SII FOR EMERGENCY RESPONSE: THE 3D CHALLENGES

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ABSTRACT:

Emergency response is the disaster management phase with the most extreme requirements. During crisis management, several organizations base the coordination of their work not only on well-defined policies and procedures (products of careful preparation) but also on the outcomes of the decision-making process. Much progress has been achieved in the last years in providing the decision-making tools that help in optimal and adequate crisis response. The importance of geo-information is appreciated at many levels, and various initiatives have been funded to support research and development of systems that utilize geo-information. Many countries have started developing spatial information infrastructures for emergency response and early warning. However, most of these developments are 2D.

This paper elaborates on the need for 3D information in view of several projects carried out in the Netherlands. The results of our investigations have shown increased interest in 3D visualizations and extended functionality. Responses from questionnaires and interviews with emergency response users and urban planners have shown demand for systems utilizing standardized models and services. Based on these requirements, recently started research on the 3D BIM model and an interior model is briefly discussed. The paper concludes on the research and developments in the 3D domain that are needed to develop user-centric, context-aware applications.

1. INTRODUCTION

There is little doubt about the importance of spatial information infrastructure (SII) for the entire disaster management cycle. Use of spatial (or location) data has become an integral part of the decision-making process. Numerous activities have been initiated toward creating SII that considers technical and non-technical aspects (von der Dunk, 2008). The Open Geospatial Consortium (OGC) and ISO/TC211 have provided domain-independent standards, as well as standards within a particular theme/domain, e.g., ISO/TC204 for transportation, ISO/TC190 for soil data, and the Land Administration Domain Model (Lemmen and van Oosterom, 2006). In Europe, large initiatives like INSPIRE are working on harmonizing domain models. Parallel to standards, metadata and web-services are under rapid development.

SII is discussed in the disaster management domain for risk management and capacity building, emergency response and even integrated disaster management (Köhler and Wächter, 2006). As emergency response requires the integration of data from different domains, existing domain-independent models are extensively used for crisis purposes. However, many disaster domain-specific initiatives are progressing as well, e.g. GEOSS, UNSPIDER and the DHS Geospatial model of US Department of Homeland Security. In large EU projects, researchers have been working on developing web services (e.g. ORCHESTRA); appropriate data models (e.g. WIN); and organization and processing sensor networks (e.g. OASIS).

However, most of these activities are still restricted to 2D spatial data (maps) or, when available, simple 3D representations. As often discussed (Kolbe et al., 2008, Lee and Zlatanova, 2008, Zlatanova et al., 2005, Zlatanova et al., 2006, Zlatanova et al., 2007), disaster management can greatly benefit from 3D dynamic analyses and visualization. 3D data are easily produced by various sensors, and some of them are available real-time (Kerle et al., 2008, Li and Chapman, 2008, Zhang and Kerle, 2008). Standardization activities in civil engineering, such as developing models for the entire life cycle of a building or a construction, may bring useful options for 3D indoor modelling (e.g., Industrial Foundation Classes, Isikdag, 2007). This means that large amounts of 3D data will be increasingly available for disaster management. In addition, our investigations gave strong indications for the increased need for 3D models.

This paper presents results of recent investigations of users' demands performed in the Netherlands and analyzes the readiness of SII to respond to these requirements. Section 2 provides a short overview on the organization of emergency response in the Netherlands. Section 3 reports the findings our investigations. Section 4 addresses research on 3D models, which are of importance for emergency response. The last section draws conclusions and recommends areas for further research.

2. EMERGENCY RESPONSE IN THE NETHERLANDS

Situated at a delta of two large rivers, the Netherlands has struggled from various floods caused from high river or sea levels. Two large floods in 1953 and 1995 had a large influence on risk prevention and emergency response policies. After the first flood, many dykes were built, and after the second, the see protection constructions on both rivers (Delta Plan) were completed. The first crisis management organization (named Protection of the Population) was established in 1952 under the jurisdiction of the municipality. This organization was active until 1980, after which a new structure was implemented.

The first document to address emergency organization and coordination appeared in 1975, followed by several other legislation acts such as that for the fire brigade (1980) and the Law for disaster and large incidents (1981). Shortly after that, the municipalities were given responsibility and obligations in case of emergencies. In the years 1995-2000, further organization improvements have taken place, either within a response sector or between sectors (mostly between police and fire brigade sectors). For example, after the fireworks disaster in Enschede of 13th of May 2000 (and several other large incidents), the safety regions were synchronized.

