FRAMEWORK FOR MULTI-RISK EMERGENCY RESPONCE

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ABSTRACT. Recent emergency situations such as large fires (in cities, forests), flooding, terrorist attacks, road-side emergency, etc, have shown the indispensable need of a geo-information in reliable systems to help rescue operations. Specialised systems are necessary not only for rescue teams but also for ordinary people in/around the area with emergency occurrences.

The presented framework for the use of geo-information in emergency response is motivated by fast developments in hand-held industry and maturing 3D GIS. Presently, almost everyone possesses a handheld device. A process of convergence is observed overall: Cell phones incorporate functionality, which was the domain of ultra-portable computers, while later ones are updated with communication abilities. GIS are in growing expansion and changing nature. The third dimension is getting increasingly familiar. Many GIS vendors already provide extended 3D visualisation although spatial analysis is still in the 2D domain. The traditional stand-alone, desktop GIS evolve into a complex system architecture in which DBMS play the critical role of a container of administrative, geometric and multimedia data.

This paper promotes wider utilisation of 3D geo-information in an integrated system for different types of users (working in different environments) and decision-makers in the response phase. The paper is organized in three general sections. The first section discusses requirement for such a system taking into account different factors. The second section outlines the proposed system architecture. The third section provides an elaborated discussion on needed research and developments.

1. Requirements for technical support in emergency response

Defining requirements for a disaster management system is a huge task that needs investigations of different aspects: type of disaster, phases in disaster management, involved people, available technology, etc. The consideration of any of these individually reveals the complexity of the problem. Two examples follow.

Intuitively the classification of hazards is done regarding the hazard's origin. So the usual classes are natural (e.g. flood, landslides, earthquake, tsunami, volcanoes, etc.) and human-caused (e.g. industrial accidents, fires, terrorist attacks, etc.) hazards. However, other classifications (e.g. Stingfield, 1996) are known from literature. The authors distinguish between:

- Primary disasters such as: fire, power outage, terrorism (bombing incidents, bomb threat, taking of hostages, etc.), chemical releases (radioactive materials, toxic gases, etc.), earthquake, flood, hurricanes, etc.
- Secondary disasters. For example, an earthquake could cause a structural fire, which may in turn burn out circuits resulting in a power failure.

Apparently, it is difficult to consider only one type of disaster. Floods near industrial areas may cause industrial hazards (explosions, fire, etc.); power failure may result in an explosion and damage of dike, which consequently may transform in a flood disaster; earthquakes may provoke landslides, etc. Therefore, risk management is often mentioned in this context (Bell and Glide, 2004).

The Federal Emergency Management Agency (http://www.fema.gov) of the USA suggested four phases to describe disaster management namely: *Mitigation*, *Preparedness*, *Response* and *Recovery*. These phases are

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currently widely accepted by all kinds of agencies all over the world, although some implied specifications at a national basis. The fist phase is related to activities aiming at a reduction of occurring emergency situations (e.g. construction specifications for building to resist at earthquakes, dikes to prevent flooding, etc.). Preparedness focuses on the active preparation for an occurring case of emergency. The rescue forces (e.g. police, ambulance, fire brigade) are trained how to operate and cooperate in emergency situations. Response is an acute phase after the occurring of a case of emergency. Recovery is a phase after the acute emergency including all arrangements to remove detriments and long-term supply of irreversible detriments. All the phases are interrelated and equally important. However, the requirements to eventual systems supporting different phases vary. The most critical are the response and recovery phases (Cutter et al 1999). They require fast response, up-to-date field information, integration (for decision-makers) and distribution (between rescue teams, citizens, etc.) of information.

