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Proceedings of the 8th International Conference on Geo-information for Disaster Management – Best Practices

Editors:

Sisi Zlatanova, Rob Peters and Elfriede M. Fendel

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Sisi Zlatanova, Rob Peters and Elfriede M. Fendel (Eds.)

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Book orders:
Dr Sisi Zlatanova
GIS Technology Section
OTB, Research Institute for the Built Environment
Delft University of Technolog
Jaffalaan 9, 2628 BX Delft, The Netherlands
Phone: +31 15 278 2714
Fax: +31 15 278 4422
E-mail: s.zlatanova@tudelft.nl

Preface i-Bridge

In 2005 the Advisory Committee Coordination IT Disaster management published a report on the status of information management in the public safety sector. The report described a fragmented and greatly compartmentalised organisation, poor national direction and funding. Information was not shared in an efficient manner and quality of the information was poor. The report was a stimulus to improve information management and to work towards a common operational picture. Central to this was the netcentric philosophy as used by the Ministry of Defence. It is against this background that the first Civil Military Collaboration and later the Intensification of this Civil Military Collaboration were realised in a series of programmes. i-Bridge became part of these programmes. The goal of the i-Bridge program was to improve crisis management by developing, testing and evaluating new (IT) technologies on their usability and added value. i-Bridge offers a platform to the security sector with the possibility to test and evaluate these new (IT) technologies.

In 2008 the Dutch government initiated social innovation programmes in the fields of water management, safety and security, health care and energy. The goal of the programmes was solving major social issues. In the safety and security program the input of know-how, innovation and entrepreneurship for solving social issues was the central subject. i-Bridge started as a collaboration between the Dutch Ministry of Defense and the Dutch Ministry of the Interior (Now: Ministry of Security and Justice), within the Civil - Defense cooperation Program.

i-Bridge is based on the concept that communication components can be linked in various combinations using internet protocols. By using internet protocols secure, real-time collaboration and logging become possible. Internet protocols also solve a number of bottlenecks, as identified in the roadmap of the Social Innovation Agenda Safety, including the build-up of an integrated common operational picture.

The objective of i-Bridge is threefold: showing innovations in the public safety domain, involving (NL) industry in these innovations and finding a practical use that may lead to possible industrial activity. Between 2008 and 2012 i-Bridge started more than 10 projects that all met these criteria and delivered Proof-of-Concepts.

The Minister of Economic Affairs, Maria van der Hoeven, complimented the i-Bridge project for being successful in bringing different safety organizations and industry partners together to collaborate on innovations. For further information see pp. 151-160 of these proceedings and also www.innovatieinveiligheid.nl.On behalf of i-Bridge we wish you an interesting read of the Proceedings of the 8th International Conference on Geo-information for Disaster Management,

Relinde van Bladel and Eric Spronk,
IVENT | Operations | Advies & Applicaties | DM4 | unit 2,
Defensie Materieel Organisatie,
Ministerie van Defensie.

Preface Innovation Platform Regional Safety Authorities

Dear Reader,

Welcome to the 8th Gi4DM conference!

Innovation and collaboration are key factors in emergency management. Information management requires both. In the last 10 years we have discovered the notion of 'information chains' and the governance challenges these models bring with them. In the more recent past we have been confronted with the possibilities of networks, sensor, semantics and social media. Such developments open up new challenges for 'applied' innovation in incident management.

The Gi4DM conference is about GIS systems in all its aspects of gathering, analyzing, visualization and standardization. GIS is a powerful tool. Its potency for sharing information both in preparative sense and in real time sense, is still not fully uncovered. It is only 6 years ago that Google Earth and TomTom became main stream technologies. Now we have to combine networks of networks, have sensors and place marks meshed up with geo-object attributes and reduce an overload of linked data. Fire brigade, ambulance and police forces find themselves suddenly in the front line of digital innovation. So we all have a job to do.

In my role as Commander and CIO, I have invested considerable time and energy on the concept of digital maps. The DBK or, roughly translated; 'the approachability map' has been the answer to a dream about information availability during the emergency at the fingertips of every vehicle commander. It has taken five years of hard work and we are close to its usefulness in real life, now. A technical development like the DBK concept requires many years of collaboration among many players, such as R&D, suppliers, standardization agencies, end-users and decision makers. Innovation without people, trust and interaction does not exist. At least, it will hardly ever reach the people who need it most.

This conference is one of those precious moments of interaction. We try to bridge the gap between scientists, R&D, suppliers and officers in the context of the Urban Search and Rescue Reality. This is the pragmatic approach that is typical for the i-Bridge Programme, which has been supporting innovation for emergency management over the last few years.

The Innovation Platform of Regional Safety Authorities will happily adopt those practices in the future, since they have proven to create the right atmosphere for co-creation and innovation. We hope to provide suppliers, R&D and scientists with a first responders platform to improve the innovation process, to speed up standardization and above all, to learn from each other's experience. Please be reminded that at the end of the day, this is all about saving lives and the environment. Technology is a means to achieve that goal.

Thank you,

Sjoerd van de Schuit,
Innovation Platform Regional Safety Authorities.

Introduction

Geo-information for Disaster management (Gi4DM) is an annual conference devoted to the use and application of geo-information technology in disaster management. The fundamental goal of the conference is to provide a forum to join science, technology and practice towards better support of risk and disaster management. Seven editions of this series have taken place in different parts of the world (www.gi4dm.net).

Gi4DM 2012 is specifically significant because it was initiated by the Public Safety Regions of the Netherlands. The Safety Regions were actively involved in the preparation and organisation of the conference, which took place at two locations: the Holland Casino, Enschede for the scientific sessions, and the former Twente Military Airport for the demonstrations and field tests.

The topics covered by Gi4DM 2012 were: Cross border and cross sector semantics, Semantics and situational awareness, Agent-based systems, Multi-platform and multi-sensor data collection and processing, Crowd sourcing and volunteered geographic information, Design requirements and design processes for information systems, Simulation, decision enhancement systems and evacuation and navigation systems. The papers in these proceedings were selected from the 65 papers submitted to the Gi4DM conference. Each paper was double-blind reviewed by two scientific reviewers and one practitioner. The best 29 papers were included in the Springer LNG&C volume "Intelligent systems for emergency response". The abstracts of these papers are included at the end of these proceedings.

The organisers of this conference acknowledge all members of the Scientific committee for their time, careful review and valuable comments: Andrea Ajmar (Italy), Orhan Altan (Turkey), Costas Armenakis (Canada), Robert Backhaus (Germany), Vera Banki (Netherlands), Jakob Beetz (Netherlands), Piero Boccardo (Italy), Alexander Bouwman (Netherlands), Martin Breunig (Germany), Jeroen Broekhuijsen (Netherlands), Eliseo Clementini (Italy), Joep Crompvoets (Belgium), Tom De Groeve (Italy), Marian de Vries (Netherlands), Ioannis Delikostidis (Germany), Eduardo Diaz (Netherlands), Arta Dilo (Netherlands), Gilles Falquet (Switzerland), Yoshikazu Fukushima (Japan), Marcus Goetz (Germany), Ben Gorte (Netherlands), Ihab Hidjazi (Palestine), Liu Hua (China), Bo Huang (China), Umit Isikdag (Turkey), Alik Ismail-Zadeh (USA), Ivana Ivanova (Netherlands), Zhizhong Kang (China), Milan Konecný (Czech Republic), Petr Kubicek (Czech Republic), Monika Kuffer (Netherlands), Werner Kuhn (Germany), Zentai Laszlo (Hungary), Hugo Ledoux (Netherlands), Ki-Joune Li (South Korea), Martijn Meijers (Netherlands), Nirvana Meratnia (Netherlands), Darka Mioc (Den-

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The organisers are especially thankful to the group of practitioners, who took the great challenge to advise on the value of the scientific research for the emergency response sector: Henk Djurrema (Netherlands), Dave Fortune (UK), Arthur Haasbroek (Netherlands), Robert Kieboom (Netherlands), Marcos Sacristán Cepeda (Spain), Josien Oosterhoff (Netherlands), Frederik Schütte (Germany), Cor Snijders (Netherlands), Gerke Spaling (Netherlands), Simon Stenneberg (Netherlands), Jan Willem van Aalst (Netherlands), Bart van Leeuwen (Netherlands), Benedikt Weber (Germany), Frank Wilson (UK) and Guus Zijlstra (Netherlands). We are also grateful to Frank Wilson and Dave Fortune for the thorough proof-reading of most of the papers.

The organisers would like to express their gratitude to all contributors, who made this volume possible. Many tanks go to all supporting organisations EuroSDR, ICA, IAG, ITHACA, IHO, ISPRS, GRSS, FIG, IUGG, UNOOSA, ISCGM, GSDI and JBGIS, companies Bentely Systems, ESRI, Geodana and Cyclomedia. We are especially thankfull to our sponsors i-Bridge, StudioVeiligheid, Disaster Project and Sen Safety. The editors are grateful to our media sponsor Geoconnextion, Informed Infrastructure and Directions Magazine, Veiligheidsregio Twente and Veiligheidsregio Kennemerland who endorse this conference.

Finally, the organisers are thankful to Lei Niu and Hua Liu for their valuable help in the preparation of these proceedings.

The organising committee:

Chairs: Sisi Zlatanova, Delft University of Technology; Rob Peters, University of Amsterdam and Public Safety District Kennemerland and Paul Havinga, University of Twente.

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Host and demonstrations: Rob Boots, i-Bridge 3.0; Peter de Bruijn, Studio Veiligheid; and Mario Schoonderwoerd, Disaster project, FP7 Security Programme EC.

Studio Veiligheid has contributed to the set-up and Live illustration of the Best Practices at the Gi4DM 2012 conference. Studio Veiligheid is an organisation established to foster collaboration and innovation in Safety. It addresses public safety, emergency management, event management and especially safety in transport logistics. The organisation is supported by key players that have a common interest in improving the position of the Netherlands as efficient logistic Gate to Europe. The orchestration of knowledge exchange among R&D, Scientific Research and emergency officer feed-back alongside field demonstrators and exercises is an approach typical for its general philosophy.

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Part I: User Requirements

Goal-Based Explainable Security Certificate Requests

Maaike Harbers[1], Joost Broekens[1], Thomas Quillinan[2], M. Birna van Riemsdijk[1] and Niek Wijngaards[2]

[1]Delft University of Technology, Mekelweg 4, 2628 CD Delft, The Netherlands

[2]Thales Research and Technology, Delftechpark 24, 2628 XH Delft, The Netherlands, contact: j.broekens@tudelft.nl

Abstract

In crisis situations it is important that crisis response workers can quickly get access to the right information for the tasks they are required to undertake. A distinction can be made between getting the right information and having the rights to get that information. The first is an information filtering and relevance problem, the second is a security issue related to access control. In this paper we focus on the second issue. It is impossible to predefine access rules for all players in a crisis situation that ensure that they have access only to the information they need. Therefore the key is to have a system that is flexible and timely (efficient) with respect to the decision to grant access, without a major burden on humans having to make these decisions, and without inadvertant leakages of sensitive information. We believe for crisis management it is more important to be able to hold individuals and organizations accountable for their use of information than to overly restrict access to information. We propose goal-based explainable security certificate requests as a solution to this problem.

1 Introduction

In a crisis response situation, many organizations have to coordinate their plans and actions. This requires that the actors that represent these organizations, which

can be individuals or software agents, are able to share relevant information with others, including with those who usually would not have access to such information (De Bruijn & Wijngaards 2012). Two examples are a policeman that needs to know the location of a fire squad, and a policeman that wants information about the goods in a storage facility of a chemical plant to decide if the area has to be secured or not.

There are several challenges related to the information exchange in crisis situations (Goal et al 2004). A key characteristic of a crisis situation is that it disrupts normal operations. As such, crises also disrupt normal information flows. As each crisis is unique, it is not possible to predict the information flow in a crisis beforehand. Therefore, information should be shared and distributed in a *flexible* way. Another challenge in crisis situations is that crisis workers need to operate effectively and efficiently in order to save lives and reduce damage. Therefore, information should be shared and distributed in a *timely* manner with *minimal human involvement*. Finally, the information being shared is often classified. For example, the stock information of a chemical plant is normally not available. However, stock information is of great importance when dealing with a fire in the chemical plant, e.g. to anticipate explosions. We believe that classified, but relevant information should be provided under such exceptional conditions, and that this can best be achieved by making individuals and organizations *accountable* for their use of this information.

We propose a goal-based solution to the problem of flexible rights management. The solution involves goal hierarchies with the possible goals and subgoals of crisis workers, and organization hierarchies indicating the roles and hierarchies in organizations involved in crisis management. When crisis workers request information, they indicate the particular goal for which they need that information. Certificates can automatically be generated by software agents when the indicated goal is a subgoal of a goal for which a certificate has already been accredited, and the requesting worker is a subordinate of the creator as defined by the organization hierarchy. In those cases where the certificate cannot be automatically generated, the responsible person is asked. Our approach is inspired by approaches involving task hierarchies such as (Lesser et al 2004), and in particular by goal-based explanation based on hierarchical information structures (Harbers et al 2010; Core et al 2006).

The approach enables flexible access rights management in a way that it can be semi-automized limiting the burden on humans to make decisions. Moreover, all grants for information access are auditable. The goal hierarchies can be integrated with organization hierarchies and cross organizational trust in such a way that it does not force organizations to share a common goal ontology. Although the system, in principle, enables users to fake goals, the combination of enforced auditability of who accessed what for what reason (goal), the organization hierarchy and trust provide sufficient security for accountability.

The outline of this paper is as follows. In the next section we will discuss the requirements that an information management system should fulfill. In the third section, we will discuss our goal-based approach to flexible information access rights management. Due to space limitations we have to omit the implementation

details of our simulation of the approach. We end the paper with a discussion and suggestions for future research.

2 Requirements on an information management system

In the introduction we argued that an information sharing mechanism used in crisis situations should be flexible, timely, accountable and involve minimal human effort. We will discuss each of these requirements in more detail.

An information sharing mechanisms must be *flexible* with respect to who can access what information and for what period of time this access is necessary. Such mechanisms need to be able to adapt information disclosure rules to fit the crisis at hand, and allow humans to override these rules when needed.

Crises require *timely* delivery of information. Information sharing mechanisms need to rapidly perform one of three actions: (1) retrieve the information requested by an individual; or (2) deny access rights, or (3) quickly resolve a request to get access rights.

The information sharing mechanism should yield *minimal human involvement.* Crisis management workers need to cope with a large amount of information, manage stress and make decisive decisions where necessary. Use of an information sharing mechanism must be targeted towards reducing the cognitive load needed for the sharing of information and the mechanism itself must be easy to use. This means that the mechanism must include support for the semi-automatic resolving of access requests.

The shared information in a crisis situation should be *accountable*. We believe that in times of crisis it is more important to share information than to restrict information access due to pre-existing security policies; information safety is important, but the safety of people is paramount (Massacci 2010). However, a mechanism needs to be in place to safeguard against abuse of access rights. A way to do so is to ensure that information access can always be accounted for, in such a way that it can be explained why someone requested information. An information sharing mechanism that is accountable will allow organizations to make classified information available under certain conditions.

3 Explainable security certificate requests and generation

In this section we introduce our solution to cope with changes in information sharing during crisis situations. It is based on the concept that for each new information source a requester requires access to that it does not already have, the requester indicates why it needs this information, i.e., the requester gives the goal he/she is working towards for which the information is necessary. Goals are organized in a so-called goal hierarchy *h*; indicating how main and subgoals are de-

pendent upon each other. So, each goal *g* has a possible parent g_p and possible children $g_{c1..n}$. For example, extinguishing a fire involves investigating the fuel that nourishes the fire (e.g., oil, sodium, wood) getting the appropriate extinguisher (water, powder), and actually extinguishing the fire. So, any *extinguish fire* goal has at least three subgoals: *investigate fuel*, *locate extinguisher*, and *use extinguisher* (see Figure 1).

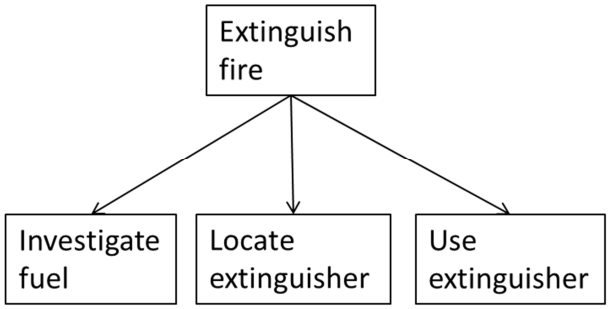

Figure 1: Part of a firefighter's goal hierarchy.

We propose to use these hierarchies to order the different goals each organization has. Each organization *o* (itself a hierarchy of workers *w*) has its own goal hierarchy, so $h_{o1..m}$ hierarchies exist. Typically such goal hierarchies will follow roles and organization hierarchies but will be more specific than roles (because goals and subgoals are more task specific than roles). A practical way to couple goals to individual workers is to attach goals to roles, so, each role *r* has associated with it a set of goals $g_{r1..i}$. Each individual worker *w* has a set of roles R_w, and, thus, a set of goals within one organization, i.e., the superset GR_w of all goals $g_{r1..i}$ for all *r* in $\underline{R_w}$.

In the following two subsections we describe the uses of the goal hierarchy and organization hierarchy to manage information access rights in a crisis situation. The first subsection discusses how goal hierarchies are linked to information and information requests. In the subsection thereafter we detail how information access requests can be automatically and manually generated using goals in a goal hierarchy, and workers in an organization.

3.1 Motivated security certificate requests

The information flow in crises can be described as sources that produce messages on different topics and workers that want that information. If a worker *w* needs information from a source *s* on a topic *t*, then that worker *w* issues a request from *s* for messages about topic *t*. It tags this request with a goal g from its personal goal list GR_w. A request thus consist of the following tuple of information (w, g, s, t), i.e., a specific worker *w* asks for a reason *g* from source *s* the access to information posted by *s* on topic *t*.