At the moment, the Netherlands consists of 12 provinces that are further subdivided into 24 safety regions (www.rivm.nl, Diehl and Heide, 2005). The fire brigade, (para)medical teams, municipalities and police are the first responders in the management of emergencies. There are 19 types of disaster that are of importance for the country. These disasters are subdivided in seven categories (incidents with transport, disasters with dangerous substances, epidemics and other health-related problems, incidents with infrastructure, problems with large groups of citizens, natural disasters and remote disasters). The disasters are managed by processes, and each emergency response sector is responsible for a cluster of processes. Each process is also very well-defined with respect to actors and tasks to be performed. The levels of emergency can be scaled from 0 (normal accident) to 4 (national coordination) (Diehl et al., 2006).

Having a relatively short history, the Dutch emergency response has developed to a well-organized system in terms of legislation and organization. In the last few years, nine large national projects were funded to develop SII using spatial information. Foe example GDI4DM (www.grdi4dm.nl) concentrates on SII for command and control based on web services (Scholten et al., 2008); VIKING (www.programmaviking.nl) is a cross-border project with Netherlands for monitoring and prevention of floods; GeoRisk (www.georisk.nl) focus on improving risk management by extensive use of geo-information, etc. Geonovum (www.geonovum.nl) was formed recently as the executive body of the Dutch NSDI (National Spatial Data Infrastructure) and is responsible for developing domain models (including a model for safety). Several data providers, for example the Dutch Cadastre and the Directorate-General for Public Works and Water Management (Grothe et al., 2008), are re-organizing their internal structures to respond better to emergencies by providing web services. The map contains risk and vulnerable objects as described by SEWESO but also areas prone to flooding. These maps are available on the Internet (Basta et al., 2007).

The necessity of SII for disaster management is well-understood by geo-specialists and spatial data providers. Similar tendencies are also observed world-wide (Parker et al., 2008, Johnson, 2008, Kevany, 2008, Brecht, 2008). There is agreement on several critical SII aspects:

- Data should be kept by the provider and accessed via web services.
- Standards must be available
- Operational data have to be recorded and provided to all the participants in an incident
- Situational awareness is an important factor in decision-making, and location information is critical
- Data should be available 24 hours per day through the whole year.

The acceptance of spatial information has drastically increased since our initial investigations in 2005 (Diehl and Heide, 2005, Diehl et al., 2006). Identification, authorization, authentication and billing are most of the hot discussion points at the moment.

3. DEMAND FOR THE THIRD DIMENSION

Several studies were performed in the last year on the request and usefulness of 3D data in emergency response, of which two will be discussed here: use of 3D advanced visualization by emergency responders (Shoeren, 2007) and perception of 3D visualization by urban planners (Kibria, 2008).

3.1 Emergency response users

Snoeren (2007) has investigated 71 users directly involved in emergency response (fire brigade: 27, police: 11, and municipality: 33) within one of the safety regions, Midden Gelderland in the Netherlands. This region had an experimental geo-based Command and Control System (CCS) VNet (Figure 1), and there was a clear demand for further improvements. The system offers basic tools and symbols to share and exchange spatial and non-spatial information. Once sent to the server, the data are available for all users.

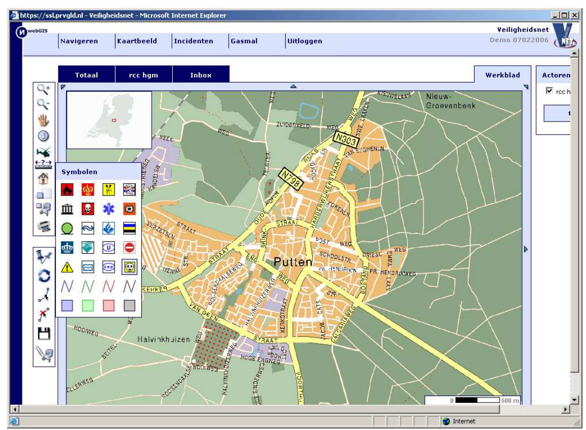

Figure 1: CCS: VNet in safety region Midden Gelderland

The user population in this survey was diverse: 13 participants worked in the field, 21 in the call center, and 20 in the regional operational team; 17 people held different responsibilities in the municipality management team. Most of them (52 users) were familiar with GIS and used it in their work with variable frequency. All of them also used CCS VNet.

