cable bandwidth (that may vary within different networks)
- Requested data
- Data to be introduced in the system for use by the rest of the users.

Data middleware: The data middleware has three important responsibilities:

- Routing the front-end data to the database(s). In this respect, an important issue to be resolved is the discovery of the most appropriate data sources. As one does not know what data will be necessary, external data source has to be accessible via the Internet.
- Establishing semantic data translators (Mark et al 1999) based on ontologies to be able to compare and evaluate data. Furthermore, the data may be stored in different software packages such as GIS, CAD, DBMS. The system still has to be able to cope with different formats, structures and representations.
- Adapting fetched data to the type of the front-end

Visualisation of data

Visualisation of information contributes largely to the success of a rescue mission. The way of representing information (text, graphics, and image) has been always a topic of investigation (Verbree et al 2005, Verbree et al 1999, Pasman et al 1999). How to represent information to a user under stress is one of the major questions in disaster management. Some initial experiments already give indications that:

- users react better on graphics navigation compared to text navigation (Kray et al 2003).
- users orient better in 3-D view (Figure 2) compared to 2-D (Rakkolainen and Vainio 2001, Holweg and Jasnoch, 2003).

The type of user poses requirements to four different environments for fast and appropriate visualisation, intuitive and flexible interfaces. As mentioned before, the most demanding requirements are to the 3-D graphics on mobile devices. The 3-D capabilities of mobile devices are largely restricted in several aspects: dedicated 3-D hardware chip, floating point units (floating point calculations are done by the software), hardware division circuits (for integer division), memory bandwidth (3-D rendering needs large amounts of texture to be read from the memory) and CPU speed. Besides, visibility scene management algorithms have to be adapted for the low-resolution screens of mobile devices. Breakthrough in 3-D rendering on mobile devices are observed in several directions: faster chips, many operation systems, APIs for 3-D graphics, standards for 3-D visualisation on mobile. 3-D rendering is available for gaming (e.g. http://www.xengames.com/) and intensive research is carried out to visualise 3-D geo-data (Chun-Fa and Ger, 2002). However, many perception aspects still need to be investigated.

For the preparation of 3-D visualisation, shown objects shall be represented in a geometrically correct way and at the right position. Furthermore, the visualisation used as a communication instrument demands an adequate degree of readability. Several principles are valid:

- 3-D visualisation has to be very close to the real view. In contrast to maps, where a lot of symbology is used, 3-D view should convey by realism and not by abstraction.
- To emphasise an important information in the 3-D view, new approaches to attract the user's attention have to be used. For example, usage of a textured building amongst shaded ones.
- It is practically impossible to represent all the details but too few details may create unrealistic views. In contrast, high graphic density does disturb the users and understanding of the message.

These principles are partly contradictory. For instance, a geometrically exact representation of all geographic objects of a city model automatically leads to a high graphic density. This makes the graphic differentiation between single objects nearly impossible. It has to be taken into account that a model refinement through a scale modification is possibly done via network. This requires adequate techniques to avoid long waiting times. Alternatively, the presentations can be prepared at the data middleware and streamed to the hand-held device.

> The major responsibility of database in a crisis centre is to manage 1) own data and to 2) include data from or connect to other data sources

6. Conclusions

Numerous research questions still have to be addressed to ensure knowledge-based intelligent utilisation of geo-data (when applicable 3-D) in emergency response. Many typical GIS questions have to be given an answer for obtaining a 3-D solution (3-D data structures, DBMS support of 3-D topology, indexing, metadata, consistent update) but complicated with additional requirements for short time response and appropriate graphics user interface for work in stress situations and diversity of data. Integration of geo-data for emergency response has to be robust, based on ontology and geo-semantics. A breakthrough in 3-D geo-display on mobile devices is of particular importance.

The article discusses only issues related to utilisation of information and not hardware issues (graphics accelerators, possibilities to increased memory, bandwidth, reduce power consumption, range of devices, networks and communication protocols). Parallel to the technology developments, disaster management requires a serious progress in structuring, analysis and visualisation of geo-information and more specifically of 3-D geo-information ■

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