Further consideration of human or technology factors cause even more complexity. The logical question arises, whether it is possible to build an integrated system capable to provide services for multi-risk management? This paper suggests that such a system can be build for the extreme case (i.e. response phase). Different components can be lately adapted to different phases, applications and users. The current developments reveal different tendency: systems are developed for a particular type of disaster, group of people (police, fire brigade, and ambulance) or disaster management phase. The number of systems for technical support during Response phase is quite limited and group oriented, e.g. software for monitoring and routing ambulances, police and fire-brigade cars; software for monitoring victims (*I-RIS,* http://www.octaafadviesgroep.nl), pollution (*Urbis,* http://www.inro.tno.nl/urbis), early warning using sms (*GorupSMS*, http://`www.groupsms.com`), etc. In most of the cases geo-information either is missing completely or the management is done with 2D maps. Integrated systems to support all the users in the response phase are missing nearly complete.

Keeping in mind the complexity of problems in disaster and risk management, we are considering general requirements for a multi-risk system giving support to different groups of users managing (or otherwise involved) response and relief phases. Two general premises have to be achieved for such a system:

- Due to the seldom known point in time when a case of emergency occurs, the tools to support decision-makers have to be integrated into overall architecture for multi-risk management. This overall architecture covers in a way all phases of emergency management so that the tools are available whenever necessary.

- To provide the most appropriate data to the user, the user himself and his technical environment have to be considered. Since mobile devices are essential tools in everyday life, it will be necessary to integrate them in a useful support system for decision-makers. Respect to the user means to be able to estimate the stress he/she is experienced. Among all an intuitive visualisation is critical. Including 3D visualisation is a good way to make visualisations more intuitive in stress situations.

Such a system has to be multi-risk, multi-user and knowledge-based oriented. The system has to fulfil the following generic requirements:

- Taking into account work in high stress environments, the field workers usually will 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 or particular training areas. 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) 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, the need of appropriate guidance is especially appealing.
- Able to trace the most appropriate information and provide 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, data about the construction of the buildings can be available for 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. 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 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 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.

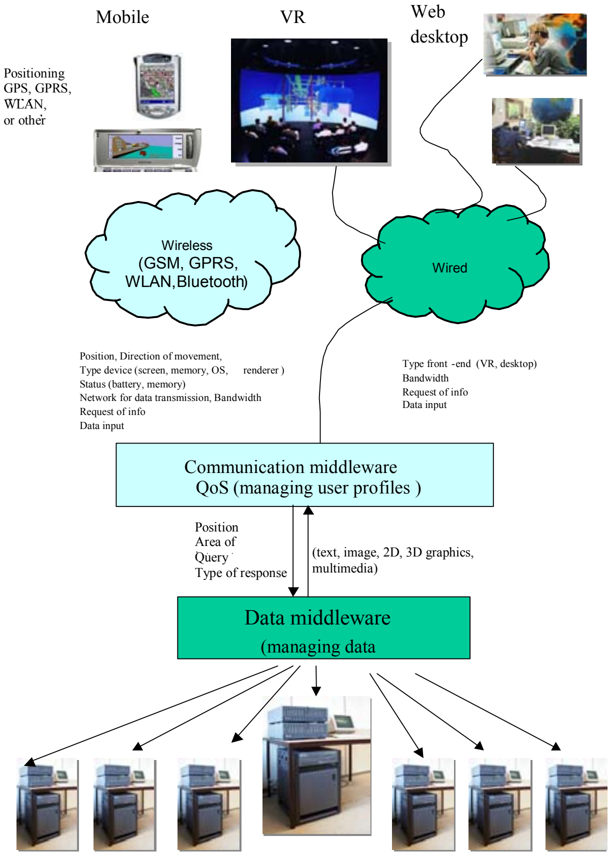

Figure 1: Overall architecture of the proposed system

2. Overall Architecture

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 our view about the overall architecture for an efficient emergency management. The components of a particular interest for us can be separated into four general levels: end-users, networks, middleware and database.