In practice, many of the active goals and roles of a worker can be predicted based on the activities of that person, or could be detected from the context. The worker only has to check that the request for information has the right goal attached. This means that it is rare that a worker actually has to manually fill-in the current goal, unless the worker is doing something out of the ordinary.

The information source *s* in a request (w, g, s, t) can be a software agent or a human. If source s is a human, he or she would receive a request for access to a particular topic. Because the request includes a reason, it is now easier to decide to grant access or not. For example, if a journalist would ask the fire brigade for access to the estimated endangered area due to a forest fire, the squad leader will refuse. However, if the reason is that the journalist happens to be a civilian who is already in danger and the restricted area is the only path to safety, the squad leader will grant the request. Tagging information requests with the reason why is useful as a quick heuristic to decide whether or not to give access to information.

3.2 Automated generation of security certificates

We now explain in more detail how information requests can be dealt with in relation to the generation and distribution of security certificates. First we assume a *valid* certificate is always needed to access information. So, any request for information needs a valid certificate, with *valid* defined below. Second, we assume that the organization hierarchy *o* is used to resolve requests for certificates (w, g, s, t), such that a worker *w* in organization o_w always asks its parent p_w in o_w for a valid certificate in case *w* does not have one, unless $w = p_w$ in which case *w* asks the top of organization o_s, with *s* being the information source. Third, validity of certificates is contextualized, by which we mean that a certificate is only valid (i.e. can be used to retrieve information) for a particular context uniquely defined by the tuple (w, g, s, t), potentially enriched with other relevant information such as the crisis level *l*. A certificate $c_1 = (w_1, g_1, s_1, t_1)$ is greater than $c_2 = (w_2, g_2, s_2, t_2)$ if and only if g_1 is a (possibly recursive) subgoal of g_2 and $w_1 = p_{w2}$ or $w_1 = w_2$. If a certificate c_1 is greater than c_2, the holder of the certificate can create c_2. The creator's ID w_c is added to the certificate, resulting in what we define as a *valid* certificate (w, g, s, t, w_c) for accessing information from *s* for topic *t* by worker *w* for goal *g* as issued (created) by w_c.

These assumptions enable the following. First, software agents that represent superiors holding certificates for higher level goals can automatically (without involvement of the superior) generate smaller certificates. This facilitates flexible and timely information access and limits human overhead. Any information request (the generation of certificates) as well as the actual information retrieval are fully auditable in a manner that allows explanation of why information was needed by whom and by whom the certificate was granted. Further, as the certificate is contextualized upon goal (i.e., reason of use) and as information can only be retrieved using valid certificates, as soon as a worker is not working on a particular goal, information cannot be given anymore, unless the worker lies about its goal. However, this lying is traceable, and thus the worker or his/her superior can be

hold accountable for this afterwards. Goals can serve as justifications for requests *after* the crisis. For example, if an organization revealed information about its security system to the police during a crisis, it probably wants to check which information has been provided to whom for what reasons. The goals that accompanied exchanged information can be used to justify the information exchange.

4 Discussion and future work

We have presented an approach for flexible information access right management for crises. The approach is based on goal-based motivated information requests and proposes a method for automated security certificate generation. We anticipate that this promotes accountable, flexible and timely delivery of information during crises with minimal human involvement. Our next step is to show these benefits experimentally. Besides this, we anticipate two other benefits of our approach: information filtering and explanation of the need for pushed information to workers. We will briefly address these two benefits now.

This paper discusses information requests from workers to information sources, which we call *information pull*. Due to the time pressure in crisis situations, however, it can be beneficial for workers to receive information without asking for it, i.e. to receive an information push. It is important that the *information push* only contains relevant information. When the worker receives more information than he/she is able to process, the worker will start ignoring the information and in that way will miss important messages.

A way to create an automatic information push with relevant information is to annotate information with goals. A worker *w* has a certain role *r* in the organization *o* it is part of. A role *r* is associated with it a set of goals $g_{r1..i}$, so it is known which goals a certain worker is trying to achieve. Now when information is annotated with goals, these goals can help to filter the information that should be sent to a worker, using either a static (pre-configured) or adaptive (machine learning) approach.

In addition to delivering the information, workers need to know why this information is relevant to them. The same goals can be used to explain this relevance. For example, consider a gas leak situation. If information about a change in wind direction is pushed to a police officer in the area, it is helpful for this officer to know that this information is relevant for investigating the presence of civilians in the newly affected area. Otherwise, it would merely be information about the weather, and the burden of inferring what to do with it would be upon the officer or the information source.

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Disaster Managers' Perception of Effective Visual Risk Communication for General Public

Marie Charrière, Thom Bogaard and Erik Mostert

Water Resources, Delft University of Technology, Stevinweg 1, 2628 CN Delft, The Netherlands, e.mails: m.k.m.charriere@tudelft.nl, t.a.bogaard@tudelft.nl, e.mostert@tudelft.nl

Abstract

Risk communication is one of the measures that should be implemented to increase the awareness and preparedness of the general public in order to attain disaster risk reduction. Among the various forms that can be used in communication campaigns, visualizations are appropriate to disseminate information about spatial phenomena such as natural hazards. In order to be effective, communication campaigns should be designed according to the specificities of the targeted audience. Risk and disaster managers are seen as a source of information about the latter as their tasks put them in direct contact with the general public and they need to communicate risks. Hence it is assumed that investigating their perception on the informative needs of the general public can help to design effective visual risk communication campaigns and to evaluate them.

1 Introduction

During the ongoing decade disaster risk reduction has received more and more attention from society and is now considered a global issue. This is emphasized by the adoption in 2005 of the Hyogo Framework for Action (UNISDR 2007). It acknowledges that the vulnerability to disasters is increasing due to phenomena such as demographic changes, urbanization, environmental degradation and climate change and that this is a menace to "*the world economy, and its population and the sustainable development of developing countries*" (UNISDR 2007). Nevertheless, examples such as the Katrina hurricane in 2005 and the Japanese tsunami in 2011 show that this is also valid for developed countries.

In the risk management cycle (prevention, preparedness, response and recovery), communication is one of the key parameters, among others, to manage the consequences that an event has on the community. The general framework on risk governance proposed by the International Risk Governance Council (IRCG) (Renn 2005) shows that communication is the central element. Indeed, it is linked to all 'stages' of the risk governance: from pre-assessment to risk management, highlighting the complexity of the role of communication.

Risk communication has several purposes. However, usually it aims at fulfilling one specific objective and the communication campaign can be declared effective if the latter is met. One possible risk communication's goal is the increase of awareness and preparedness of the general public. Multiple means and tools, including visualization, can be used to do so. In order to assess their effectiveness direct testing of changes in awareness and preparedness should be conducted. However, before starting this type of research, preliminary information is needed. Indeed, communication campaigns should be designed to fit the needs of the targeted audience. One possibility is to investigate the opinions and perceptions of risk and disaster managers as there are assumed to have a practical experience of the communities in which they work. Questionnaires can be used to gather data on the perception of risk and disaster managers concerning the requirements for risk communication to specific groups in the community they work in. If the analysis of the collected data reveals significant elements for risk communication in the community, these elements will be used to design visuals for risk communication.

2 Risk communication

In addition to a global increase of the vulnerability to natural hazards, three social trends encourage the diffusion of hazard and risk related information (Fildermann 1990): the growth of the information society, the increased reliance on high technology systems and the growing interest in health and security.

Risk communication is a complex process that is constituted by several elements (Höppner et al 2010):

(i) Actors that are involved and that have different characteristics and perceptions which have to be taken into account when designing risk communication efforts in order to make them effective (Lundgren and McMakin 2004).

(ii) Mode(s), channel(s) and tool(s) that refer to the way risk communication is implemented. The possibilities are multiple to practically disseminate a message although their relative performance may be variable depending on the context.

(iii) Message(s) that is the core of the communication. The content should follow several principles to make the communication effective: it has to fit the audience needs, it should be transparent (what is known and not known), the language should be adapted to the audience and it should be

embedded in wider frames (the effectiveness of short-term communication may be related to long-term communication).

(iv) Purpose(s) or goal(s) that the risk communication is aiming at. They are various and a given communication effort can consider one or several of them.

Although its purposes are multiple, risk communication can be seen as a mean to raise awareness, improve knowledge or change behaviors and beliefs of involved stakeholders (exposed people, experts and managers, decision-makers, general public and media). In case of crisis (e.g. occurrence of a natural hazard), the importance of communication is crucial to minimize damage and save lives as it influences the response of all concerned parties.

3 Visual communication

In addition to verbal and written means of communication, visualization can be used. In a broad sense, visualization can be defined as the representation using visuals. It has become an important topic of research in the last decade due to the extension of the size of data-sets produced by the most recent data acquisition techniques (Post et al 2002). Due to increasing computing power, new research fields such as 'Information Visualization' and 'Data Visualization" have emerged. Visualization can also be used in communication. Trombo (1999) defines visual communication as "*a process of sending and receiving messages using visual images and representation to structure the message*".

Visual communication can be implemented through a wide range of means: pictures, movies, charts, graphics, maps or objects. Moreover, lately, increasing use is made of new technologies such as Geographic Information System (GIS), web-based platforms and Smartphone applications which all have a strong visual component.

In general, the advantages of visual communication "*include the capacity to convey strong messages, making them easy to remember; condense complex information and communicate new content; provide the basis for personal thoughts and conversations, contributing to people's memory and issue-awareness; and communicate idea in an instant using many different media and contexts*" (Nicholson-Cole 2005). Geospatial solutions, i.e. based on maps, are particularly well adapted to communicate about natural hazards as the latter "*have a strong spatio-temporal component*" (Dransch et al 2010). The authors specify the large variety of potential objectives of maps: (i) improve risk perception (increasing knowledge and understanding, enabling appropriate risk assessment, allowing information accessibility), (ii) support personal risk framing (creating a personal view, allowing confirming information with others through interaction) and (iii) establish credibility (informing objectively or giving consisting information).

Nevertheless, visual communication has limitations and drawbacks. Bresciani and Eppler (2008) listed the sources of potential negative effects of visualization: (i) cognitive designer induced effect: ambiguity, over-complexity/simplicity and

unclearness, (ii) cognitive user induced effect: depending on perceptual skills, misuse, and high requirement on training and resources, (iii) emotional designer induced effect; disturbing and boring, (iv) emotional user induced effect: visual stress and prior knowledge experience, (v) social designer induced effect: inhibit conversation and unequal participation and (vi) social user induced effect: cultural and cross-cultural differences altered behavior.

4 Effectiveness and its evaluation

As seen previously, visuals can have potential positive as well as negative effects that should be taken into account when designing communication efforts in order to make them effective. This is particularly valid for risk, emergency preparedness and crisis communication for which a failure can lead to disastrous consequences. Therefore, it is necessary to determine what constitutes effective visualization. Moreover, the evaluation of risk and crisis communication's effectiveness allows improving future programs, choosing between alternative efforts and justifying them (Rohrmann 1992, 1998). The need for evaluating risk communication efforts is stressed by several authors (Penning-Rowsell and Handmer 1990, Covello et al 1991, McCallum 1995, Lipkus and Hollands 1999, Lundgren and McMakin 2004).

Effectiveness of risk communication and the criteria to assess it is widely discussed in literature. Rohrmann (1992, 1998) proposes a relatively vague definition of effectiveness: "*the degree to which an initial (unsatisfactory) situation is changed toward an intended state, as defined by the (normative) program objectives*". On the other hand, the author listed a large amount of very specific criteria that can be used to evaluate the effectiveness of risk communication: (1) content evaluation (correctness, completeness, comprehensibility, meet of user needs, personal relevance, ability to be believable, not frightening or hurtful, and ethic), (2) process evaluation (identification, inclusion and motivation of relevant actors/parties, feedback and difficulties that occurred running the program) and (3) outcomes evaluation (improvement of comprehension, knowledge, problem awareness, involvement and change of behavior, beliefs or attitudes of the targeted audience). The particular criteria for evaluating visual displays for risk communication and cartographic visualization of risk as well as uncertainty are respectively comprehension, acceptance, dose-response consistency, hazard-response consistency, uniformity, audience evaluation and direction of communication errors (Weinstein and Sandman 1993, cited by Lipkus and Hollands 1999) as well as accuracy and congruence, accessibility, retention, change in perceived risk and subjective measures of quality and usefulness (Bostrom et al 2008).

Few examples of evaluation of effectiveness were found in literature. Moreover, they focus on users' requirements, ability to read the communication means, ability to understand the content, or satisfaction with the diverse components of the tool(s). No published evaluation of the impact of visuals for risk communication was found (Charrière et al (in press)). When talking about impact, we refer to

effectiveness as the degree to which the purpose(s) of the communication has been met ("outcome evaluation": Rohrmann 1992, 1998). Here visual communication practices are considered to be effective if they result in a change in the target group's preparedness and public awareness, as defined by UNISDR (2009), i.e. "*the extent of knowledge about disaster risks, the factors that lead to disasters and the actions that can be taken individually and collectively to reduce exposure and vulnerability to hazards*".

5 Studying the effectiveness of visualization

This research, which is part of the Initial Training Network 'Changes', aims at determining what elements make a visualization tool effective for risk communication. More precisely, what is the most effective visual for a given purpose, message, phase and audience? It is highly probable that different visualization tools will have different levels of effectiveness depending on the content and the stakeholders involved. Visuals can have various forms: graphics, pictures, movies, maps as well as objects. Each of them presents characteristics that can make them more effective relatively to others for a given situation. The focus of the research is hence to determine which visual is more effective for risk communication, in prevention and preparedness phases, linked to short lead-time hydro-meteorological hazards occurring in alpine areas.

This research is relevant because it is important to understand what are the best existing visual communication practices and what makes them more effective than others in order to improve further developments of risk communication principles and practices. The social significance of the research is relatively obvious as the improvement of the dissemination of information to all involved stakeholders is believed to increase their awareness, improve their knowledge or change their behavior or beliefs; and hence reduce their vulnerability to natural disasters. As no examples of evaluation of effectiveness in terms of impact was found, the scientific relevance of the research lies in the development of a methodology to evaluate the effectiveness of visualization tools as well as in the technical guidelines for future visualization tools that will arise from the evaluation.

6 Risk and disaster managers' perception of general public's needs

As a starting point to conduct direct testing of effectiveness of visual communication to increase awareness and preparedness of the general public to hydro-meteorological hazards, the risk and disaster managers' perceptions and opinions about the communication needs of the general public in France, Italy, Romania and Poland will be assessed. Indeed, to be certain that any risk communication practice is effective the design should fit the targeted audience's needs (Lungren

and McMakin 2004). These can be determined by direct user needs assessment, that are highly time consuming and complex due to the large variety of social, economical, psychological characteristics of the individuals that compose the general public. Hence, it is also interesting to conduct research on the perceptions and opinions that risk and disaster managers have about the needs of the public. Due to their tasks, some of these actors are in direct contact with the public during any of the phases of the risk management cycle (prevention, preparedness, response and recovery) and therefore have a practical experience of the awareness and preparedness of the population. Moreover, depending on the country and responsibilities of these managers, it is their duty to inform communities at risk and they should know on which basis to do this.

Under the assumption that perceptions and opinions of risk and disaster managers regarding the requirements for risk communication in a community can help to design effective risk communication practices, a standardized questionnaire is formulated. The questions relate to the level of awareness and preparedness, to past risk communication efforts made in the respective working area as well as to future risk communication designs in terms of content and visual tools. Detailed topics are provided in Table 1.

If the assumption above mentioned proves to be correct, the elements highlighted by this questionnaire will be the basis for the testing of the effectiveness of visual communication targeting the general public. The anticipated results are the specification of priorities in terms of (i) sub-groups of the general public to address communication campaigns to, (ii) the phase(s) of the risk management cycle for which the risk communication campaigns should be designed, (iii) the content of the message(s) that should be included in the communication campaigns and (iv) the visualization tools that should be used.

Table 1: Detailed topics and related questions' themes of the standardized questionnaire.

TOPICS	QUESTIONS ON THE FOLLOWING THEMES…
Awareness	Definition of the concept, comparison of awareness levels of sub-groups of the community
Preparedness	Definition of the concept, comparison of preparedness levels of sub-groups of the community
Past communication campaigns	Types, frequency of dissemination, effectiveness, appropriateness of the content depending on the audience
Future communication campaigns	Link between content and audience, improvement and priority of action depending on the phases of management cycle
Legal requirements	Laws that require communication to the general public in all disaster management's phases
Visualization	Communication of uncertainty, appropriateness of visualization tools depending on the audience

While the questionnaire's dissemination is under process in different case studies in Italy, Romania and Poland, preliminary results in the French case study show that opinions on awareness and preparedness levels of different sub-groups

of the general public are similar among risk and disaster managers. Moreover, although knowledge and opinions on past risk communication efforts are highly various, there is a common agreement that improvements can be made in particular concerning the dissemination of information related to individual mitigation measures and emergency procedures. In terms of visualization tools that should be used to communicate to different audiences, opinions of risk managers are not completely homogenous. Nevertheless, some combinations of visualization tools and types of audience are revealed: graphs, charts and maps for risk managers; Smartphone applications, interactive environments and websites for adults and children; information boards for tourists. In addition, pictures and movies appear to be universal mean of visual communication (i.e. appropriate for all types of audience) in the opinion of risk managers. From these findings we can assume that risk managers have determined from their experience that visual risk communication practices should be audience specific and that this is not only a theoretical guideline. Moreover, the use of geospatial mean, such as maps, is no seen to be the most appropriate tool for communicating risk to the general public as a whole. It suggests that geospatial information and tools might not be the top priority when targeting the general public on the contrary of managers and decision-makers that crucially need such things (Neuvel and Zlatanova 2006). In addition, more than 75% of the surveyed risk managers believe that there is a need to communicate uncertainty to the general public. This is an indication that they have faced or believe they will face situations where the unavoidable uncertainty issue can not be dissimulate to the public without having consequences (e.g. decrease of risk avoidance or trust). In terms of the way of communicating uncertainty, although the risk managers prioritize the use of probability over return period, the visual form is almost always preferred to numbers and text.