Among the various questions related to cooperation and communication during emergencies, two groups of questions were related to 3D data: demands for 3D visualization and 3D models. 3D visualization was considered important by 62% of the users, quite a high result bearing in mind that half of the users were not familiar with GIS. Visualization within Google Earth was considered important by 55% of the users; use of panoramic images was important for 42%; use of animations (with prognosis about the disaster) was demanded by 67%; and use of video was considered useful by 79% of the users. It should be noted that the results were very much influenced by the familiarity of the users with the manner of visualization. For example, video transmission was ranked high, but the call center of this safety region has good facilities for watching real-time videos. In contrast, the use of a new type of hardware, i.e., tangible tables (Scotta et al., 2006) was not well accepted (29%). Later investigations (Hofstra et al., 2008) in which the hardware device was available for testing have shown much more positive results (70%).

The second group of 3D questions focused on 3D models: simple 3D block models of buildings (as on Figure 2), indoor models, and underground structures. It was encouraging to see that about 64% of the users considered availability of indoor models and underground structures important for disaster management. Currently, fire fighter trucks are equipped with printed books that contain floor plans of the first floor of all large buildings in the area they are responsible for (which will soon be replaced with digital maps). The added value of the 3D models was seen by most of the questioned users. The existing hesitations were related to the availability and accurateness of the models, cost to obtain them, and performance of the systems. 3D models of the environment and the exterior of the building structures were considered important by 60% and 58% of the users, respectively. The relatively low percentages could be explained by the relatively low quality of 3D (extrusion) models, which are presently available within most municipalities.

Figure 2: TU Delft campus, LOD 1

Important findings from this study (not specifically related to 3D) are the need of extended functionality, e.g., the users welcomed connection between GIS and CCS (70%) and routing algorithms that can avoid blocked roads and dangerous areas (72%). The acceptance of context-aware software, i.e., software that can provide filtered data with respect to the performed task, was still low (46%). Most of the users (49%) preferred to receive all available information as soon as they logged into the system. The importance of the timely response was recognized by 53% of the users.

3.2 Urban Planners

Kibria (2008) completed an extended study on the need and use of 3D models within the municipalities. Although the study was focused on the urban planning process, the results are highly relevant for crisis response because the municipality is legally responsible for managing the disaster. The municipalities posses and often maintain most of the spatial information available for the city. Urban planners are not directly involved in emergency response, but they are the most important actors in risk management, because they consideration risk factors and vulnerable objects in preparing new developing the (Basta et al., 2007).

This study investigated 3D information that would be necessary for urban planners with respect to realism and resolution such as the level of detail (LOD), and 3D functionality or how a person would interact with a municipality system. The investigation considered a municipality system that can serve different phases of the urban planning process (and not a public participation system). Therefore, the users were predominantly people responsible for urban design. Thirty participants represented three large municipalities (Rotterdam, Amsterdam and Groningen), four small size municipalities, and five housing companies.

Figure 3: TU Delft campus, LOD3

The investigations have shown that 54% of the users used Google Earth daily in their work (either for investigating areas or for presenting models), and 13% of them visited it several times per day. In general, the acceptance of desktop virtual reality (VR) tools was estimated as very high. 75% of the users considered that a municipality system should have tools for *walk-through* and *fly-over* and allow different views in which 2D/3D graphics and images can be observed simultaneously. 3D animations were also ranked very high. Like the first study, the users considered access and authorization critical. More that 75% of the investigated population required controlled access.

Figure 4: TU Delft campus, LOD3, textured model (courtesy Toposcopie, www.toposcopie.nl)

Within the study, different models were created and discussed, either directly with the users or during the workshop. The created models followed the concept of LOD of CityGML (Kolbe et al., 2008). The discussions revealed that the users considered detailed representations (Figure 3 and Figure 4) clearer and more acceptable than LOD 1 (Figure 2). The more schematic the representations, the more attention was concentrated on the entire environment. Some interviewed users indicated that the orientation in LOD1 models was quite difficult and somehow confusing. This conclusion is quite important for managing crisis situations. If only a global view has to be created, LOD 1 details would work, but any other (street level) navigation should be performed on more detailed models. Similar findings were reported by Essen (2008). The textured models (Figure 4) were considered most appropriate for 3D visualization (60%), while block models (LOD1) were preferred for analysis (58%). LOD1 models were well accepted also for shadow analysis (as they are most important for urban planners).

Indoor models became important only if the interior had to be investigated. Many of the users (60%) considered query (by mouse click) of objects important for better orientation and understanding of the presented model.