End-users: To address all users in emergency management with the system, we distinguish between several generalised groups of clients: high-level decision-makers, mobile clients, desktop clients and web clients. High-level decision-makers responsible for technical, strategic or information management, such as mayors, heads of civil protections institutions, red-cross, etc., have to coordinate all the arrangements necessary to handle the situation. These decision-makers usually stay outside the disaster location, which can be an centre containing advanced equipment and shall be provided with elaborated VR environments (e.g. auditoriums), in which they will be able to observe last developments in 3D large screens, discuss possibilities and give orders to the rescue teams. Other specialists form the variety of organisations contributing to the handling of the situation by providing special data and expertise, usually use desktop clients. Mobile clients are both rescue teams (police, fire brigade, ambulance, army, special forces, red cross) and 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 handheld 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 for 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. A subdivision is made with respect to the used technology (mobile, VR and Web/Desktop). The variations in the needed technology are apparent. While mobile users have small devices with limited characteristics (screen, power, memory, hardware acceleration), wireless connection and 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 six-wall CAVE, six parallel computers are required). Mobile users demand a quick response and pose high requirements to the provided information.

Middleware: Within the system, middleware levels have to be organised for communication between the front-end and the database. Conceptually, we distinguish between Communication middleware and Database middleware. Depending on the front-end technology used, the risk management phase considered, scenarios and organisations involved, the system has to be able to recognise the 'user profile' and forward it to the database middleware information search. The Communication middleware has to be able to detect the type of front-end, the current status (e.g. capacity of the battery and memory available), the bandwidth of the communication channel (wired or wireless) and the position of the mobile users. In addition to the technical factors, human factor (age, gender, disability, stress level) and the environment factor (safe exits, dangerous part, etc.) have to be taken into account. For each particular request for connection to the database, the middleware has to be able to create a user profile on 'the fly' and maintain it only within the time of disaster management. The profile will be used to introduce intelligence in the system. For example, if the request is coming from a mobile phone allowing only text display, the system should be able to recognise the situation and generate only text answers.

We identify two types of profiles 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 3D 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
- Data input of field data into the system. The profile has to initiate a separate connection to the data middleware that will decide on data update.

The wired profile is relatively simple compare 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.

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 the different formats, structures and representations.
- Adapting fetched data to the type of the front-end

Database: Major responsibility of database is to manage own data and include data from, or connect to other data sources. For efficient management, a geo-DBMS has to be considered as a basic component of the system. Geo-DBMS allow maintenance of all data (spatial and non-spatial) into an integrated model. This ensures data consistency and data integrity, which is necessary for field update and spatial analysis during use. 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) to be analysable by all parts of the system.

This overall architecture actually would serve as a support of decision-makers in all phases of emergency management, in different cases of emergency and would be able to support different users of the system. Furthermore, the system has to provide an answer real-time or near real-time.

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

To demonstrate how the system will operate in the Response phase, we will use two virtual scenarios:

Scenario 1: A fire alert is received from a large building in a city. While the fire fighters are already on the way to the fire, the fire brigade officer uses his mobile unit to get a view of the building and its neighbourhood. There he sees small streets in the surrounding of the fire. He initiates a query to calculate the best position of the ladder-car to be able to get the necessary part of the building. He gets three possible positions for this and decides to choose the second one. Immediately this information is integrated to the system. The driver of the ladder-car gets a navigational support to the location. As it is a stress-situation for everyone, the co-driver decides to have a look to the more intuitive 3D navigational support. The fire fighter driving another car gets a message to move his car to another position in order to avoid blocking the ladder-car. When the ladder-car arrives, the fight against the fire can start immediately. Further, some people are still captured by the fire in their offices on the 5th floor. A group of fire fighters is on the second floor. How to get to their offices? The detailed technical breakdown of the navigation can be as follows:
Initial positioning of the fire-fighters (e.g. one mobile device), i.e. topological search in database to locate the device

- Negotiate with the device for the optimal output, i.e. evaluating the complexity of the surroundings and negotiating for possible output, e.g. 3D navigation or map of one floor and the stairs.
- Create an optimal route to the offices
- Process and present the route, i.e. re-structuring the data with respect to the negotiations on the previous steps.
- Periodically get the device location, i.e. tracking the position with respect to the current data set available, topological query, e.g. ‘point-in-body’
- Compare the planned route with the current position: e.g. 3D overlay ‘point-on-line’.
- Compute a way-around if obstacle is discovered or data are exceeded: new shortest way, or new data set.