7 Perspectives

This study is believed to assist the development of further research in the effectiveness of visual communication to increase awareness and preparedness to hydro-meteorological hazards of the population of several alpine countries. Increasing awareness and preparedness to natural hazards is one of the element that determine risk behaviors (Enders 2001). Hence there is a link between these factors and risk avoidance. Awareness and preparedness are site specific processes, not only from the point of view of the natural phenomena but also from the perspective of the specificity of the community that faces them. Indeed general public has contextual characteristics deriving from cultural, social, economic… conditions. And these should be taken into account to design risk communication campaigns that are effective, i.e. that meet their goal(s). Due to their tasks, some of the risk and disasters managers might be in contact with the general public and have opinions and perceptions on the level of awareness and preparedness of the general public and on how much and how it is needed to improve them. Then their knowledge can be beneficial in order to design effective risk communication cam-

paigns that are part of the overall goal of disaster risk reduction. Taking this into account in addition to direct testing of the impact of visualization on the awareness and preparedness of the general public has at least two benefits. First, it can be used as substitutive information when direct assessment is too time consuming or too complex due to the high variability of the characteristics of individuals in one community. Second, if it is combined to direct testing, it can provide an assessment of the correspondence of risk managers' opinions and perceptions on the effective visual risk communication practices with their real effectiveness. This can hence allow adapting or changing existing ineffective practices into ones that would have a real impact on awareness and preparedness with the goal of increasing risk avoidance of the general public.

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Design of Fuzzy Inference Engine for Earthquake Risk Assessment

Seyyed Babak Mirjafari[1], Seyyed Ali Alavi[2] and Hossein Helali[3]

[1] GIS and RS Center, University of Tabriz, 29 Bahman St, Tabriz, Iran, e.mail: B.Mirjafari@yahoo.com

[2] GIS and RS Center, University of Tabriz, 29 Bahman St, Tabriz, Iran, e.mail: a.alavi88@ms.tabrizu.ac.ir

[3] Civil Engineering Department, University of Tabriz, 29 Bahman St, Tabriz, Iran, e.mail: Helali@tabrizu.ac.ir

Abstract

Rapid assessment of the damaged buildings in a disastrous event is a drastic measure to be taken in order to allocate shelter to homeless people as quick as possible. Natural disasters as earthquakes may cause considerable losses to the cities and prevent development processes. Urban planning as well as city designing projects concern to decrease vulnerability of buildings against earthquakes. In this paper, AHP method and MATLAB Software is used for designing Fuzzy Inference Engine. The used data are: material type, age building, quality, number floor, rate occupation, area parcel and population. ArcGIS software is used to mapping the results of Fuzzy Inference System. The results of the regions vulnerability assessment also shows that 73.66 percent in this area have moderate vulnerability, that are the northeast, east and southeast parts of this regions that included a maximum number of building.

1 Introduction

Every year, numerous natural hazards such as earthquakes and floods occur all around Iran and cause many lives or financial losses. Meanwhile, thousands of people lose their lives as a result of natural disasters and hundreds of thousands of people get wounded and many others lose their homes all over the world. Danger is the occurrence of phenomena detrimental to human. The existence of a danger is therefore the cause of worry. In the meantime, GIS in risk and crisis management plays a conspicuous role, because proper planning and management of risk or seismic risk is only feasible via collecting locational and descriptive information of a city or any intended place. Of course, analyses of the information together with their update are only possible in GIS. Generally speaking, a GIS facilitates data gathering, analyzing, modeling and displaying of two or three dimensional maps of vulnerable areas and seismic risk.

Due to high complexity of crisis management, the development of a decisive model that can determine the relation between input and output space is very difficult. Therefore, there is a need for a model that considers the uncertainty. The theory of fuzzy sets has been successful in modeling some uncertainties.

The concept of Fuzzy logic was conceived by Zade (Zadeh 1987) as a way of processing data by allowing partial set membership rather than crisp set membership. Fuzzy logic can deal with verbal descriptions and is a particularly good choice to handle uncertainty issues (Smith 1993). Such descriptions model a system within "if-then" framework of the expressions.

Fuzzy logic starts with the concept of a fuzzy set. A fuzzy set is a set without a crisp, clearly defined boundary (Cox 1992). It can contain elements with only a partial degree of membership (Beranrdis 1993). Fuzzy set theory permits the gradual assessment of the membership of elements in a set; this is described with the help of a membership function valued in the real unit interval [0, 1].

2 Background

Among the special specifications of the district is the old area in city center, which are considered the important hubs for tradition and plays a conspicuous role in marketing people to all over the state. This area has a population of 36091 and includes 10305 building and big shopping center and important cultural centers. It also includes structures with different strengths. The study case expands 36 km2. These data are prepared from centre of IT in municipality of Tabriz and the scale of data is 1/10000.

Among parameters effective in the rate of the earthquake damage are terrain characteristics, type of buildings and their construction materials, age of buildings, rate of occupation, quality of building, land use.

In this research, the study area is District 8 of Tabriz as shown in Figure 1.

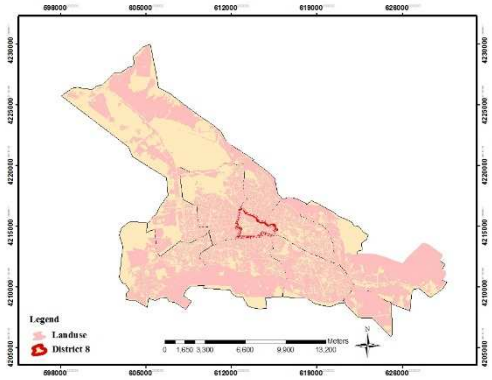

Figure 1: Study Area, District 8 of Tabriz.

Different methods have already been used to evaluate the vulnerability of cities against earthquake. One of the used methods is multi-criterion analysis. This method combines spatial data and attributes as an input and finally calculates the degree of vulnerability of every building element against the earthquake (output), also combining this method with fuzzy logic in GIS, vulnerability of the cities against the earthquake may be assessed with higher accuracy (Rashed and Weeks 2003).

Vulnerability assessment and earthquake modeling of Iranian cities against earthquake using Analytical Hierarchy Process (AHP) have not yet been employed. The only experience in this concern relates to sampling from the buildings in order to apply for the whole city. Numerous factors, including unknown nature of the variables, existence of uncertain factors in analysis of the earthquake crisis and disability in determining the exact limit of local vulnerability and reliefs result in uncertainty in preparation of vulnerability. Therefore, the fuzzy logic has been considered to deal with such uncertainties.

In recent years, fuzzy modeling techniques have been very successful in modeling complicated phenomena as earthquakes (Vahidnia et al 2010). There are many methods for fuzzy modeling such as Takagi & Sugeno and Mamdani which are so-called fuzzy inference systems. The salient advantages of fuzzy deduction systems are high flexibility and simplicity in understanding rules and their changes and development (Cordon et al 2001).

Fuzzy inference systems are based on knowledge or rule. A rule-based fuzzy inference system is a method for making qualitative models out of human knowledge and making computations without relying on quantitative calculations. The system comprises of four main components (Figure 2).

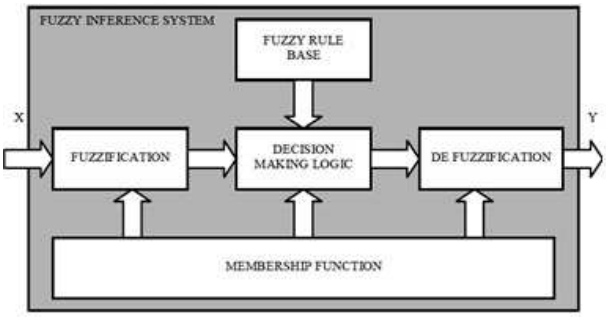

Figure 2: Structure of Mamdani's fuzzy rule based inference system (Cordon et al 2001).

Fuzzification Interface: fuzzification interface has a function, which changes crisp data to fuzzy values (Wang 1996). In other words, fuzzy inference is the process of formulating the mapping from which decision can be made, or patterns discerned. Fuzzification module transforms the system inputs, which are crisp numbers, into fuzzy sets. This is done by applying a fuzzification function. Fuzzy inference methods are classified in direct methods and indirect methods. Indirect methods are more complex ones. Direct methods, such as Mamdani's and Sugeno's, are the most commonly used. These two methods only differ in how they obtain the outputs.

Therefore, the support selection has only one member as in equation 1:

$$A = \{x, \mu A(x) \mid x \in X\} \quad (1)$$

$\mu A(x)$ is called the membership function (or MF) of x in A. The membership function maps each element of X to a membership value between 0 and 1.

Knowledge Base: knowledge base stores "if-then" rules provided by experts. It includes two components, that is database and rule base. Database contains verbal terms used in membership functions and rules; and rule base includes verbal rules set in the form of if-then statements (Ross 2004).

Inference system: inference engine simulates the human reasoning process by making fuzzy inference on the inputs. The function of inference system is to calculate the fuzzy outputs via fuzzy inputs and is defined according to the rules (Wang 1996).

Defuzzifier interface: defuzzification is a process for changing the fuzzy output to non-fuzzy optimal values. defuzzification module transforms the fuzzy set obtained by the inference engine into a crisp value. There are different methods for defuzzification. Some of the common methods for defuzzification are as below: Maximum Membership, Mean Maximum Membership (Ross, 2004), and gravity center (Jarrah et al 2006). This research defuzzifies the results of Mamdani's deductions by gravity center method and implemented in ArcGIS environment.

Gravity center defuzzifier (equatin. 2) considers the effects of all rules appropriately; therefore, it is used in this research.

$$Z^* = (\int z.\mu_C(z).dz)/(\int \mu_C(z).dz) \quad (2)$$

In equation 2, stands for regional gravity center, which is covered by belonging function. This research considers membership functions as many as entry parameters and makes use of 24 rules for modeling the relations between outputs and inputs. The results obtained from Mamdani's method show a high similarity.

In this paper, the vector-format entry data were changed into raster-format data making use of ArcGIS Software. Then, the entry data were put into fuzzy deduction systems in MATLAB environment and determining the membership functions and fuzzy rules. The Sub-Criteria weights used in the AHP method, applied to the membership functions and fuzzy inference engine. Finally, the membership functions are adjusted so that the output of the inference engine is calibrated to the AHP result, then they were visualized in ArcGIS.

There are seven fuzzy entry parameters. The membership functions were defined for each input inclusive: triangular and trapezoid function; and then membership functions related to the output parameters were developed. In Mamdani's method, five membership functions are defined for output vulnerability parameters, which consists of very low, low, medium, high and very high (Figure 3).

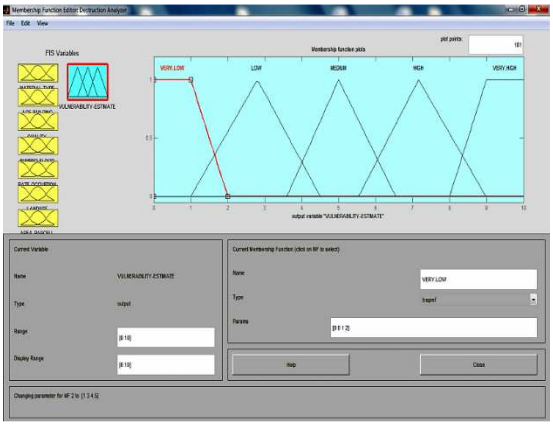

Figure 3: Five membership function for Mamdani method.

About 24 conditions written for this analysis. In the next stage, the input data is introduced into fuzzy deduction engine. Some samples of rules that used in IFS:

-**IF***(MATERIAL-TYPE IS STEEL-CINCRETE) AND(AGE-BUIDING IS +80)* **AND** *(QUALITY IS NEW)* **AND** *(NUM-FLOOR IS 1FLOOR)* **AND** *(RATE-OCCUPTION IS 0 -25)* **AND** *(LANUSE IS OFFICIAL)* **AND** *(AREA-PARCEL IS +500)* **THEN** *(VULNER IS VERY LOW)*

-**IF***(MATERIAL- TYPE IS BRICKAND)* **AND** *(AGE-BULDING IS 70-80)* **AND** *(QUALITY IS DESTRACTIVE RUN)* **AND** *(NUM-FLOOR IS 2FLOOR)* **AND** *(RATE-OCCUPTION IS 25-50)* **AND** *(LANUSE IS COMMERCIAL)***AND** *(AREA-PARCEL IS 100-25-)* **THEN** *(VULNER IS MEDIUM)*

-**IF***(MATERIAL- TYPE IS BRICKAND-WOOD)* **AND** *(AGE-BULDING IS 50-60)* **AND** *(QUALITY IS RESTORATION)* **AND** *(NUM-FLOOR IS 4FLOOR)* **AND** *(RATE-OCCUPTION IS 75-100)* **AND** *(LANUSE IS COMMERCIAL)***AND** *(AREA-PARCEL IS -100)* **THEN** *(VULNER IS HEIGH)*

-**IF***(MATERIAL- TYPE IS BRICKAND-STEEL)* **AND** *(AGE-BULDING IS 60-70)* **AND** *(QUALITY IS RESTORATION)* **AND** *(NUM-FLOOR IS 3FLOOR)* **AND** *(RATE-OCCUPTION IS 50-75)* **AND** *(LANUSE IS EDUCATION)***AND** *(AREA-PARCEL IS 100-250)* **THEN** *(VULNER IS LOW)*

-**IF***(MATERIAL- TYPE IS ADOBE-WOOD)* **AND** *(AGE-BULDING IS -50)* **AND** *(QUALITY IS NEW)* **AND** *(NUM-FLOOR IS 1FLOOR)* **AND** *(RATE-OCCUPTION IS 0-25)* **AND** *(LANUSE IS COMMERCIAL)***AND** *(AREA-PARCEL IS 250-500)* **THEN** *(VULNER IS VERY HEIGH)*

….

The results disclosed that Region 8 of Tabriz (Figure 4) is due to a very high degree of damage, because of the old building as well as using low quality building material**.** While the south of the area is the least vulnerable area due to using the stronger building material and applying the construction standard as the 2800 construction act (Table 1). The BAZAR building in central area due to age and weak material, most destruction will saw.

Table 1: The vulnerability District 8 of Tabriz.

Vulnerability Range	Number of Building	Percent in Area
Very low vulnerability (0-2)	1672	16.2
low vulnerability(0.2-0.4)	1696	16.4
Medium vulnerability (0.4-0.6)	3011	29.2
High vulnerability (0.6-0.8)	2670	25.90
Very High vulnerability(0.8-1)	1256	12.3
Total1	10305	100

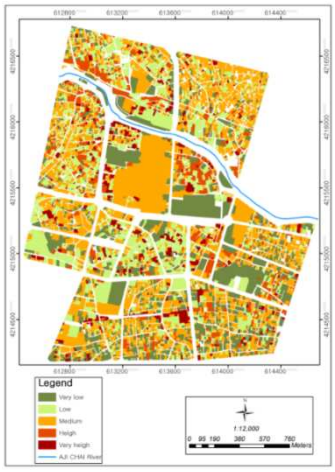

Figure 4: Overall vulnerability based on the used criteria using fuzzy logic.

3 Conclusions

The vulnerability of a city, defined as the losses imposed to urban components in case of a disaster and its intensity may vary based on its nature and quality. The vulnerability of a city is an extensive factor encompasses all existing in a city and all components in a city are connected to each other. Therefore it increases very quickly. Due to lack of digital spatial data throughout the country, risk zoning map against earthquake have not been prepared for Iranian cities. Other studies are mostly based on statistics and housing census which is done as pilot and in some cases applied for the whole country. Therefore an accurate analysis of the vulnerable urban elements against earthquakes has not been yet achieved. In order to obtain real results and use of the fuzzy model, if the factors effective in determining the vulnerability rate have fuzzy nature, we must combine fuzzification of gradual factors and changes. Fuzzy logic is more suitable for combining and analyzing data because the nature of data is fuzzy in environmental disasters.

In this research, the vulnerability rates of blocks against earthquakes were determined. For this purpose, Mamdani's method is used and it is observed that the fuzzy expert system is a powerful method for earthquake risk assessment modeling.

In the process of research, due to the limitation of data availability, some elements are ignored. Therefore, in order to come to better conclusions, all the involved parameters such as materials of buildings, properties of the land under construction together with their weights should be included. For future researche in this regard, examination of the factors effective in vulnerability rate is proposed.

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The Economic Valuation of Geospatial Information and Risk Management

Tessa Anne Belinfante[1], Niels van Manen[2] and Hendrik J. Scholten[2]

[1]VU University, De Boelelaan 1105, 1081 HV, Amsterdam, The Netherlands, e.mail: ta.belinfante@gmail.com

[2]Faculty of Economics and Business Administration, VU University, De Boelelaan 1105 1081 HV Amsterdam, The Netherlands, e.mail: n.van.manen@vu.nl, h.j.scholten@.vu.nl

Abstract

Recent studies have proven the variety of ways in which geospatial information contributes to disaster and risk management (DRM) practices. Geospatial information and associated technologies also play a central part in new methods for assessing costs of DRM itself and of disaster related damages and losses. However, determining the *economic value* of geospatial information in DRM remains an understudied topic. This paper, based on research conducted as part of the United Nations VALID program, proposes an innovative method for determining this value. A systematic analysis of a questionnaire designed for this purpose provides a template to chart the economic value of one geospatial information product. A case study, the Namibia flooding disaster of 2009, is selected to illustrate the application of this valuation method. Here one specific geo-information product, an early warning system, is analyzed. The findings illustrate the steps needed for valuation assessment, which has high potential for future research on the added value of geospatial information products in DRM. In addition, as a co-product of testing the questionnaire, some specific recommendations for the Namibian case study regarding effective application of geospatial information are made.