The general conclusion from the two studies was that the third dimension was accepted and that there was demand for increased level of interaction with 3D models. The progress compared to earlier studies from 2005 (Diehl et al., 2006) is apparent. The models were interesting not only for 3D visualization but also for analysis (route navigation, buffering, overlap, etc.) and query of thematic/attribute information. Building SII based on standards, services and domain models was considered advantageous. The emergency responders had preferences for simple interfaces, but this was mostly due to low performance expectations. As discussed in the literature (e.g., Neuvel and Zlatanova, 2006), our two investigations (with emergency responders and urban planner) has also revealed time as the most critical difference between the two phases: emergency response and urban planners. Theoretically, a system for emergency response may serve (without major modifications) for risk prevention, but the reverse would not be true. A timely response was not an issue for urban planners.

The acceptance of the third dimension was relatively high, and this is not a surprise. Technologies such as Google Earth, Virtual Earth or Second Life have greatly contributed to understanding and recognizing the benefits of the third dimension.

4. 3D SII FOR EMERGENCY RESPONSE

3D aspects should not be overlooked and should be simultaneously developed while addressing any SII components: standards, metadata, services and policies. 3D standards and 3D services are most critical for achieving 3D SII from a technical point of view. The possible standards to exchange 3D information are limited and domain dependent; the provided services with small exceptions are only 2D. Research on 3D extensions is currently underway, e.g., extending the OGC Styles (Neubauer and Zipf, 2008).

The most significant 3D initiative in terms of standards is the development of CityGML (Kolbe et al., 2008) and the OGC activities within the BIM WG group. Tests within the OWS-4 testbed have demonstrated that data from Industrial Foundation Classes (IFS) and CityGML can be integrated in one visual (virtual environment) via web services (Lappiere and Cote, 2008). The very strong characteristic of CityGML is that it incorporates semantics (theme) and geometry. The semantic aspect of information is critical for crisis management because of semantic heterogeneity at different levels: data, organization, task/responsibility, etc. (Pundt, 2008, Xu and Zlatanova, 2007). Therefore 3D models like 3XD might not be appropriate for emergencies (except for pure visualization). KML (recently approved as the OGC standard) has gained popularity because of Google Earth. It serves for 3D visualization tasks above the ground, but it falls short in dealing with underground data.

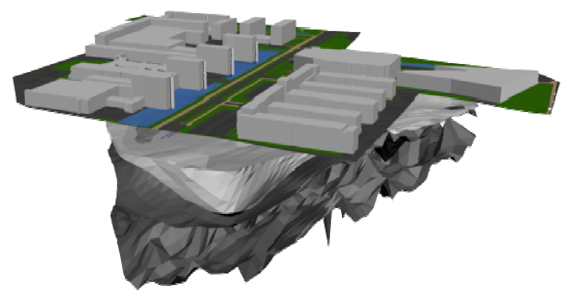

Figure 5: TU Delft model in LOD1 (from Emgard and Zlatanova, 2008a)

We consider the concept of CityGML highly appropriate for representing real-world features (as a domain independent core model), but it must still be extended to comprise subsurface structures. We have recently begun research on extending this concept with underground features. New features were introduced for geology formations, utilities and underground constructions. Specific intersection features on the earth surface define the intersection between the above and below surface features with the earth surface. These additional intersection features allow defining relationships and maintaining consistency between all features. A number of rules were developed, e.g., all features on the earth surface must form a non-overlapping full partition. The 3D BIM model is intended as a model to store data and as an exchange model between different domains. Two alternatives were tested in Oracle Spatial (Emgard and Zlatanova, 2008). Figure 5 shows the test area of the TU Delft campus organized according to the 3DIM.

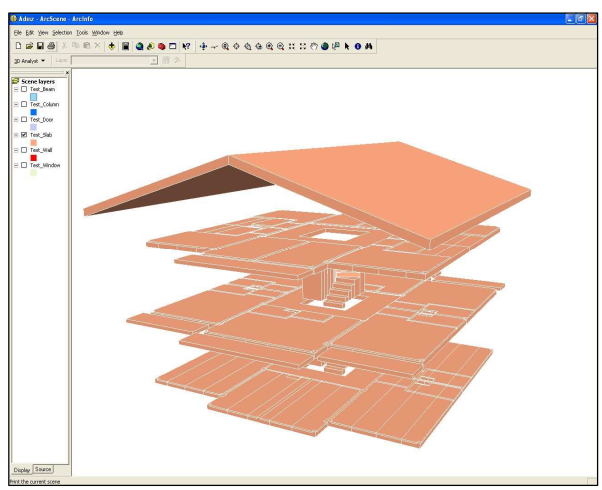

Figure 6: Roof and building from BIM (IFC) models (from Isikdag, 2008)