Could be that the time needed to get to the fifth floor is too long. Instructions have to be given from the System directly to the people in danger. The System sends a message to some of the group to access the System (name and password) and begin negotiating with the mobile device (e.g. mobile phone). The safe route has to be adapted to the current status of the telephone cell. The battery is too low to receive long messages, i.e. the system should convert the navigation into short expressive instructions.

Scenario 2: An earthquake with magnitude greater than 6.4 on the Richter scale hits the island of Crete during a hot summer morning. The area most significantly damaged covers about 30,000 km^2. The 40 seconds duration of shaking caused major structural damage in many buildings at the old historical center of the Heraklio city. The epicenter is detected only 20 Km north of Crete. Furthermore, due to the high population density of the area, the time of occurrence (morning peak hour) and the material used to construct many buildings (old stone-built buildings), there are many heavily injured and trapped people within the collapsed buildings, while almost all the narrow roads in the historical center of the city were either blocked by ruins or congested by traffic jams.

The fire brigade and police departments using state of the art 3D VR technologies are able to get an instant 3D view of the old centre of the city, in order to get an overall picture of the area before their vehicles arrive on the scene. 3D views integrated with information from the city registers give indications of the floors (now partially or completely destroyed) and number of people possibly available at this time in the buildings. A group of specialists record and send to the main central system information concerning blocked roads, faults in water and electricity supply networks, which are immediately recorded and are made available for further analysis.

From the headquarter of the Civil Protection Service the master chief, using GPS receivers, 3D Routing technologies and electronic maps, manages to guide the Technical Services to open the blocked roads, as well as effectively leading them to spots where the rescue squads are in need of their assistance. Three vans equipped with a portable, distributed WLAN are providing the necessary connectivity to several mobile devices, covering a core area within Zone 1 (see Figure 3). Public servants, using their Always-Best-Connected PDAs verify that electricity and water supply have been cut so that rescue squads may proceed

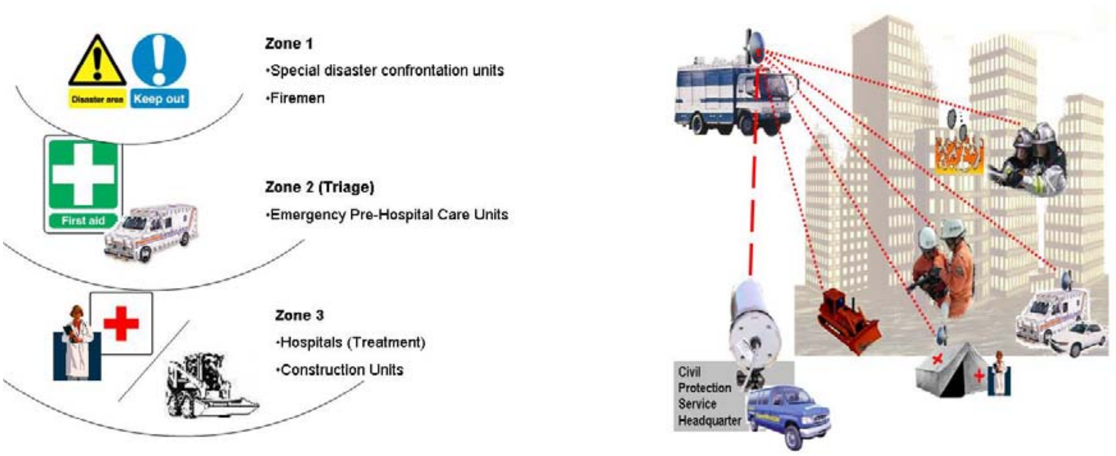

Figure 3: Zones in disaster management and WLAN connection in zone 1 (courtesy FORTHnet)