1 Introduction

This paper is based on research conducted as part of the VALID program, executed by the Joint Board of Geospatial Information Societies (JBGIS) and United Nations Platform for Space-based information for Disaster Management and Emergency Response (UNOOSA), which is a program of the United Nations Office for Outer Space Affairs (UNOOSA). The VALID acronym stands for "Value of Geo-information for Disaster and Risk Management" which has the ultimate purpose to:

1.) Raise awareness in the political and programmatic environment for the importance of geospatial information for DRM.
2.) Set priorities in research and development regarding the application of geospatial information in DRM.

The VALID project consists of a stakeholder assessment and an economic assessment; the latter will be the focus of this paper.

1.1 Purpose of the study

Recent studies have illustrated the variety of ways in which geospatial information contributes to risk and disaster management (Geoinformation for Disaster and Risk Management, 2010). The potential value of geo-information in DRM is high because it can improve the quality and speed of decision making in DRM, which may result in lower associated damages and losses. If we are able to quantify the value of specific geo-information products for different aspects of DRM, it is possible to focus and justify investments on those geo-information products that have the greatest potential to reduce the costs of DRM and to minimize the damages and losses in case a disaster strikes. Attaching a measurable value to the benefits of a geo-information product for a specific DRM task, can thus contribute to a more rational basis for policy makers to make these decisions. This is particularly pertinent because previous studies suggest that spending on geo-information products is often politically driven and concentrated on the direct aftermath of a disaster incident (Grayman and Males 2002). This obstructs rational and continuous investment required for the maintenance and enhancements of products that have proven to bring benefit to DRM.

1.2 Problem statement

The aim of this paper is to propose and illustrate an innovative method for assessing the added value of geospatial information in DRM. The two research questions of this study are as follows:

1. How can the added value of geospatial information in DRM be measured?
2. How can the value of geospatial information in DRM be improved?

A questionnaire has been developed as a tool in order to appraise the added value of one particular geospatial information product: an early warning system,

which relies on the input of geospatial information. A case study has been selected to illustrate the application of this valuation method, namely the Namibian flooding disaster in 2009. DRM experts and local end-users of geo-information contributed their knowledge by filling in the designed questionnaire. In addition, as a co-product of testing the questionnaire, this study, will present some case study specific recommendations regarding effective applications of geospatial information in Namibia.

2 Determining the value of geospatial information in DRM

Geospatial data refers to interdependent data sources (i.e. imagery, maps, datasets, tools and procedures) that link every event, feature or entity to a location. When data is converted into something meaningful it becomes *information* (Alberts et al. 2001). As this study focuses on the value of geospatial information, the definition *geo-information product* is adopted after Krek and Frank (1999) referring to geospatial information that is used to make decisions. The value of information is highly dependent on who receives it and what subsequent actions are taken. Consequently, the economic value of information should be determined by estimating the impact of an altered decision making process resulting from this information (Figure 1). When the impact can be economically assessed, the value of geospatial information can be deduced. This value can in turn be used to make rational decisions regarding investment in specific geo-information products.

Figure 1: From Information to Impact (after Fritz et al 2008).

Studies that value the type of geo-information product considered in this paper, namely early warning systems, generally make use of either the cost avoidance method or the contingent valuation method. Klafft and Meissen (2011) have highlighted the biases to which contingent valuation methods – models based on respondents' estimation of their willingness to pay for a specific service – are prone. Therefore the research underpinning this paper takes the cost avoidance method as its starting point. This method starts by determining the impact of the early warning system by assessing the damages and losses that were avoided based on protective actions taken following the warning. The avoided costs are then interpreted as the benefits of this product. An important assumption made here is that geospatial information forms a vital input for the early warning system. Finally, the costs of the early warning system and of all the protective measures based on the warning (including those taken in areas where the disaster did *not* strike) should be de-

ducted from the benefits to calculate the economic *added* value of the system (Klafft and Meissen 2011).

Klafft and Meissen (2011) have formulated a detailed model for calculating the tangible economic benefits of an early warning system. To estimate the likely benefit, they take account of the likelihood of a warning message reaching the recipient and being translated into protective action based on personal and cultural factors, prediction-related factors and dissemination-related factors. Their cost estimation includes the costs associated with protective actions informed by the early warning systems as well as a detailed breakdown of initiation and running costs of the early warning system. Advantages of their model are its applicability to different disaster types (by incorporating lead time, which varies considerably between disasters – into the equation) and its focus on the overall potential of early warning systems rather than their specific contributions at times of disaster (by taking account of disaster frequency and likelihood). Downsides are the need for very detailed information, requiring a very substantial research effort in order to apply the model to even a single disaster area and type.

This paper proposes an alternative model. It lacks some of the detail of Klafft and Meissen (2011), but is more easily replicated. It takes the damage assessment reports that are routinely compiled when disasters strike and determines the percentage that were saved thanks to the actions taken based on the early warning system. A questionnaire has been designed to query field experts about the damage reductions. Because the damage reports have a generic structure, almost universally including the same damage categories, this questionnaire can be applied with little adjustment to other cases of the same disaster, to other disaster types and also to other geo-information products. For this study, the questionnaire has been applied to the *potential* benefits of an effective early warning system in a case where the actual warning system failed completely: the Namibian floods of 2009. The next three sections will provide necessary information about early warning systems, the Namibian floods, and the questionnaire. Next, the outcomes of the Namibia questionnaire will be evaluated. Finally, recommendations will be made regarding the improvement of geo-information products in Namibia and suggestions will be made regarding improvements to the questionnaire (crucially, adding a section evaluation the cost of operating the early warning system) and how the questionnaire may be applied to other cases.

3 Geospatial information product selection

Preparedness for natural disasters is a key factor in reducing their impacts (Alfieri et al. 2012). The importance of increasing preparedness of society is a major conclusion of the extensive World Bank publication *Natural Hazards, Unnatural Disasters* (2010). The report identifies three specific spending items desirable for disaster prevention, namely: critical infrastructure, environmental buffers and early warning systems. Early warning systems have been furthermore confirmed as an attractive prevention option for reducing the impacts of natural disasters, be-

cause the benefits can significantly exceed the costs of developing and maintaining such devices (Rogers and Tsirkunov 2011 and Teisberg and Weiher 2009). Especially in case of hydro-meteorological hazards, which can be detected with a sufficient lead time for adequate action, early warning systems can save lives and properties while providing additional benefits by optimizing economic production in weather sensitive sectors (Hallegatte 2012). Note, however, that care must be taken to not overestimate the impact of an early warning system, as not all property is suitable for protection and removal. On the other hand, the potential of saving lives is present (Teisberg and Weiher 2009).

4 Case study selection

When selecting a case study, several reasons have led to the Namibia flooding event in 2009. (1) Namibia's *geographical location* makes the country vulnerable to recurrent climate hazards, including floods. (2) Also Namibia is considered as one of the most vulnerable countries to future climate change in sub-Saharan Africa (PDNA 2009). Projections show greater anomalies in rainfall, increasing chances for high intensity rainfalls and thereby subsequent flooding. Optimizing the (future) use of geo-information would therefore be highly valuable. (3) There is a high potential for the development of an early warning system due to the nature of (part of) the flooding events, as the headwaters of the main rivers originate far upstream and thereby potentially a high lead time. (4) As the 2009 flood covered a large area and timing and dynamic behavior was variable among regions. Therefore, especially satellite data is very suitable in this case as this provides overview of the situation by mapping areas that are remote and/or difficult to reach (Namibia PDNA 2009). Concluding, geo-information has a lot to offer to this country and a potential high impact. (5) There is already a history of contact between UN-SPIDER and the Namibia Hydrology Department, which is vital for this study to provide context, additional information and the distribution of the questionnaires. (6) An extensive 'Post Disaster Needs Assessment' (PDNA) was written after the flood of 2009. The National Planning Commission of the Government of Namibia requested the World Bank, through the Global Fund for Disaster Reduction and Recovery (GFDRR), for this assessment. In collaboration with the UN and the European Commission, the report was published in 2009. An extensive description of the damages and losses can be consulted, which forms crucial input for the analysis, just as the needs for early and midterm recovery, and a long-term risk management and reduction strategy.

5 Methodology: design of the questionnaire

The questionnaire consists of two parts: (1) a numerical part, attempting to indicate the damages and losses that could have been avoided, had there been an ef-

fective early warning system in place, which provided an early warning with sufficient lead time to take protective action (2) a case specific qualitative part. As the flood warning in 2009 did not result in subsequent adequate actions, this second part of the questionnaire focuses on the causes of failure, the improvements (if any) that have been implemented since 2009 and desirable future developments. Respondents were systematically queried regarding the elements identified by the UNISDR (2004) for an effective early warning system: monitoring and warning capacity; communication of the warning; awareness of communities and response capacity.

The focus of this paper is on the valuation methodology, introduced in section 2 above, also known as a 'cost avoidance approach'. As an early warning system, supported by geospatial information, can provide earlier actions, it has the potential to reduce damages and losses. Vital input needed for such an analysis are the damage and losses figures resulting from the flood, provided here by the Namibia PDNA (2009), divided into four different sectors: infrastructure; productive; social; cross-sectoral. Based on a literature review, it was found that it is possible to foresee flooding events in Namibia resulting from high intensity rainfall events, on average, for at least 10 days in advance (De Groeve 2010).

The first part of the questionnaire is dedicated to a systematic evaluation of the damages that could have been avoided had an effective warning system been in place. Because cost-benefit estimations are known to have a relatively low accuracy level (Klafft and Meissen 2011), an order-magnitude answer structure was used. The participants were asked to indicate on a scale ranging from 0-100%, what damages and losses could have been avoided, per economic sector, had there been an effective warning 10 days prior to the flood? Some assumptions had to be made, including the availability of the means to act. Furthermore, participants were asked what % of lives could have been saved, had there been an effective early warning.

Next, the percentages indicated by the respondent were coupled to the damage and losses figures, which provides a monetary indication of the cost and loss reduction had an effective warning system been in place.

In the end, these figures should be corrected for the correct currency, the occurrence time of such a severe flooding happening and the costs involved developing and operating the proposed system, in order to estimate the *added* value of geospatial information. This, however, is beyond the scope of this research and the focus will lie on identifying the *benefits*.

The questionnaire was tested beforehand and the participants were ensured that their answers would be treated confidentially and that the findings would be shared with them. The questionnaire was send to members of the scientific community, related to the Namibian Early Flood Warning SensorWeb[1] and to the

[1] The pilot project started after the flooding events in 2009, via an international partnership between NASA, UN-SPIDER, Namibia Department of Hydrology, Canadian Space Agency, Ukraine Space Research Institute, DLR (Germany) and others (10 p.). For more information please visit:
http://sensorweb.nasa.gov/NamibiaFlood.html

Head of the Namibian Hydrology Department Guido van Langenhove, who in turn distributed the questionnaire internally in the department itself and externally to members of the flood bulletin, which provides updates on river levels received by for example tourist lodge owners or private homes. The respondent rate was unfortunately too low for statistical analysis, which might in part be due to the time that has passed since the flood event (some respondents indicated they were tired of surveys and investigations regarding the event) or the fact that the questionnaire was not distributed directly by the researchers. Nevertheless, the 14 questionnaires that were returned provide useful case-specific qualitative information as well as important insights regarding the feasibility of this 'cost avoidance approach' and the steps to be taken for further development of this method.

6 Results

First, the cost avoidance approach will be discussed, which forms the focus of this study. Secondly, some the Namibian case study specific results regarding the use of geospatial information in this particular context are discussed, which are a co-product of testing this questionnaire.

6.1 Cost avoidance approach

Out of the 14 respondents, 8 completed the economic valuation part. Five gave estimated ranges (as was asked for), 3 gave average estimates. In order to combine and analyze all 8, the choice has been made to translate the average estimates into estimated ranges (based on the average range span). This was done for each of the four categories (infrastructure; productive; social; cross-sectoral) plus for the reduction of lives lost. In the figure below, the averages are displayed as the thick bars, where the average range per category is displayed as the thin black lines on either side of the maximum point of the blue bars.

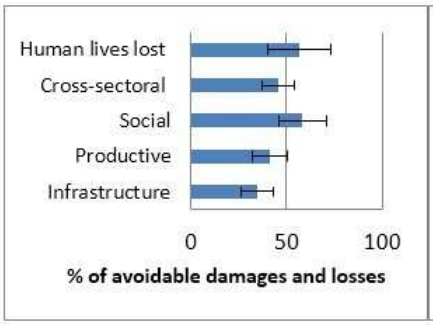

Figure 2: Avoidable damage & losses in percentages.

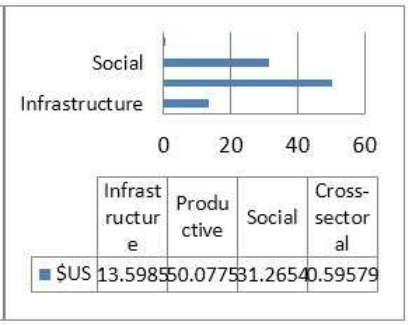

Figure 3: Avoidable damage & losses in US$ 2009.

Note that the number of respondents is small and that outliers are present in a small number.

In total 102 persons lost their lives due to the flood (PDNA 2009). The percentage that could have been saved, had there been an effective early warning system was estimated to be 56,88%, with an average range of 33%. This was the largest range to be discovered among the different categories. The cross-sectoral category, covering the environment, was estimated on 54,83%, with an average range of 6.67%. The social sector had most to gain from an effective early warning system, namely 58,44%, with an average range of 25%. The productive sector was estimated on 41,25% of the damages and losses that could have been avoided, with an average range of 18%. The sector infrastructure was estimated to have the lowest gains, namely 34,69%, with an average range of 33%. Summarizing, the respondents indicate they feel that most gains of the effective application of an early warning system are to be expected in the social sector, closely followed by the number of human lives lost in the flood. The range provided by participants was largest in the category number of lives lost, indicating there is much uncertainty in providing an estimate.

The average percentage numbers were subsequently coupled to the actual occurred damage and losses monetary figures. Note that the currency is from the year 2009. The largest amount of money to be saved, according this approach, can be found in the productive sector (US$ 50.08), followed by the social sector (US$ 31.27). Damages and losses that could have been avoided in the infrastructure sector are estimate to be US$ 13.60. The cross-sectoral is said to be at US$ 0.60. In total the four sectors add up to a sum of US$ 9554, that could have been avoided had there been an effective early warning system. The number of lives has not been calculated to an economic figure due to the word limit of this report.

6.2 Case specific qualitative analysis

13 out of the 14 respondents identified causes concerning the ineffective response to the early warning system at the time of the flood in 2009. The primary cause was the insufficient response capacity on a local level (35% of respondents), followed by a lack of awareness of the communities (23%), poor communication of the warning (15%), insufficient monitoring and warning capacity (15%) and other causes (12%).

All participants indicate that improvements have been made to the early warning system since 2009. Especially the ‘flood bulletin’ provided by the Hydrology Department is mentioned several times as a positive development. The respondents were asked to evaluate whether improvements had occurred regarding the factors that caused ineffective response to the early warning in 2009, which was affirmed for all four factors, see Figure 4.

The following recommendations are based on the PDNA that was produced in the aftermath of the 2009 Namibian flood. (1) Improving the trans-boundary collaboration with the Zambezi River authority and the Okavango River Basin Commission, to ensure communication across borders. (2) The installment of 17 new

gauging stations and 20 new rain gauges in the Cuvelai basin, to increase the monitoring and thereby warning capacity. (3) The development of warning systems that match local conditions; such as the use of flags, megaphones or other means of communication. Community volunteer groups could play an important role here.

Future developments priorities specified by the participants are further improvements in communication, together with a larger pool of resources and additional developments of models for better flood prediction.

7 Discussion

Two problems were encountered during this study: (1) a relatively low respondent rate and; (2) participants indicated they experienced difficulties answering the questions concerning the 'cost avoidance approach'. Reasons provided were that participants did not find themselves to be qualified or informed enough to provide answers, or that the scenario, concerning a possibility of a 10 days in advance warning, and research approach are unrealistic. Also the head of the Namibian Hydrology Department indicated that it should have been made more clear on a local level why their participation was needed and what they personally had to gain by participating, as this is not the first study on the flooding events in Namibia and locals pointed out to be 'fatigues' regarding flood studies.

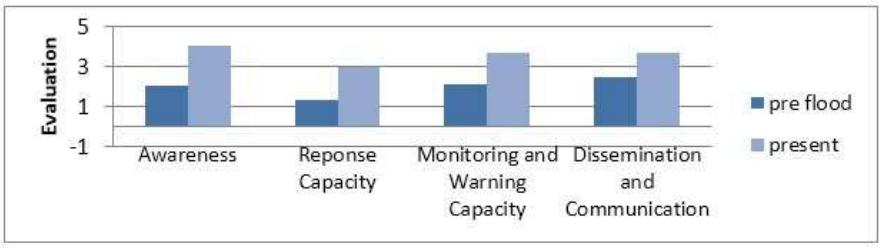

Figure 4: Evaluation early warning system elements.

In order to address both issues, one major recommendation to improve future research on this valuation method, is to conduct the questionnaires in situ. Multiple contact moments can then be initiated (individually or group sessions), providing the participants more detailed information on (1) the purpose of the study and why their participation is important (increasing the number of participants) and (2) to gather more background knowledge on the disaster itself, including subsequent damage and losses. Also, concerning the issue of a non-realistic scenario, more research is needed on the feasibilities of techniques serving DRM, in order to strengthen the assumptions and form a more grounded and realistic scenario concerning the warning time possible. Concerning the case study specific analysis, governmental and political constraints should be more included, to formulate ade-

quate and feasible recommendations regarding the application of geospatial information. This was also pointed out by one of the respondents.