The second very important missing aspect is the indoor standard. Interiors of large buildings are important for navigating rescue forces to the place of incident and give evacuation directions to citizens. Relatively limited research is being carried out in this area. Some initial ideas could be borrowed from CityGML LOD4. Relation structure with the support of the Poincare Duality theory, which treats a 3D entity as a topological node and the shared face as a topological link, is presented by Lee (2001). Meijers and colleagues (2005) presented a semantic model representing 3D structuring of interiors to be used for an intelligent computation of evacuation routes. Slingsby and Raper (2008) have investigated a surface model containing only parts of real-world surfaces that are needed for walking and realistic visualization. Semantic models to represent the interiors with the purpose of emergency response are discussed by Lee and Zlatanova (2008).

The principle idea of this approach is to deliver those elements from buildings (and other types of constructions) that are important for giving directions, such as doors, windows and stairs. Is there a need for a specific model, or could the parts be derived on the fly? To investigate this question, we have initiated research on deriving those elements form BIM (IFC) as discussed by Isikdag (2007) (Figure 7). BIM models are supposed to maintain information during an entire building life cycle, a feature that will make them an attractive option for emergency response. Generally, BIM models will be always updated and feed from semantic information. These models can be 'translated' to the 3DBIM semantic model for analysis, computations of routes, and realistic 3D visualization when appropriate (Pu and Zlatanova, 2008).

5. OUTLOOK

This paper reported the investigation of user requirements on needs for the third dimension during emergency response in the Netherlands. The output is interesting with respect to the emergency response developments in the country. The country has good organizational structure, well-defined actors performing clearly specified tasks, and a successful start for creating National SII (also for support of emergency response). Under these conditions, the interest in the third dimension is well founded. New emerging technologies, such as Google Earth and Virtual Earth, have also contributed to better acceptance of 3D visualizations.

It is no longer disputable that disaster management is a domain that has to be modelled independently. Emergency response can benefit from many domain models, which can be integrated via translation to a domain-independent model (e.g., CityGML based), but operational information still requires good formalization. The operational model could become very complex depending on the type of disaster that is monitored. The model should definitely be spatio-temporal, representing the thematic nature of the real-world phenomena causing the incident (flood, earthquake, air pollution). 3D representations of such phenomena are still to be investigated. Very challenging cases are 3D modelling of a gas plume, effected area around a malfunctioning pipe, oil spilt, etc. Research on 3D TEN models might be very well-suited in these cases (Penninga and Oosterom, 2008)

The issues of developing an operational model for emergency response are closely related to formal approaches of storing/archiving 3D data (raw data from sensors as well as 3D models from real-time reconstruction). Such data may become a major bottleneck for data integration and analysis if standard outputs and agreements on LOD are not also available for data acquisition techniques.

3D services should provide timely responses. Besides various technology requirements, context-aware approaches should be considered. They are expected to bring significant performance improvements by reducing the data to only the information needed for the specific task. Our investigations did not reveal great enthusiasm about context-aware filtering, but good examples were also not available. On the other hand, emergency managers (operators, decision-makers) required simple intuitive interfaces with simple methodologies for communication and data access. This could be an indication that users would consider the context-aware aspect, especially with respect to LOD, if 3D models were provided.

The requirement for extended (GIS) functionality, although not related to 3D, has increased. It should be taken into consideration that more functionality would require more training and preparation. In stressful situations, system operators place more reliance on their own judgment and the judgment of other human beings than they do on any form of artificial intelligence (Kevany 2003). The best solution would be the use of the systems in daily routine work. As often mentioned, working with a non-familiar system increases stress, which may lead to 'expensive' errors when mobilizing emergency resources during life-threatening situations.

Extended technologies as augmented reality and tangible interfaces have increasingly been under consideration for discussions and decision-making in high-level operational teams. Recalling the results of user requirement investigations, acceptance of technology was higher if the users had had the chance to acquire hands-on experience with it. In this respect, it is important to prepare 3D SII before the need for it becomes apparent.

The success of 3D SII for emergency response depends on modular, easily employable 3D services and standards that allow for access to and visualization on both specialized software and well accepted Internet tools.

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