Having assessed the situation, the police department sends their units to the surrounding area of the old city centre in order to decongest the roads that are still in use and to provide information about traffic flow. At the same time, several ad-hoc wireless network equipped ambulances arrive on the scene, providing on-the-spot first aid assistance to injured civilians, by using medical tools and mobile clients of the information system when useful. Through this network, the ambulance crew performing Triage is able to communicate with medical staff through their PDA, providing vital information such as the number and condition of patients during their transportation to the hospital. This helps doctors to get a quick overall idea of what to expect and be prepared in the best possible way. Through GPS technologies and electronic maps, the crew is getting live feedback concerning the state of roads, in order to identify the best possible route to reach the hospital. The Emergency Pre-Hospital Care Units receive continuous information to their PDAs about unblocked roads that are available to be used by the rescue teams.

At the same time informative SMS messages of critical importance are sent to citizens warning them about possible tsunami waves triggered by the earthquake, so they can immediately evacuate the north coast. The master chief simply and effectively with a drag of the mouse on the sensitive live map is able to select groups of people that need to be notified using SMS or IM techniques.

3. Research questions

To be able to respond in a way similar to scenarios described above, several groups of research questions related to geo-information have to be addressed, namely positioning, database systems, data discovery and integration , and visualisation and navigation. Each of these comprises a wide range of problems related to the third dimension. These will be briefly described bellow.

Positioning and communication: Two critical questions can be outlined (also Zlatanova and Verbree 2003): 1) tracking of rescue workers everywhere (outdoor and indoor, providing their 3D coordinates) and 2) ability to exchange data over wireless network. Several additional aspects influence the way of positioning and communication:

- Positioning accuracy (3D): The required positioning accuracy depends on a particular situation and may vary from 500 meters (locating a hospital) up to 5 meters (locating a safe exit in a building with reduced visibility).
- Availability of networks: The system has to be aware of the available networks. The configuration for a given region may change. For example, in case of fire in a building, a mobile WLAN can be configured only for the area of the fire (thus positioning and communication will be based on WLAN).
- Bandwidth of used network: The bandwidth is of major importance for transmission of 3D geo-data (often reaching GBs).
- Urgency of the situation: Last, the system should be able to detect which kind of situation appeared and selectively decide on the preferred way of positioning (depending on the availability of networks).

Several positioning possibilities should be under considerations: global positioning systems (GPS, Galileo), telecommunications networks (GSM, GPRS), Wireless Local Networks (WLAN) of hybrids of them. In general, the navigational (design) accuracy of GPS for consumer devices (i.e. single frequency) is 30 metres. The accuracy of GPS even goes bellow 30m, due to natural phenomena (atmospheric affects) or problems with satellite configurations. In dense built-up areas, the GPS positioning even may fail due to the lack of satellite visibility. Furthermore, the GPS receivers are not operational within closed spaces (buildings, tunnels). The global positioning systems are the only ones providing true 3D coordinates. However they cannot be isolated from the mobile networks, since a communication channel for user data exchange is lacking. Currently, GPS coordinates have to be sent to the server manually.

Telecommunication networks can trace a mobile phone almost everywhere but the accuracy is very low. In most of the cases mobile phone can be related to a network cell, which corresponds to 100-500 m accuracy. The urban areas are again problematic. A mobile phone can be easily connected to a transmitter (e.g. on a high building) that is 2-3 km far way from the current position of the user. A number of hybrid systems, e.g. combination of mobile networks, GPS and additional information (i.e. postal code) are already in use. A lot of emphasis is on so called Assisted GPS (A-GPS) (Bedford, 2004). In such hybrid systems, the telecommunication network provides additional information to the GPS receiver and the initialisation is much quicker. A-GPS achieves accuracy of ten meters, but it works only when both signals are available.