8 Conclusion

This methodology can serve future research as it provides a systematic manner of identifying the economic value of a specific geospatial information product. This section has formulated recommendations to serve future development of this proposed valuation methodology, in response to the problems encountered during the execution of this research. In a later stage of this line of research, the experimental design of this questionnaire can be altered accordingly to other geospatial information products that assist in minimizing losses and damages of other disaster types and at other stages of the DRM cycle.

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Training of Crisis Mappers and Map Production from Multi-sensor Data: Vernazza Case Study (Cinque Terre National Park, Italy)

Piero Boccardo[1,2], Filiberto Chiabrando[1], Anna Facello[1], Loretta Gnavi[1], Andrea Lingua[1], Paolo Maschio[1], Fabio Pasquale[3] and Antonia Spanò[1]

[1]Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129, Torino, Italy, e.mail: filiberto.chiabrando@polito.it, anna.facello@polito.it, loretta.gnavi@polito.it, andrea.lingua@polito.it, paolo.maschio@polito.it, antonia.spano@polito.it

[2]ITHACA (Information Technology for Humanitarian Assistance, Cooperation and Action), Via Pier Carlo Boggio 61, 10138, Torino, Italy, e.mail: piero.boccardo@polito.it

[3]SiTI Istituto Superiore sui Sistemi Territoriali per l'Innovazione, Via Pier Carlo Boggio, 61, 10138 Torino, Italy, e.mail: fabio.pasquale@siti.polito.it

Abstract

This aim of paper is to presents the development of a multidisciplinary project carried out by the cooperation between Politecnico di Torino and ITHACA (Information Technology for Humanitarian Assistance, Cooperation and Action). The goal of the project was the training in geospatial data acquiring and processing for students attending Architecture and Engineering Courses, in order to start up a team of "volunteer mappers". Indeed, the project is aimed to document the environmental and built heritage subject to disaster; the purpose is to improve the capabilities of the actors involved in the activities connected in geospatial data collection, integration and sharing. The proposed area for testing the training activities is the Cinque Terre National Park, registered in the World Heritage List

since 1997. The area was affected by flood on the 25th of October 2011. According to other international experiences, the group is expected to be active after emergencies in order to upgrade maps, using data acquired by typical geomatic methods and techniques such as terrestrial and aerial Lidar, close-range and aerial photogrammetry, topographic and GNSS instruments etc.; or by non conventional systems and instruments such us UAV, mobile mapping etc. The ultimate goal is to implement a WebGIS platform to share all the data collected with local authorities and the Civil Protection.

1 Introduction

Some 75 percent of the world's population live in areas that have been affected at least on one occasion from 1980 to 2000 by earthquake, tropical cyclone, flood or drought. Natural disaster and their consequences are intimately connected to processes of human development. The loss of human beings and the destruction of economic and social infrastructure are expected to worsen as climate change increases the frequency and magnitude of extreme meteorological events, such as heat waves, storms and heavy rains. The community has already developed a set of instruments to address various aspects of disaster preparedness, response and recovery (UNDP 2004).

The creation and formation of a crisis mappers team is an example of a disaster response system. This team is a volunteer resource, and they can work to gain information about damages, needs, locations and security conditions.

The project is directed to provide specific contributions to improve the attention for the natural and cultural heritage, environmental protection and enhancement, through the protection of the landscape and of the architectural and archeological heritage, damaged or under risk (Spanò and Costamagna 2010).

The purpose is to build capacities in the Geomatic field using innovative methodologies and techniques for achieving advanced metric surveys using multi sensors and multi precision data (from space, aircraft and terrain) (Boccardo and Tonolo 2008).

The project has involved graduate students attending master degree in Architecture and Engineering at the Politecnico di Torino; the students can rely on basic qualification in topographical and mapping or GIS technologies derived from core subjects, and the key point for achieving the effectiveness of the training consists in the organization of all day long activities on site. The full immersion work, managed in small groups of students (4 or 5) per each tutor, adding the pre and post site experimental sessions, allow to obtain a good level of expertise for the new crisis mappers team.

2 Test site: Vernazza (Cinque Terre National Park, World Heritage List)

The Cinque Terre National Park was selected as test area for two principal reasons: the high value of landscape and environment, then the severity of the flood event happened on the 25th October 2011 and the large damages occurred after that.

The Cinque Terre area (Monterosso, Vernazza, Riomaggiore, Corniglia e Manarola) covers approximately 15 km along the extreme eastern end of the Ligurian coastline, between Levanto and La Spezia.

The position of the five small towns and the shaping of the surrounding landscape, characterised by steep and uneven terrains, encapsulate the continuous history of human settlements in this region over the past millennium (Dongiovanni and Valle 2007, RSA Parco Nazionale delle Cinque Terre 2004).

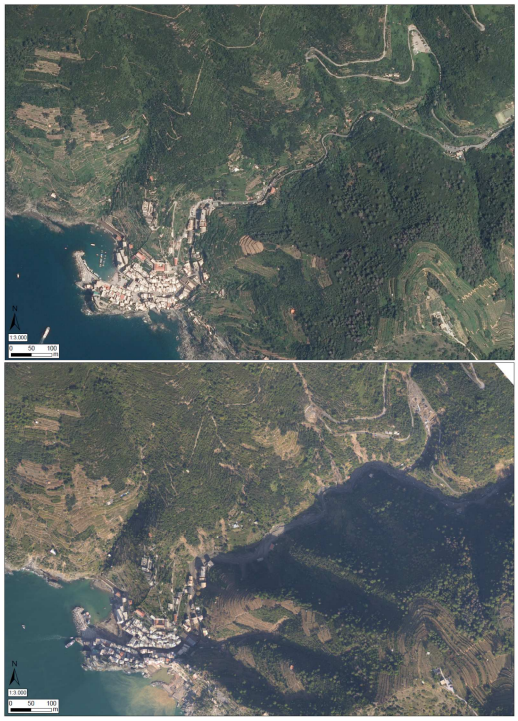

Figure 1: Excerpt of the ortophoto pre-event August 2010 and post event November 2011 (Source: BLOM-CGR Parma).

This Park has been recognised by UNESCO on its ‘World Heritage’ list, on the basis of cultural landscape criteria and its out-standing value, representing the harmonious interaction between people and nature (World Heritage Report 1997).

The coastal area is typically characterized by high and steep slopes artificially re-shaped during the centuries by human activity, through the construction of dry stone walls.

The surveys have been focused in the area of Vernazza, a coastal village which reported extensive damages since the flood event of 25th October 2011 that has been caused by the overflow of the Vernazzola stream (Figure 1).

2.1 Geological and geomorphological setting

The Cinque Terre coastline is one of the four zones of the province of La Spezia, morphologically indistinguishable (Federici et al 2001). There are two major lithological and structural units: Tuscan unit and Ligurian unit.

The Ligurian unit is represented by the Canetolo subunit and the Marra subunit (CARG Project, foglio 248 La Spezia), while the Tuscan unit by the Falda Toscana (Figure 2).

The Canetolo subunit includes a basal portion (Paleoc.-Eoc.), mainly composed of clay (Argille e calcari di Canetolo), to which are associated limestone with a percentage of peat (Eoc.) (Calcari di Groppo del Vescovo), and an upper portion predominantly with sandstone (Olig.-Mioc.) (Arenarie di Ponte Bratica) (Barbieri and Zanzucchi 1963).

In the investigated area the Falda Toscana is only represented by the formation of Macigno.

Figure 2: Geological map 1:25000, Project CARG, F. 248, La Spezia (2003).

In the Cinque Terre area, slope instability is mainly due to the presence of landslide-hill and lithological composition of the substrate to which has been added, over the last decades, the gradual loss of maintenance and defence of the territory operated by human activity (Federici et al 2001).

The drainage network is poorly developed and consists almost exclusively of canals, ditches and channels. These are rivers, with a very limited scope, which, in some cases, may remain almost dry during the dry season.

2.2 Flood event (25th October 2011)

The Liguria region is located in the North of Italy and is characterized by a steep and complex orography in the proximity of the coastline. This geographical position is particularly favourable to the development of heavy precipitation events. This aptitude connected to particularly intense and organized convective systems, in some cases could lead to severe flood events.

The heavy precipitation event, occurred in autumn 2011 over the Ligurian Sea, affected an area of about 10x40 km, extending from the Tyrrhenian coastline to the Apennine watershed. The exceptional rainfalls were notably linked to the development of a V-shape Mesoscale Convective System (MCS) that remained over the same area for more than 6 hours and as a consequence producing an impressive amount of accumulated precipitation over a relatively small area (Turato et al 2011).

The rainfall accumulated on the 25th of October 2011, over the area of Vernazza, exceeded 500 mm in 12 hours, with peaks above 100 mm/hour, leading to a real hydrogeological disaster over the zone by the most organized convective systems.

All along the mountainside and hillside of the area characterized by an artificially altered substrate (the typical terracing of the Cinque Terre hillside), the rainfalls have caused an instability of the land and of the vegetation.

As a consequence several slides occurred in the area. The surface runoff, due to the inclination of the terrain caused a big amount of detritus resulting from landslides and soil cover and in few hours the centre of the town was reached and partially flooded (Ortolani 2011).

3 Methods

3.1 GeoNode and data collection

In the field of natural disasters and emergency management there is a strong interest in geospatial data sharing, with the aim of avoiding duplication of efforts and allowing a quicker operational response. GeoNode is an open source platform that facilitates the creation, sharing and collaborative use of geospatial data.

The aim is to surpass existing spatial data infrastructure solutions by integrating social and cartographic tools. The promotion of data sharing is a main factor. On the one hand data sharing means that a user is put in condition of being able to upload data into the system and to give other users the possibility of exploring these data. Contemporary the user is provided with the capacity of taking advantage of

data shared by others either through online tools or by downloading them locally in formats suitable for desktop applications (Heinzelman and Waters 2010).

In this case, the data collected from the available database collection and from terrestrial surveys will be implemented in a WebGIS. Thus, through a dedicated platform, the end user may consult and interrogate in a simple and rapid way all the information made available.

Since the area is large and complex, the most suitable strategy for assessing impacts and damages caused by the flood, is the analysis of images acquired by satellites or aerial platforms (pre and post event), conveniently integrated by ground surveys.

LiDAR data and high-resolution aerial orthophotos, adding to the basic and thematic multiscale maps, have been collected for supporting the project development. They are useful in order to plan and locate the deepening area, to detect the major damages and to check the issue of access.

The aerial orthophotos and LiDAR flights (post event) are those provided by Blom CGR Parma[2] and Helica[3] for the Friuli Venezia Giulia Region.

Moreover, the Liguria Region has provided several databases: the basic maps (Carta Regionale 1:25.000 ed. 1994/95; CTR 1:10000 ed. 2007; CTR 1:5000 ed. 2007), the Regional Geological Map 1:25000, the Inventory of Landslides 1:10000 (IFFI project), the monitoring network of the slopes 1:10000 (Remover) and post flood erosion/accumulation maps, performed by the difference of LiDAR data acquired in 2008 and 2011. Even this last products have been achieved by the Friuli Venezia Giulia Region.

3.2 Terrestrial laser scanning (TLS) surveys

The Vernazzola watercourse and the provincial road streaming next to the river, which have been damaged by the flood, have been the main objective of ground documentation of the calamities. Moreover, along the stream of water, several artefacts, including bridges, stone masonries opposing the slope pressures, gardens, houses, terraces and other built structures have been heavily damaged or completely destroyed (Figure 3).

The choice of the survey methods had to satisfy the following demands:

- documentation requirements regarding the new watercourse configuration, enabling to fulfil an hydraulic previsional model, aimed to simulate and design the appropriate safety and restoration measures;
- the survey had to provide information about the state of conservation of the artefacts that testify evidence of human-environment interaction, which constitutes the identity of the landscape of those places;

[2] BLOM CGR Ortophotos: pre-event GSD (ground sampling distance) 0.50m, post–event GSD 0.20m

[3] Helica flight height 700m AGL (Above Ground Level) density ground points 5.45pt/m2, GSD 0.15m

- the representation requirements are aimed at preserving existing assets in conjunction with the need to model the interaction of various territorial, environmental and urban phenomena. The objective is to consider the complex temporal dynamics and to support the decision-making and planning processes.

The laser scanning technology compared with other traditional ground survey methods has been chosen for the following reasons:

- integrated with digital photogrammetric application, is a very effectual solution to produce extensive, accurate, dense and three-dimensional spatial information;
- combined distance and imaging clouds processes respond to the requirements of speed, sustainable and flexible solutions to diverse needs, by means of high productivity.

Figure 3: Examples of damages to buildings along the Vernazzola stream.

The scanner Focus 3D (Faro Cam2) effectively fitted to the needs of damages documentation due to the portable ad handy characteristics and because of it is easy to use. The range of scan distances is variable from 0.6 to 120 m for reflective surfaces (> 90%), the error in linear distances is equal to ± 2 mm at 10 m and 25 m for reflectivity of 10% and 90%; the scan speed is up to 900 000 points per second. In addition, the noise is low and it is possible to acquire radiometric information thanks to the digital camera which is armed with an optical axis that is coaxial to the laser beam.

The Faro instrument has been used for surveying the watercourse of the river (about 2 km from the beginning of the overflow to the sea estuary), and the area of the village where we planned to document the state of built heritage (the main street, the square with the harbour, the castle built on the top of the little hill dominating the town); finally we surveyed the beach which was created by the accumulation of debris due to the flood event.

3.2.1 Scans recording and georeferencing

Since the study object has a prevailing direction and a significant extension, a careful evaluation of acquiring resolutions and registration strategies have been accomplished in order to ensure data processing and 3D multi-scale modelling (Bornaz et al 2003).

For these reasons, the scans resolution has been chosen medium-high so as to be suitable for both natural and man-made land elements (the scan density has been set to obtain 1 point for each 6 mm at distances of 10 meters). During a first step of elaboration a regular set of cross sections at the distance of about 10 m have been briefly extracted, without performing accurate clouds filtering and colouring procedures.

The availability of automated tools in terrestrial laser data management software, allow the use of recording techniques that are endowed with procedures of automatic recognition of geometric correspondences (best fitting).

However, the detected object features, characterized by very few geometric elements, are easily identifiable and the abundance of repetitive and similar elements (the stones of the river) have resulted in the use of procedures strictly controlled by measured targets. By means of these control points we achieved the transformation in a single coordinate system based on the reference system WGS84-ETRF2000.

Other targets, with a spherical shape and unknown position, have been acquired during point clouds collection with the sole function of tie points, aimed to the registration of adjacent scans.

Then, the presented workflow together with a good distribution of tie points and control points enabled rapid registration and recording of scans, obtaining a contextual georeferencing of data and an accurate control of the residuals.

A good overall quality has been obtained both in the blocks of approximately 10 to 15 scans, and in the total survey.

The topographical network of the area (Figure 4) has been defined by the GPS/GNNS method. It has been connected to the permanent stations of ITALPOS BRUGNATO (BRU1) with a gap of 11 km between them, and of La Spezia with a 15 km gap.

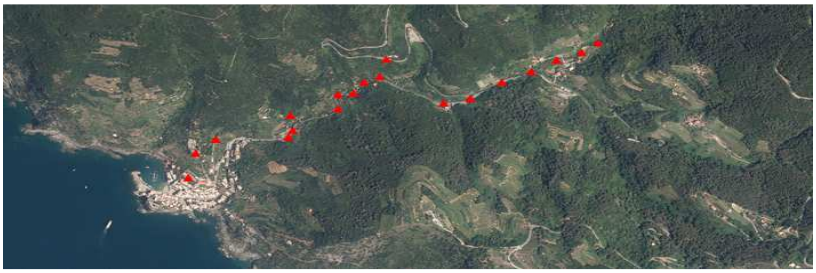

Figure 4: Location of vertices of the topographical network along the Vernazzola stream.

The network represents the basis for the next map updates and for the multi-scale integration that will support the recovery and rehabilitation projects of the land.

Table 1 below shows some information about raw data and results of performed processing:

Table 1. Data showing large size of Lidar ground collection.

Total Scans	48
Used GCPs/CPs	74
Total raw points	≈ 1 Billion
Dimension (.xyz file format)	≈ 48 GigaByte
Total points after the post processing (cleaning, noise reduction, decimation etc.)	≈ 250 Million
Dimension (.xyz file format)	≈ 12 GigaByte

The next image (Figure 5) shows different steps of data processing: coloured points models, mesh surfaces, a total image of recorded clouds and excerpt of cross sections extracted from the cloud model.

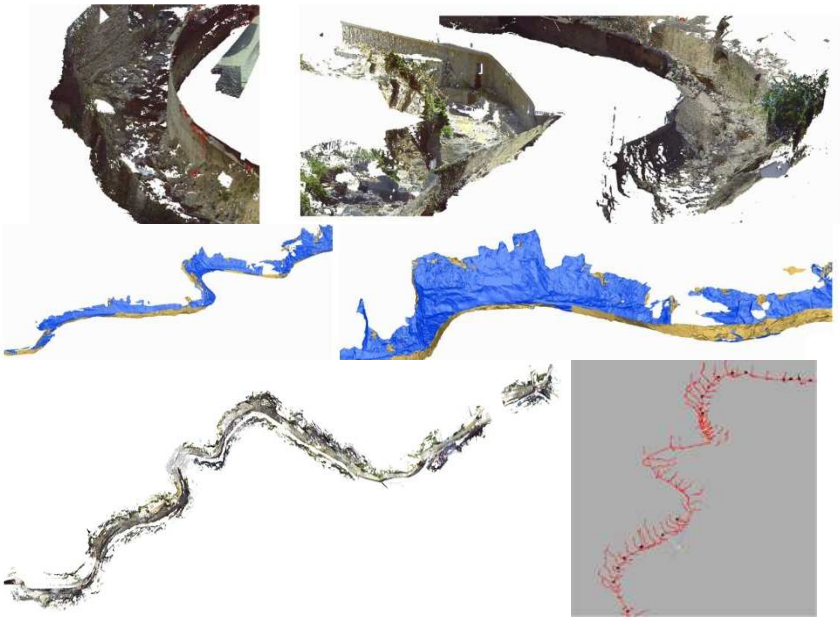

Figure 5: A collection of images showing TLS data processing results. Colored models, mesh models and (below) overview of recorded clouds representing the entire section of Vernazzola. A general view representing 3D cross section briefly extracted.