The progress in the WLAN offers yet another alternative to position a user in close ranges (30-40m). First systems for 3D positioning in a building are already reported, e.g. by *Ekahau Positioning Engine* (www.ekahau.com). This is a solution available for 802.11 and HiperLAN2. The positioning is based on a priory accomplished calibration map created by collecting sample points of the area. Each sample point contains received signal intensity and related map coordinates (for the current floor). The accuracy achieved by such positioning is up to 1m.

Apart from these technologies, alternative approaches for tracking have to be investigated. Examples may come from augmented reality systems, which also need accurate tracking of the user. Very appropriate systems for outdoor tracking are some of the tools reported in literature (Behringer 1999, Davison 1999, Harris 1992, Zillih et al 2000, Kretschmer et al 2003, Zlatanova and Verbree 2004). Alternative positioning systems are already reported in the literature (Haala and Buohn, 2003). Having many possibilities for positioning and communication, a challenging research and technology issue is to switch between them to be able to provide accurate positioning at any time.

Bandwidth is yet another crucial component in success of 3D for mobile services. With the progress of telecommunications from GSM to UTMS, the data transfer is increasing from 9.6 Kb/s to more than 300 Kb/s (theoretical maximum data rate 384 Kb/s). For the first time the GIS specialist will be able to transmit large 3D data sets to mobile devices. Many telecommunication networks (3, T-mobile, Orange) will launch 3G services in the coming two years. Satellite alternatives are available as well. *Iridium* (http://www.iridium.com/) and *Globalstar* (http://www.satellitephonestore.com/), allow connection of respectively 2.4Kb/s and 10 Kb/s. Currently *Inmarsat* (http://www.inmarsat.com/) offers the highest rates (64 Kb/s) with their GAN services, which are to be extended to 432 Kb/s. These developments surely give the optimism bandwidth bottleneck will be overcome is the future. For the time being the several hundreds Kb/s will not be sufficient for uploading of large 3D vector models. For example, transmitting a 3 MB VRML file via UMTS will last about 60 seconds. A standard compression algorithm like *gzip* reduces the data volume to 1 MB and transmission time to 20s. Still, 20s is a long time in the response phase. Compression algorithms, specialized on 3D geometry are already reported. Coors and Rossignac, 2004 suggest a compression reducing the size of such file to 180Kb. Transmission of this file will take less than 4 seconds.

Database systems: In the last few years, management of geo-information and spatial relationships progressed to a stage at which they are maintained directly in the database, without a need for any specialised applications (having different file formats and requiring a variety of viewers). Such developments ensure integrated thematic and spatial analysis for any wireless handheld device or desktop system. Although current DBMS made a large step toward maintenance of spatial data, many 3D issues remain to be addressed. The support of 2D objects with 3D coordinates is already almost a standard (Oosterom et al 2002, Zlatanova et al 2002). However, the offered functions and operations are still only in the 2D domain (Stoter and Zlatanova 2003). Concepts for 3D objects and prototype implementations are already reported (Arens et al 2003). Furthermore, no 3D 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). This means, currently, no system can compute e.g. the shortest or safest route to the ground level of a building. Appropriate data structures, indexes and generic spatial functions have to be investigated and developed. The base system has to be ready to switch between 2D and 3D analysis, if this is requested by the application.

Data discovery and integration: A lot of geo-information exists in different information systems (CAD, GIS, Geo-DBMS). How to find the most appropriate data for the particular situation? Most of the problems are pure semantic one. A representation of a building may exist in one system as a complex CAD model and in another only as a simple box but with a lot of information about utilities. How to match these two data sets to get information about, e.g. gas pipe lines that may explode. The two databases, created for different purposes, may have used completely different terms and descriptions. Semantic translators, metadata, ontology, data integrity are only few of the research questions that have to be addresses (Zlatanova et al 2004). Moreover, offline data mining process can highly contribute to the efficiency of the system. Whether some data have been already requested and have been useful (i.e. highly ranked) will give indications which data sets have to be first traversed. Creating history (data mining) of the most used data will speed up the search.