The large set of cross sections extracted from the recorded point clouds along the Vernazzola stream (Figure 5) has been used to develop an hydraulic model, using HEC-RAS software. The simulations implemented intend to evaluate the stream cross sections more vulnerable to flood events.

3.3 Report on the state of conservation of the paths network

Typical slopes planted with vines by terraces systems, are a unique testimony of the transformation of the area by human activity as well as local areas of interest. Difficult access, due to the land features of the area, is made possible by a network of paths, sometimes overlooking the sea, which represents an important component of the landscape and for hiking the Cinque Terre National Park.

A team of experienced cyclists[4] has covered almost all of the tracks on mountain bikes, conducting surveys using stereo cameras with GPS receivers (Figure 6), in order to collect and to georeference important data on the state of the paths (Figure 7), which are afflicted by several interruptions due to landslides, or simply slipping tracts of dry stone walls after the last flood.

The georeferenced data collected during the surveys will be useful to produce an updated map of the tracks in the Cinque Terre National Park.

Figure 6: Mountain bike fitted with the stereo 3D go-pro cameras and a GPS receiver.

[4] Civil Protection Group – Val Sangone (resp. Fabio Pasquale) www.valsangone-mtb.it

Figure 7: Example of a pair of images taken from video and 3D geographical location.

4 Conclusion

The enhancement of documentation processes and the development of procedures for the planning of emergencies management has been continuously updated according to the renewed methods and technical tools.

Regarding the on-site training, all the students attending the apprenticeship are now able to manage independently the acquisition of topographical and TLS data.

The integration of data obtained by ground metric surveys, advanced with those derived by the analysis of aerial or satellite images will lead to the achievement of a WebGIS, aiming at the collection of spatial information suitable for the updating of the existing maps collection. Even in this phase the students will be involved in map generation from different sourced data, assessing metadata editing and evaluating overall data quality. All the data collected will be available for local and regional authorities and for the Civil Protection through a GeoNode platform, in order to provide useful information for disaster management and emergency response.

In perspective, this experience will seek the feasibility of implementing 3D metric data archives pertaining architectural heritage, yielded by high detail surveys intending to identify the architectural features of building complexes andfollowing their paradigms in geometric and semantic organization (Van Oosterom et al 2005).

Acknowledgements

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(June and July 2012). We also thank Blom CGR for facilitating the use of low altitude photogrammetrical data and post event LiDAR data.

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Rock Slopes Hazard Analysis based on Traditional and Remote Geostructural Survey: Case Study Vernazza Coast Village (Cinque Terre National Park)

Rossella Vigna [1], Anna Facello[2], Loretta Gnavi[2], Anna Maria Ferrero[3], Gessica Umili[4] and Maria Rita Migliazza[5]

[1]ITHACA (Information Technology for Humanitarian Assistance, Cooperation and Action), Via Pier Carlo Boggio 61, 10138, Torino, Italy, e.mail: rossella.vigna@polito.it

[2]Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129, Torino, Italy, e.mail: anna.facello@polito.it, loretta.gnavi@polito.itloretta.gnavi@polito.it

[3]Università degli Studi di Torino, Facoltà di Scienze Matematiche, Fisiche e Naturali, Dipartimento di Scienze della Terra, Via Valperga Caluso 35, 10125, Torino, Italy, e.mail: ann.ferrero@unito.it

[4]Università degli Studi di Parma Dipartimento Ingegneria Civile, dell'Ambiente, del Territorio ed Architettura, Viale G.P. degli Usberti 181/A, 43100 Parma, Italy, e.mail: annamaria.ferrero@unipr.it, gessica.umili@unipr.it

[5]Università degli Studi di Milano, Via Festa del Perdono 7, 20122, Milano, Italy, e.mail: mariarita.migliazza@unimi.itmariarita.migliazza@unimi.it

Abstract

The present work has been developed in parallel to a multidisciplinary project carried out by a cooperation between Politecnico di Torino and ITHACA (Information Technology for Humanitarian Assistance, Cooperation and Action), in order to start up a team of "volunteer crisis mappers" and to propose a methodology to collect and analyze multi-sensor data. The testing site of activities proposed for the project is the Cinque Terre National Park, registered in the World Heritage List since 1997, in particular the Vernazza village. This area has been strongly affected by the flood of 25th October 2011. In this case, the study focused on rock slopes stability analysis, based on an accurate geostructural survey, considering both the traditional method and the laser scanner acquisitions. Discontinuity orientations which lead to the isolation of blocks are basically derived from the elaboration of the point clouds.

1 Introduction

1.1 Methods of rock mass stability analysis

The study of the stability conditions of a rock mass is usually based on a geo structural survey of the existing discontinuities. Surveys are devoted to a systematic and quantitative description of rock discontinuities. Traditionally, surveys are performed by using a compass directly applied to the rock face. In several cases, this operation can be difficult to perform because:

- rock faces cannot be easily reached or their dimension is so large that the data acquisition may be long and expensive when done directly on site;
- rock masses are so heavily fractured and not supported that being close to the slope can be dangerous;
- the interpretation of the acquired data can be difficult to perform on site whilst the possibility to make additional measurements and to observe images of the rock mass in the office, at subsequent time, possibly gives a better understanding of the rock structure.

When performed in the traditional way, surveys are carried out on scanlines or in a more detailed way through observation windows. In several cases, traditional survey methods do not allow the identification of important fracturing aspects that are needed to carry out a stability analysis. In particular, the relationship between discontinuity sets in terms of joint hierarchy and different kinds of joint terminations can strongly influence the rock mass mechanical behaviour.

In order to set up a 3D geometrical model of the rock mass, both the topographical description of the rock slope and the geostructure have to be known.

Alternative methods to traditional surveys can be supplied in two different ways: photogrammetry and laser scanning. Several authors have studied this kind of new techniques and a detailed description is out of the scope of this work (Fer-

rero et al 2009, Ferrero and Umili 2011, Gigli and Casagli 2011, Lato and Vöge 2012, Lemy and Hadjigeorgiou 2003, Post et al 2001, Slob et al 2007, Reid and Harrison 2000, Roncella and Forlani 2005).

The first approach is aimed to utilise simple instruments, like a digital camera and to work directly on the slope photograph; the second approach allows the acquisition of a very large number of measurement points in very short time. Both measurement methodologies make the realisation of a 3D model of the points measured on the rock slope possible (Digital Surface Model DSM). This model is composed by a "cloud" of points related to an image of the rock slope. This model allows, through a specific software set up for this purpose, the reconstruction of the slope topography and a quantitative identification of the discontinuities in terms of position on the slope and orientation, spacing, persistence and joint hierarchy.

In order to set up the rock mass geometrical simulation the equations of the discontinuities, that are on the rock face, have to be determined in terms of orientation data and position.

Through these models we can obtain more information when compared with the traditional surveys concerning:

- a larger number of measured values on the whole slope, even in the not accessible part;
- less subjective evaluation and more objective information on the slope;
- the possibility to reconsider the slope in subsequent times after the survey.

Once both the topography of the slope and the geostructure are known, a stability analysis can be performed through different methods.

Since the rock blocky nature strongly influences the stability conditions of the slope, a method which takes the discontinuities into account must be considered.

Both the Limit Equilibrium Method (LEM) and the Discrete Element Method (DEM) can be applied. In the first case (LEM) the presence of a single removable rigid block is considered and the factor of safety computed. In the second case (DEM, Cundall 1971) the interaction of all blocks is considered in terms of interacting forces and induced displacements. Blocks can be rigid or deformable.

With both the described approaches the rock block geometry must be accurately determined. Block geometry is due to the rock discontinuity intersection. When the discontinuities are known both in terms of orientation and position we can reconstruct the rock mass in a deterministic way while, when we have just the orientation of the planes, a statistic reconstruction of the rock mass can be performed.

1.2 Rock instability on the test site

The test area identified, Cinque Terre National Park and in particular the village of Vernazza, is interesting for both the high values landscaped environment, and for the severity of the flood and insecurity that is still the subject in the area concerned.

The village of Vernazza (Figure 1) is crossed by the stream Vernazzola which has a NW-SE trend.

Figure 1: Ortophoto pre-event August 2010 and post event November 2011 (Source: BLOM-CGR Parma).

During the 25th of October 2011, along this stream the flood event has given rise to a number of phenomena that are all merged into a single debris flow that has led to massive deposition of material along the stretch of the river.

Slope instability phenomena represented an extremely diffuse and impacting element also concerning rock slopes, that assumed and still assumes high significance regarding Vernazza's urban settlement and infrastructures (e.g. primary and secondary roads insecurity).

Analysis of slope status is aimed at the evaluation of the landslides types, calculation of the volume of the detachable rock blocks, and the calculation of the kinematics. The proposed methodology is based on a traditional geological survey aiming at understanding the geological setting and finding out the macro-structure that can lead to instability and a geostructural survey integrated with an advanced metric survey, through the use of topographic tools and techniques.

Acquired data with these different approaches have been merged together in order to validate the topographic model and calibrate the used (commercial and non-commercial) software for analysis and automatic extraction of discontinuities.

1.3 Geological setting

The Cinque Terre coastline is one of the four zones of the province of La Spezia, morphologically indistinguishable (Federici et al 2011). There are two major lithological and structural units: Tuscan unit and Ligurian unit.

The Ligurian unit is represented by the Canetolo subunit and the Marra subunit (CARG Project, Foglio 248 La Spezia) and the Tuscan unit by the Falda To-scana (Figure 2).

The Canetolo subunit, a typical outcrop area (Val Parma, Valle Roccaferrara), includes a basal portion (Paleoc.-Eoc.). It is mainly composed of clay (Argille e calcari di Canetolo), to which are associated limestones with a percentage of peat (Eoc.) (Calcari di Groppo del Vescovo), and an upper portion predominantly with sandstones (Olig.-Mioc.) (Arenarie di Ponte Bratica) (Barbieri and Zanzucchi 1963).

In the investigated area Argille e Calcari di Canetolo and Calcari di Groppo del Vescovo outcrop, the Falda Toscana is only represented by the formation of Macigno.

Figure 2: Geological map, Italy, Project CARG, Foglio 248, LaSpezia (2003).

The geological features (composition, schistosity, layering, degree of erosion) are characteristics of the particular morphology of the coastal area. External factors, in particular the wave activity, affect it in different ways, according to the different lithological nature of the substrate. The shale formations, clayey and marly, are more easily eroded, giving rise to less steep slopes rich with debris de-

posits. In the area, slope instability is mainly due to the presence of landslide hill and lithological composition of the substrate to which has been added, over the last decades, the gradual loss of maintenance and defense of the territory operated by human activity (Federici et al 2011).

The drainage network is poorly developed and consists almost exclusively of canals, ditches and channels. These are rivers, with a very limited role which, in some cases, may remain almost dry during the dry season.

2 Methods

2.1 Geological and geo-mechanical survey

The slopes instability has been initially investigated through a geological survey on the field, which has been followed by a geostructural investigation using traditional methods (along scanlines) and by using a topographical survey through laser scanning and photogrammetric acquisition. After an initial photointerpretation analysis, the study areas were chosen where instability phenomena were more wide and diffuse, surveys have been concentrated on the slopes on the sides of the road (SP 51).

Geological survey stressed the areas where structural aspects influence instability of the slopes; landslides are more concentrated in the area near the contact of the two different outcropping geological units: the Tuscany unit, in the area represented by the Macigno formation and the Canetolo unit, as it is depicted in the geological map in the previous paragraph (Figure 2).

The identified phenomena have been catalogued using the detection tabs for landslides prepared for the IFFI project (ISPRA) and they are of different types: mainly falls in rock, flows in rock and flows in soil (after the classification of Cruden and Varnes 1996). Rock and soil flows have been caused by internal factors (wide portions of relaxed and altered rocks) triggered by an external factor: the high amount of water infiltrating during the flood event.

The first type: falls in rock, starts with the detachment of rock from a steep slope along a surface on which little or no shear displacement takes place, they are among those phenomena still in progress after the event, due to the main cause of the movement that is an internal factor: the factors (structural characteristics of the slope) are on the move.

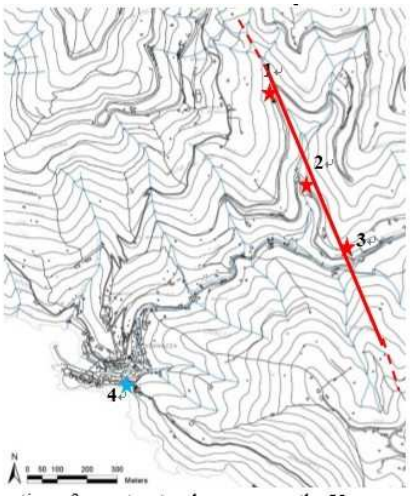


Figure 3: Location of geo-structural surveys on the Vernazza topographic map (1:5000), red line represents the major geological structure, the contact between the two formations Macigno and the Canetolo formations.

Getting back on the road (SP 51) we settled down three different geo-mechanical scanlines (Figure 4), with the aim to verify the possibility of kinematic movement in reference to falls phenomena involving the individual portions of rock mass, isolated from the families of discontinuity.

Figure 4: Pictures of slopes where geo-mechanical surveys have been conducted.

In Figure 3 red starts represent scanlines locations, they are located along the primary road (SP51), that is along the main geological contact, blue stars represent the survey conducted on the beach formed by the deposition of debris after the flood event (this last survey has been conducted also to investigate the particle size of the deposition.

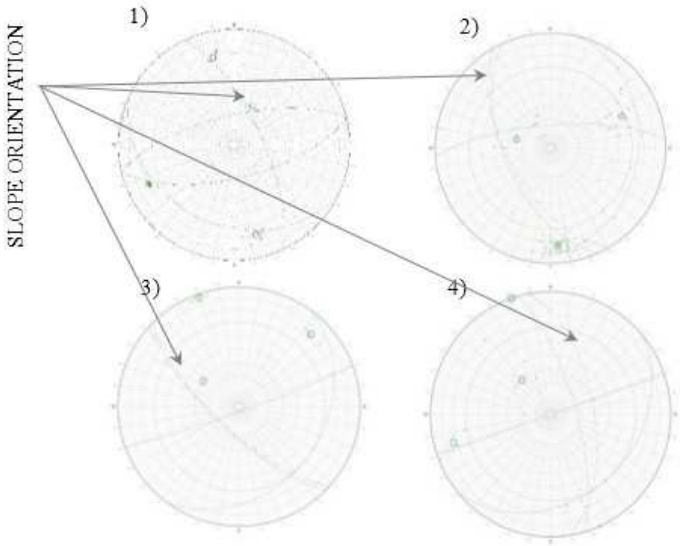


Figure 5: Stereogram reproduction of the discontinuity sets identified in each slope.

In Figure 5 the stereographical projections of the measured discontinuities are shown together with the slope projections and the joint sets determined by clustering. Basically 3 joint sets are constantly present on the slopes: two sub vertical sets and one sub horizontal. Table 1 shows the joint set orientation data.

Table 1. Joint sets parameters.

set.	**Dip direction [°]**	**Dip [°]**
1	(356.0 ± 180) ± 20	70 -90
2	(246.±180)±20	70.0 - 80
3	105.0±20	25.0-30

The validity of the results of the traditional method of analysis was enhanced integrating topo-cartographic techniques of investigation including digital photogrammetry and laser scanning. The application of these techniques allowed a sig-

nificant reconstruction of a detailed geometric model from which it became possible to identify planes of discontinuity.

2.2 Laser scanner survey

A detailed DSM of the rock slope has been acquired by using the LiDAR (Light Detection And Ranging) terrestrial laser scanner technique, which utilizes a system consisting of a laser telemeter and a scanning mechanism. Point clouds of rock faces, (operating ranges of lasers are from 100 to 800 m and more), with accuracies of 3D coordinates in the range $5\ 10^{-3} \div 3\ 10^{-2}$ m and a scanning role from 2000 to 12000 pts/s have been obtained. Angular scanning resolutions are in the order of 100 mrad and allow a very high sampling density on the object in relatively short acquisition times, resulting in millions of points measured on the object surface.

The survey of the slopes was carried out with a Riegl LMS-Z420i with a calibrated Nikon D70 digital camera mounted on it.

The laser scanner supplies the coordinates of points in space. The next step to realise a geometrical model of the rock mass is the determination of the discontinuity planes. For this purpose, points have to be divided into groups belonging to a single plane. In other words, the point cloud has to be analysed in order to identify the points belonging to each discontinuity plane existing in the slope (Rockscan).

Acquired data have been treated by applying the RANSAC algorithm (RANdom Sample Consensus, Fischler & Bolles 1981), that allows the segmentation of the point cloud into subsets, each made of points measured on a discontinuity plane of the rock face. For each subset, the plane's equation coefficients are first determined by robust estimation and then refined by least-squares estimation after outlier removal. The segmentation algorithm has been implemented in a specifically developed software, Rockscan (Ferrero et al 2009, Ferrero and Umili 2011) to facilitate the interaction with the point cloud in the identification of the discontinuities by a virtual projection of the three-dimensional (3D) data on a georeferenced digital image of the slope.

In this way, selecting a rock mass portion directly on the photographs by either a manual or an automatic system, the code subdivides the area in point subsets belonging to single planes of discontinuity. The code computes each equation orientation and other relevant geometrical data of the plane.

Data acquired with the two different approaches (compass and LiDAR) have been merged together in a consistent dataset and are then statistically treated. This has led to recognition of typical discontinuities for each slope describing them from a geo-mechanical point of view.

2.2.1 Systematic errors of measurement in the digital survey and the correction procedures

The planning phase of the survey must consider the resolution on the ground, the error of the points and their density in relation to the characteristics of the rock

surface. These aspects are greatly influenced by the dimensions of the wall and the angle of taking pictures.

Figure 6 shows some views of the trend of the error committed in estimating the dip and dip direction respectively, varying the shape of the surface (b/h), the density of acquired points and the orientation of the plane.

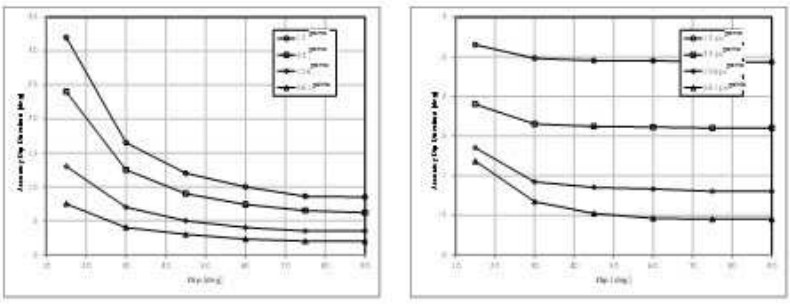
The discontinuity plane is represented by a rectangular surface on which points have been measured by laser scanning or photogrammetry.

The error decreases obviously with increasing the density of points acquired, and with the verticality of the plan. Figure 6 shows results for the case of a plane with a ratio length width (b/h) of 5, a precision of 5% ($\sigma xx/b = 0.05$), and a dip direction of 90°. On the left, dip direction accuracy variation with plane dip is exhibited, whilst on the right dip accuracy variation with the plane dip is shown.

The lower accuracy is obtained with subnormal planes to the direction of photographic shooting.

The graphs in Figure 6 can be used as a guide in survey design to obtain a certain accuracy in the dip and dip direction estimation: for a discontinuity of a given dimension and for a fixed precision it can determine the minimum numbers of points to be acquired to obtain the plane dip direction with a certain accuracy. Alternatively, the minimum dimension of an outcropping discontinuity necessary to determine its dip and dip direction with a given accuracy can also be defined.

For instance, if a precision equals to 5 cm on a discontinuity of 1 m length is required and the plane has a dip of 20° a minimum number of 156 points is needed for a plane with b/h of 5, whereas only 4 points are required for a square plane.



(a (b

Figure 6: Dip direction (a) and dip (b) accuracy computation for a plane with a ratio length width (b/h) of 5, a precision of 5% ($\sigma xx/b = 0.05$) for different value of plane inclination (dip) and point density.

Given that, the density of the points is proportional to the angle between the normal to the discontinuity and the "line of sight" of the instrument, perpendicular discontinuities will be sampled with higher probability. Assuming a tool placed at a minimum distance with orthogonal scanning beam (reference density, DL corresponding to weight equal to 1), the weight, W, to be applied to the database to correct the probability of detection of floors is the inverse of the following equation:

$$W = (\cos \alpha)^{-2} (\cos \beta)^{-1} \quad (1)$$

where β is the angle between the scanning direction and the normal to the surface, α is the angle between the scan line (perpendicular to the plane positioned at a distance) L. For practical applications it is necessary to put an upper limit to the weight relative to distance and to the angle β to prevent the weight, tenting to infinity. In addition it must be considered that, with a photogrammetric survey, the accuracy is inversely proportional to the ratios z/c and z/D, where z is the distance between the chamber and the rock surface, c is the focal length, and D the distance between the gripping point. The accuracy of the survey, however, depends also on the roughness of the surface; in fact, while a smooth plane surface can be determined very well, even having a few number of points, the roughness can determine local slope variations that increase the uncertainties and may lead to errors of several degrees in dip and dip direction. In these cases, a statistical evaluation of data is necessary.

Provided that they are well apart from each other; if planes are very small or elongated, points must be closely spaced to ensure that at least some fall in each plane; in such cases, however, even small uncertainties may lead to errors of several degrees in dip and dip direction.

The accuracy of the survey, however, is also influenced by the roughness of the floor fact. While a smooth surface can be determined with accuracy even with a limited number of points, the roughness can cause local slope variations that increase the uncertainty and introduce errors in determination of dip and dip direction. In these cases, a statistical evaluation of data.

3 Results

The aim of the survey was the production of a Digital Surface Model (DSM) of the rock mass, that could be used to perform the automatic geostructural survey. A laser scanner was placed along the road SP 51, in order to have a complete and front view of the rock mass; the mean distance from laser scanner to rock mass is about 50 m. A GPS survey allowed us to georeference the point cloud according to the local geographic system.

The DSM (Figure 7) was created triangulating the point cloud; it represents an area which is about 39 m large and 9 m high. The DSM is composed by 2’967’901 points, with a density of about 8500 pts/m^2.

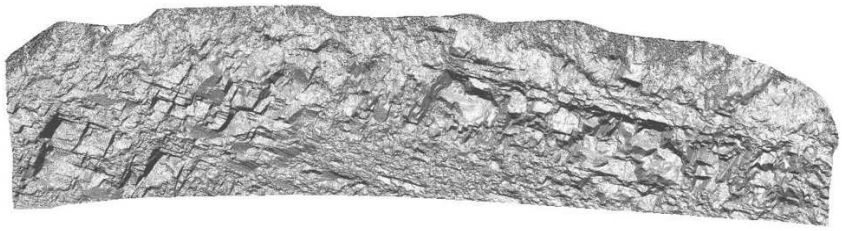


Figure 7: DSM obtained with the laser scanner (39 m x 9 m, 2967901 points).

The automatic geostructural survey to infer discontinuity planes orientation from the DSM was carried out by applying the above mentioned code developed at Parma University, Rockscan (Ferrero et al. 2009).

The output obtained by these techniques allowed the deterministic treatment of the stability both with conventional methods of dynamic analysis of the limit equilibrium. This was done with separate elements to make a numerical simulation of the entire slope. This simulation is based on the geometry of the systems of discontinuity, on boundary conditions, on the stress state and on the behaviour of the integrate rock and discontinuities.

The stability of the rock slopes is due mainly to the rock mass structure. The orientation of the discontinuities in relation to that of the slope determines the kinetic potential of the rock blocks to move along the discontinuity planes of their intersections. In all analyzed areas, the blocky system is determined by the intersection between the three sets where one of the plane is sub parallel to the slope. The blocks are supported by the sub horizontal plane and they are cut laterally by the sub vertical planes. The kinematics can then evolve into sliding along the horizontal plane or block toppling on the same plane. In such a geometrical configuration water under pressure plays a key role in triggering the block movements since the sliding plane is dipping with an angle that is smaller than the joint friction angle, so the failure must be induced by an extra acting force.

4 Conclusions

A method for rock discontinuity mapping that relies on accurate traditional methods and on high-resolution survey technologies has being proposed in this work to rapidly face the production of hazard estimation.

As far as data acquisition is concerned, photogrammetry and laser scanning are the best technologies available today. The survey must be carefully designed to ensure reliable quality standards that are able to capture all relevant discontinuity features.

The paper proposes a traditional survey (geological and geostructural) coupled with semi-automatic procedures, implemented in the code Rockscan, which represents a convenient operational tool, in the context of the ‘Cinque Terre’ park, especially in parallel to a project among the park and the Politecnico di Torino,

aimed at providing specific contributions to environmental protection and to the enhancement of natural and cultural heritage.

Tests on different sites in Vernazza show that this methodology could be considered as a proper tool in order to obtain a sufficiently simplified estimation of hazard concerning slopes. This is because large number of data can be safely and rapidly collected even in difficult environments (such as after a flood event) Furthermore it is possible to utilize semi-automatic tools for discontinuity identification and measurement.

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Development of a Spatial Information-based Decision Support System for Multi-stakeholder Dam Reservoir Operation

Czar Jakiri S. Sarmiento[1], Rhodora M. Gonzalez[1] and Peter M. Castro[2]

[1]Geosimulation Research Group, Department of Geodetic Engineering, University of the Philippines, Diliman, Quezon City 1101, The Philippines,
e.mail: cssarmiento@up.edu.ph

[2]National Hydraulics Research Center, Institute of Civil Engineering, University of the Philippines, Diliman, Quezon City 1101, The Philippines

Abstract

The 2001 Electric Power Industry Reform Act (EPIRA) in the Philippines formed a complex multi-stakeholder dam reservoir management situation in which the government and the private sector possess different decision-making responsibilities that affect the amount of water to be released for purposes of flood control, irrigation and power generation. Moreover, the situation introduced different levels of decision-making based on environmental conditions and inflow parameters, that created a more complex management set up. In the event of the Typhoon Emong of May 2009, lives and properties were destroyed due to the bad weather and water releases from the dam. This event prompted the stakeholders and policymakers to review and strengthen the existing national dam protocols and estimation methodologies to improve dam response in extreme rainfall events. In the light of these developments, we developed approaches that use readily available and economically flexible spatial datasets to support decision-making.

1 Introduction

The main purpose of dams is water storage. We store water for irrigation, power generation, potable water allocation and floodplain protection. Information regarding the amount of water that flows in a reservoir is essential in providing flood control, scheduling dam discharges for irrigation, measuring and anticipating current and future power production, and optimizing reservoir operations (Zsuffa 1987). The estimation of the reservoir inflow with high accuracy is one of the challenges in harmonizing the different reservoir purposes (Fourcade and Quentin 1994).

Hydrological and meteorological models are used in reservoir inflow estimation. These are representations of reality and are primarily used for understanding and predicting terrestrial, hydrological and meteorological processes that influence water-related disasters, such as: weather (Kunstmann et al 2008) and land cover change (Verburg et al 2007). They are used to “create solutions to engineering problems with detail and accuracy which could not be achieved by mere conventional paper and pencil analysis” (Linsley et al 1958).

Researchers around the world have studied the potential use of remote sensing to obtain accurate information about watershed hydrology (Cashion et al 2005). Remote sensing has "developed into a most promising technique for regional analysis of both small- and large-scale hydrological systems. After a review of the concepts of partial-area hydrology and processes involved, the potentialities of remote sensing for partial area hydrology are discussed for the various bands of the electromagnetic spectrum" (Van de Griend and Engman 2004). During the time of their research, moderating high resolution remote sensing development has begun. Having a new source of information with strong spatial and temporal characteristics, they tried pushing the boundaries of the then current remote sensing applications, and concluded that maximization of the use of satellite-derived data requires an adjustment in hydrological modelling development. Bhavsar's (1984) work includes hydrologic parameters estimation using the early generations of Landsat, aircraft-based remote sensing equipment, and their country's (India) very own Bhaskara I and Bhaskara II.

Salomonson and Choudhury (1991) studied the contribution of remote sensing to land surface hydrology; they explored the applications of remotely sensed precipitation estimates in a global scale. They showed that microwave observations from the synthetic aperture radars and passive microwave radiometers effectively observe vegetation condition, biomass volume and condition, and indices of soil wetness. Milewski et al (2009) applied techniques for rainfall–runoff and groundwater recharge estimation in arid areas using information from multiple remote sensing satellites. They concluded that their regional remote sensing-based approach must not be considered as a replacement to traditional methodologies that rely on extensive field measurements, rather, it should be treated as a first-order alternative for gathering information in areas lacking in spatial and temporal precipitation and field data. Schultz (1997) studied the use of remote sensing in agricultural water management. He identified real-world problems such as water sup-

ply estimation and allocation that remote sensing could solve and illustrated the practicality of the available information from space.

Figure 1: Typhoon Emong Spill. 2009. Image Courtesy of SN Aboitiz.

For our study area, we selected the most important dam in Luzon Island-- the Magat Dam. In the event of the Typhoon Emong of May 2009, lives and properties were destroyed due to the bad weather and water releases from the dam (Figure 1). This event prompted the stakeholders and policymakers to review and strengthen the existing national dam protocols and estimation methodologies to improve dam response in extreme rainfall events. Through Remote Sensing (RS) and Geographic Information System (GIS) solutions, we looked into the following inflow parameters: Rainfall, land surface temperature, near-surface soil moisture, surface geology, and landscape features such as topography, land cover and vegetation.

2 Study area

2.1 Spatial characteristics

This case study was conducted in the watershed of Magat River in Luzon (Figure 2), the largest island of the Philippines. It is bound by the latitudes 17^{o}02'08" and 16^{o}06'05" and the longitudes 120^{o}50'00" and 121^{o}30'00". The watershed is 4463.27 km^{2} in horizontal area and is administratively divided between the provincial governments of Ifugao, Isabela and Nueva Vizcaya. The reservoir is approximately 350 kilometres from Manila.

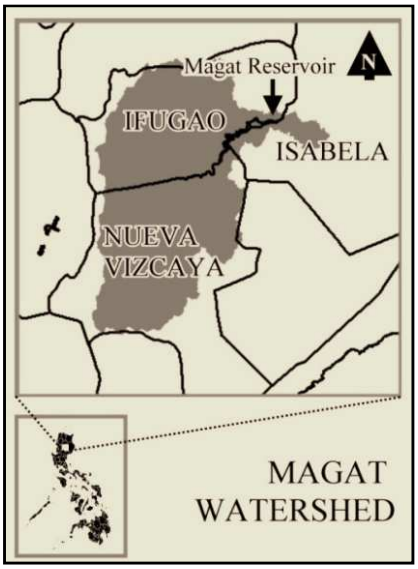

Figure 2: Magat Watershed Extent.

2.2 Physical characteristics

Various forms of clay loam and silt loam soils characterize the whole Magat watershed. Igneous rocks with high silica content (granite and rhyolite) and rocks with low silica content (basalt) as well as scattered sedimentary rocks abound. Four major sets of fault lines run in across the watershed (Palispis 1979).

2.3 Reservoir structures

Magat Dam is a multipurpose dam which impounds a large reservoir of water from the Magat river. It has a storage capacity of 1.08 billion cubic metres for irrigation to 950 km² of land and 360-MW hydroelectric power generation [14]. It's flood spillway has a capacity of 32,000 m^3/s.

2.4 Human activities

Agriculture is the most prevalent type of land use in the watershed. Gold and copper mining interests are also present in Nueva Vizcaya (Elazegui and Combalicer 2004). Some areas of Ifugao and Isabela are noted for tilapia production and other aquaculture activities.

3 Theoretical framework

3.1 RS and GIS

Spatially-distributed input data is a necessity for curate hydrometeorological model creations (Becker and Jiang 2007, Kongo and Jewitt 2007). Coupled with the improving capabilities of GIS for simulation and data visualization, RS has become a powerful source of information that can aid in reservoir management. (Kunstmann et al 2008).

4 Materials and methods

4.1 Landsat imagery

We are using archived 1991, 2002, 2005, 2008 and 2009 8-bit GeoTIFF format images of the study area from Landsat 4, 5 and 7 (L4, L5 and L7). They were designed to capture images over a 185km swath and gather data at an altitude of 705 km. The study area is within the World Reference System (WRS-2) path 116, rows 48 and 49. The 30m spatial resolution gives sufficient information for the purposes of our study.

4.2 ASTER GDEM

The used elevation data were derived from the ASTER Global Digital Elevation Model (GDEM). Fortunately, the GDEM from ASTER is recent and electronically released for free to users worldwide from the Earth Remote Sensing Data Analysis Center (ERSDAC) of Japan and from NASA's Land Processes Distributed Active Archive Center (LPDAAC) web servers. The DEM has a 1 arcsecond (approximately 30 metres) spatial resolution in the horizontal plane, which bodes well with that of the Landsat images; hence a good fit of the images draped over the DEM is ensured (Table 1).

Table 1: Comparison of ASTER-GDEM to other DEMs.

	ASTER GDEM	**SRTM3***	**GTOPO30****	**10 m mesh digital elevation data**
Data source	ASTER	Space shuttle radar	From organizations around the world that have DEM data	1:25,000 topographic map
Generation and distribution	METI/NASA	NASA/USGS	USGS	GSI
Release year	2009 ~	2003 ~	1996 ~	2008~
Data acquisition period	2000 ~ ongoing	11 days (in 2000)		
Posting interval	30m	90m	1000m	about 10m
DEM accuracy (stdev.)	7~14m	10m	30m	5m
DEM coverage	83 degrees north ~ 83 degrees south	60 degrees north ~ 56 degrees south	Global	Japan only
Area of missing data	Areas with no ASTER data due to constant cloud cover (supplied by other DEM)	Topographically steep area (due to radar characteristics)	None	None
Other examples of available DEMs - NED: with a resolution of 30 m, covering the entire U.S.A., provided by USGS *SRTM3: Shuttle Radar Topography Mission Data at 3 Arc-Seconds, **GTOPO30: Global 30 Arc-Second Elevation Dataset				

4.3 Brief overview of the methodology

We tried two approaches in solving the inflow estimation problem: The first one is creating a pixel-by-pixel (Figure 4) application coded from scratch using JAVA® and the second one is using an existing application for hydrologic modeling. Both of these approaches use satellite images as input. The first approach was taken to create a modelling system that uses satellite-derived information as direct input. This methodology explores the case of maximizing a system to fit the data. The

second approach was taken to investigate the use of satellite-derived information in an existing modeling system. This methodology, on the other hand explores the case of maximizing the data to fit the system. The corresponding results are compared for validation.