Visualisation and interaction: An appropriate 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 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 the user reacts better on graphics navigation compared to text navigation (Kray et al 2003). Furthermore, the user orients better in 3D view compared to 2D (Rakkolainen and Vainio 2001, Holweg and Jasnoch, 2003). Finally, the visualisation has to be adapted to the type of user (i.e. desktop/web, mobile and using virtual environments).

The type of user (respectively type of technology which is used) poses requirements to three different environments for 3D visualisation: web, VR and AR and handheld devices. Despite some specifics, the goal of the three types of equipments is one: fast and appropriate visualisation, intuitive and flexible interfaces. As mentioned before, the most demanding requirements are to the 3D graphics on mobile devices. The 3D capabilities of mobile devices are largely restricted in several aspects: dedicated 3D hardware chip, floating point units (floating point calculations are done by the software), hardware division circuits (for integer division), memory bandwidth (3D 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 3D rendering on mobile devices are observed in several directions: faster chips, many operation systems, APIs for 3D graphics, standards for 3D visualisation on mobile. 3D rendering is available for gaming (e.g. http://www.xengames.com/) and intensive research is carried out to visualise 3D geo-data (Chun-Fa and Ger, 2002). However, many perception aspects still need to be investigated.

For the preparation of 3D visualisation, similar principles like for the design of conventional maps are valid. The 3D visualization has a model character, i.e. the 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:

- Geometrically exact design. 3D visualisation has to be very close to the real view. In contrast to maps, where a lot of symbology is used, 3D view should convey by realism and not by abstraction.
- Keep the important, leave out the unimportant. To emphasize on important information in the 3D view, new approaches to attract the user's attention have to be used. For example, usage of a textured building amongst shaded ones.
- Emphasize the characteristic, exclude the fortuitous. 3D models may be represented with plenty of details but in most of the cases this may lead to overloading with information. In this respect, it is very important to keep the balance between important and fortuitous.
- The graphics refinement must suit the needs. It is practically impossible to represent all the details but too few details may create unrealistic views.
- The graphic density must not be too high. High graphics 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. This problem applied to 3D models is solved by using a graphic abstraction, but unlike the cartographic generalisation, an interactive 3D visualisation allows a directed refinement of the model. It has to be taken into account that a model refinement respectively a scale modification is possibly to be done via network. This requires adequate techniques to avoid long waiting times. On the other hand, the destination of the user can be identified, because the visualisation always follows a concrete request, e.g. a routing. This explicit user intention should be considered in the graphic abstraction.

Data update: A very important aspect of risk management is provision of update information about the development of the emergency situation. It can be critical for taking appropriate decisions and guiding the rescue teams, people trapped in the area and mobile workers collecting information. It is also important to update the appropriate data sets. The data before the disaster occurrence should remain untouched to be able to make estimations of the damages in the Recovery phase. A solution would be to have 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 very strictly controlled. Different priorities of access have to be created for the different users.

4. Conclusions

In this paper we have presented our concept for an integrated system to be used in response phase of emergency management. We consider the role of 3D GIS critical for providing advanced 3D visualisation, analysis and interaction to all the users involved in the disaster/risk occurrence. Actually, many of the research questions addressed above are related to and depend on core 3D GIS questions (3D data structures, DBMS support of 3D topology, indexing, metadata, consistent update) complicated with additional requirements for short time response and appropriate graphics user interface for work in stress situations and data. Another important aspect of using geo-data for disaster management is utilisation and integration of data, based on ontology and geo-semantics. A breakthrough in 3D geo-display on mobile devices is of particular importance. Positioning of mobile users needs further research to become sufficiently flexible for supporting users in any environment (indoor and outdoor).

It should be noticed that we have discussed 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). We believe that parallel to the technology developments, disaster management requires a serious progress in structuring, analysis and visualisation of geo-information and more specifically of 3D geo-information.

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