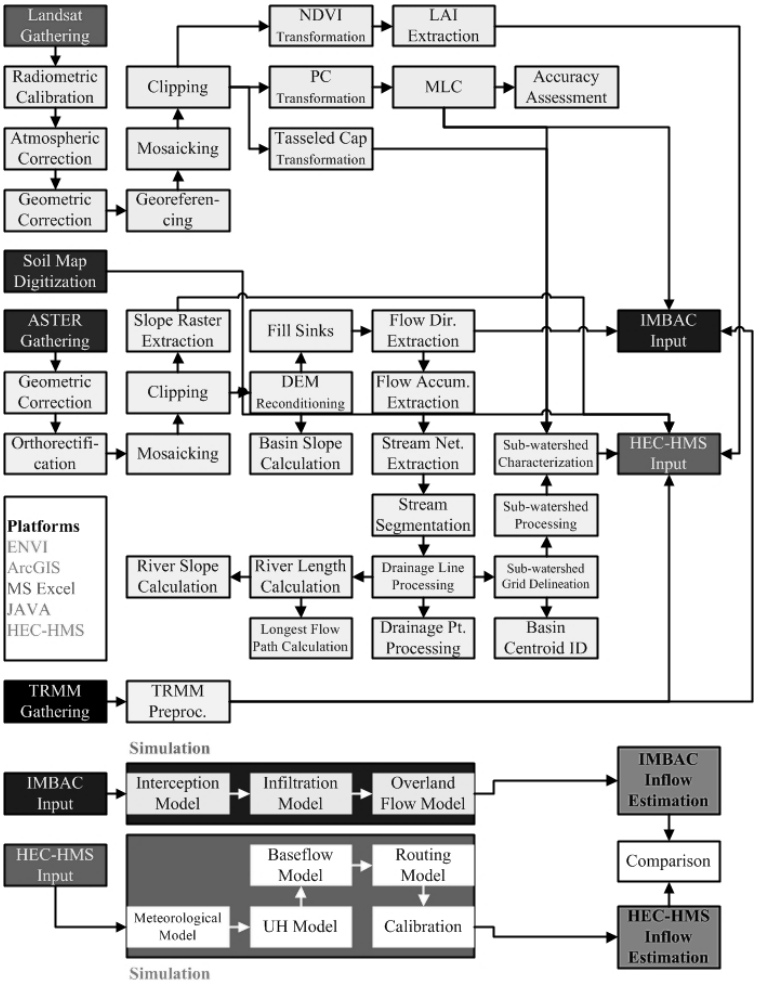

Figure 3: Methodology Flowchart.

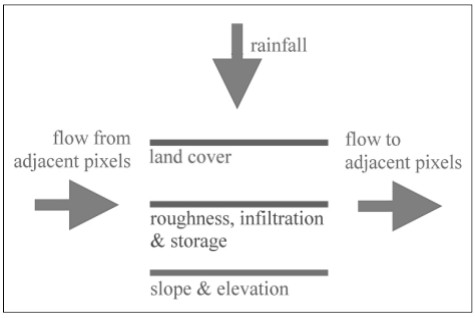

Figure 4: Basic logic diagram per pixel.

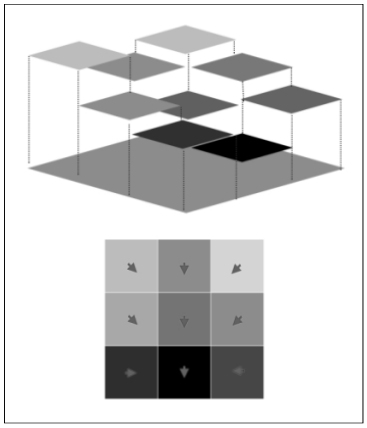

Figure 5: Flow direction 9X9 raster diagram.

The flow of runoff downstream is guided by the flow direction raster. The 9-cell flow direction raster has discrete values of powers of 2 from 0 to 7 (Figure 5).

The least separable of all the classes compared are the Medium Growth Field class and the Mature Growth field class which gave a 0.70751076 value. This means that they are almost similar and a better detection of growth is needed to accurately define the two classes. Because of this, the two classes are treated as the same in the hydrologic computations.

After undergoing classification, a majority/minority function was applied to improve the spatial coherency of the classification. This was to correct some erroneously or improbably classified pixels. The Majority function is a procedure "where a moving window of a user-selected size is passed through the image and the center pixel in the window is replaced with the class that the majority of the pixels in the window have" [34: p.1]. Table 2 and 3 shows the results of the land cover classification process.

Table 2: Overall Accuracy Table.

Classifier	Overall Accuracy	Kappa Coefficient
Parallelepiped	86.9176%	0.8303
Minimum Distance	86.6824%	0.8260
Mahalanobis Distance	78.1741%	0.7211
Maximum Likelihood	94.7671%	0.9301
Isodata	69.5529%	0.5996
Kmeans	68.8941%	0.5909

Table 3: Accuracies for the Maximum Likelihood Classification (in percent).

Class	Commission	Omission	Prod. Acc.	User Acc.
Clouds	0	3.09	96.91	100
Shadow	0	0	100	100
Water	0	1.48	98.52	100
Riverwash	46.24	0	100	53.76
Fallow field	0	19.59	80.41	100
Medium growth field	3.08	6.91	93.09	96.92
Mature growth field	6.76	3.5	96.5	93.24
Bare ground	15.2	0	100	84.8
Dense forest	8.67	14.97	85.03	91.33
Sparse forest	17.93	10.55	89.45	82.07
Builtup	0	0	100	100

5 Findings

5.1 Reservoir operation and watershed management

Magat Dam is owned and operated by the National Irrigation Authority. They provide the discharge policy based on a weekly Irrigation Diversion Requirement (IDR). In April 2007, the operation of the hydroelectric power plant was transferred from the National Power Corporation (NPC) to SN Aboitiz Power (SNAP) as a product of RA 9136 or the Electric Power Industry Reform Act (EPIRA) of 2001. The watershed is jointly managed by NIA (Isabela and Nueva Vizcaya side), NPC (Ifugao side) and SNAP (reservoir area).

5.2 Watershed characteristics

Area	= Calculated: 446326.755 has.
	= NPC Data: 412000 has. (approx.)
Area by province	= Isabela: 23988.291 has.
	= Nueva Vizcaya: 235889.234 has.
	= Ifugao: 186449.250 has.
Vegetation coverage	= 1991: 10301196 pts. 71.465%
	= 2002: 6071791 pts. 42.128%
Agricultural	= 1991: 2908333 pts. 20.179%
	= 2002: 8136107 pts. 56.451%
Cloud cover	= 1991: 1203064 pts. 8.347%
	= 2002: 204695 pts. 1.420%
Soil	= Clay and Silt Loam
Mean Rainfall[b]	= 1991: 58.8 mm
	= 2002: 93.2 mm
Mean Evaporation[b]	= 1991: 144.7 mm
	= 2002: 107.5 mm

[b]monthly, at damsite

IMBAC and HEC-HMS® simulations both achieved results which capture the behavior of the Magat watershed response, however, the HEC-HMS® approach has the immediate potential for operational use as a decision support tool for water resource management despite of its research's limitations. With field information to further calibrate the second approach, it can be used to build scenarios and simulate inflow estimates under varying watershed conditions.

Table 4: Comparison of total inflow volume estimates.

Method	Volume (cubic meters)
Reservoir water levels	68,999,040.0
Initial and Constant model in HEC-HMS®	170,715,400.0
SCS-CN model in HEC-HMS®	303,824,880.0
SMA model in HEC-HMS®	50,893,324.8
IMBAC	116,370,950.4

The discrepancies are caused by the difference in the methods used to estimate inflow, uncertainties involved in the precision of the TRMM rainfall data and the accuracy of the hydrological input used. Howeve, it is worth mentioning that, though there is a discrepancy in the magnitudes of the values produced, the trend of the simulation graphs is similar to the current method graph. The simulations produced by IMBAC produce estimates with a temporal resolution of 30 minutes, whereas HEC-HMS® simulations produce a 3-hourly output. This is significantly

better than the current method which estimates inflow per day because they capture more detail of the watershed response temporally.

6 Conclusion

This paper presents the basic concepts and approach of the research. Data gathering and preprocessing methods have been briefly outlined and the next steps are identified. We are successful in finding solutions to the challenges in data operability due to the size and difference in file formats of the remotely-sensed parameters.

IMBAC and HEC-HMS® simulations both achieved results which capture the behavior of the Magat watershed response. However, the HEC-HMS® approach has the immediate potential for operational use as a decision support tool for water resource management despite of its research limitations. This is mainly due to the development maturity of the software. With field information to further calibrate the second approach, it can be used to build scenarios and simulate inflow estimates under varying watershed conditions.

IMBAC is being developed in line with the country's development of better dam protocols. Due to the issues like data gaps, local policies and user inexperience, the HEC-HMS approach may be misused and can lead to bad decisions. IMBAC's goal is to create an easy to use tool that is localized to the specific needs and conditions of a particular reservoir.

Even with multithreading (multi-tasking within a single program), the first estimation approach using IMBAC was outmatched in efficiency by the second approach using HEC-HMS®. One-month simulation runs using the first approach were done in four days as compared to just approximately forty-five minutes using the second approach. This was something not entirely unexpected considering the IMBAC application's stage of development and the years poured by the HEC team in developing the HMS. It may also be attributed to the way the two approaches utilize satellite derived inputs. The design of the first approach handles significantly larger information stored in matrices due to the preservation of the spatial resolution and addresses of the remotely-sensed key-ins.

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Part II: Modelling and Visualisation

Integrated Semantic and Event-based Reasoning for Emergency Response Applications

Anna Hristoskova[1], Wim Boffé[2], Tom Tourwé[3] and Filip De Turck[1]

[1]Department of Information Technology, IBCN - iMinds, Ghent University, G. Crommenlaan 8/201, 9050 Ghent, Belgium, e.mail: {anna.hristoskova, filip.deturck}@intec.ugent.be

[2]IOS International nv, Wetenschapspark 5, 3590 Diepenbeek, Belgium, e.mail: wim.boffe@iosint.be

[3]Software Engineering & ICT Group, Sirris, A. Reyerslaan 80, 1030 Brussels, Belgium, e.mail: tom.tourwe@sirris.be

Abstract

Emergency response applications require the processing of large amounts of data in order to provide an accurate and concise view of the situation at hand. In this context, the adoption of semantic technologies is essential as it allows focusing on the definition of a formal model and intelligent data processing and reasoning. This paper presents a novel approach to emergency response applications, such as performed by the fire department, integrating a semantic reasoning engine into an event-based system supporting and the use of a formal domain definition. A semantic model is used to automatically generate Java objects which are consumed by the rest of the application. Object manipulations automatically update the underlying model. Additionally inference on the model performed by the reasoning engine is dynamically synchronized with the other architectural components triggering events based on predefined conditions. Validation is executed on a fire fighting scenario where the state of a fire fighter is constantly monitored based on new devices and sensor measurements such as body temperature, heart rate, location. While the reasoning engine keeps track of the fire fighter's context, the

event-based engine issues alerts to the rest of the team in case his state deteriorates.

1 Introduction

Here a fire fighting scenario, the fire fighters are continuously exposed to various risks and dangerous situations. Regular updates of their state to their team are essential. Vital for such settings are context-aware decision support systems able to provide an accurate and concise view of the situation at hand. Relevant information, captured from various devices and sensors, should be pushed pro-actively and presented in a user-specific and context-aware way (Tsiporkova et al 2012) supporting the situational awareness of the actors involved. Situational Awareness is a field of research defined as the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future (Endsley 1995). It is about being aware of the current context and the future objectives of the user. Situation-aware applications should be able to optimize the available choices while keeping the user in control.

Current emergency response research focuses on two main categories of applications: crisis simulation environments (Indigo 2012) and decision support systems (Coates et al 2011, Lijnse et al 2012). Usually, such efforts construct emergency management systems built on top of crisis databases. These attempts however provide limited information processing and reasoning. The adoption of semantic technologies enables the formal definition of the required domain concepts and their properties and supports the specification of rules and intelligent reasoning on the available data inferring valuable insights on the current context.

The proposed approach in this paper builds on these principles through the seamless integration of a domain-specific semantic model into a decision support system for emergency response by the fire department in the view of the ASTUTE project (ASTUTE 2011-2014). This multidisciplinary project aims at the development of an advanced and innovative pro-active HMI (Human-Machine Interface) interface and reasoning engine for improving user efficiency and safety in various industrial sectors such as automotive, avionics, and emergency services, all operating in data intensive and critical environments. The main contribution of the developed application is the integration of semantic and rule-based reasoning. A proof-of-concept implementation of this integration is developed through a Java Beans Code Generator automatically creating Java classes out of the concepts defined in the semantic model. A Context Engine incorporates a semantic reasoner encapsulating the low level generic reasoning on this model. Results of this reasoning are automatically forwarded to a Decision Engine. This engine includes an event-based system defining the high level application-specific rules responsible for triggering events and responding to alarms. This approach is validated by means of an illustrative example, including the development of an initial semantic model for emergency dispatching.

2 Related work

Current emergency response applications focus on various issues such as distributed communication between mobile devices, simulation environments for training purposes, decision support systems processing events from numerous sources (devices, sensors, social media), and formal domain modelling.

Interdroid (Bal et al 2012) aims at building a platform for distributed applications on Android devices. An example is Raven (Palmer et al 2012) which supports the use of smart phones for collaborative disaster data collection and sharing. Applications are shared by sharing the database and corresponding schema. The current disaster management application consists of a user interface for editing records in a database used to track lost and found people. Similarly SocEDA (SocEDA 2012, Paraiso et al 2012) enables the exchange of contextual information between heterogeneous services according to social network information. Its DiCEPE platform supports the interaction of different complex event processing engines simultaneously, while enabling communication among them through a distributed system. Currently, it supports an emergency response scenario during a nuclear disaster simulating virtual events from the involved partners.

The suite of adaptive search methods applied by REScUE (Coates et al 2011) constructs in real time a near-optimal plan with an associated response team consisting of individuals together with their equipment and vehicles. Input for the methods includes detailed information about the environment such as the location, availability, and capabilities of resources. In addition, up-to-date information of casualties and the tasks needing to be undertaken are reported to the decision support system via emergency response agents at the scene of the event. Its agent-based simulation environment, STORMI, evaluates the emergency response to hypothetical major incidents. The INDIGO FP7 EU project (Indigo 2012) also specializes in simulation technology for crisis management and training. A whiteboard is utilized to share the Common Operational Picture and associated information between the crisis centre and the mobile devices in the field.

Incidone (Lijnse et al 2012) consists of incident info, loose dynamic action lists, data-based suggestions, and task composition. Intended users are coast guard watch officers in a centralized command centre. During incidents information about the situation and what is being done to resolve it is collected. All knowledge of the area comes from contacts outside, or from automated systems like Automatic Identification System. Additionally, Incidone disposes of plans in the form of hierarchical to-do lists that can be used to coordinate actions to resolve incidents.

WeKnowIT (WeKnowIt 2012, Diplaris et al 2011) extracts information in emergency response scenarios (e.g. flooding or fire) from user-generated content. Data is gathered from sources, such as emergency response workers at the scene, the general public observing or through other parties publishing information. The information is geo-located, either from metadata provided with the images or through an analysis of textual or visual data generating tags for the information and displayed on a map. An Emergency Alert service (Ovelgönne et al 2010) works as an emergency call agent and informs social contacts and public authori-

ties about the emergency situation. All the events and user interactions are represented by means of the WeKnowIt core ontology, CURIO[1], which defines resources holding user generated content. Likewise, the FP7 EU project PRONTO (Pronto 2012, Moi and Marterer 2012) focuses on event recognition for intelligent resource management. It supports the extraction of relevant data from fire fighter radio chatter. Its semantic data store has an ontology of events defining the status of the system. Events are gathered from various kinds of sources, such as hardware devices (e.g. GPS) and user interaction with the system as well as from audio and video data streams. After aggregation, relevant information is filtered out for the users calculating events as output.

The ontology described by Dilo and Zlatanova (2010) and Fan and Zlatanova (2011) presents a data model for the organization of dynamic data (operational and situational) for emergency response developed within the RGI-239 project 'Geographical Data Infrastructure for Disaster Management' (GDI4DM). It is early stage work on the possibility of applying ontologies to resolve the semantic interoperability inherent in emergency management. The model is derived from the organization of emergency response in the Netherlands investigating the information flow from processes performed by first responders: fire brigade, paramedics, police and municipality. It captures the type of disaster, the involvement of response sectors including their locations, consequences of the disaster for people, animals and infrastructure. The main objective of the model is to enable the extraction and processing of the information from spatial datasets and its distribution to different response units.

The novelty of the described approach in this paper is the seamless combination of a semantic reasoner and an event-based system. Incoming real-time data from device and sensor measurements during an emergency is updated into a semantic domain model. The reasoner automatically derives new knowledge from a formal definition of an emergency response model. Based on the inferred context the event-based system triggers events and alarms forwarded to the right units.

3 Layered approach to context-aware event-based reasoning

The proposed layered approach in this paper supports the advantages of both worlds of event-based and semantic reasoning. It splits up the reasoning on the domain model from the application-specific actions.

Figure 1 presents an overview of the architectural layers of the ASTUTE project focusing on the importance of the semantic domain model used by the rest of the application. The lowest layer consists of the semantic model covering the ontological definition of the domain concepts. The layer above, the *Context Engine*, encapsulates the translation of the semantic concepts into Java Bean objects. These objects are queried by the *Decision Engine* which utilizes Drools for the rule-

[1] http://socsem.open.ac.uk/ontologies/curio/

based reasoning. This enables the transparent use of an actual semantic model by Drools resulting in triggering rules on the created objects in a timely manner. The *Data Aggregator* is responsible for capturing data from devices and sensors and formatting it as defined by the semantic model using the encapsulated concepts from the *Context Engine*.

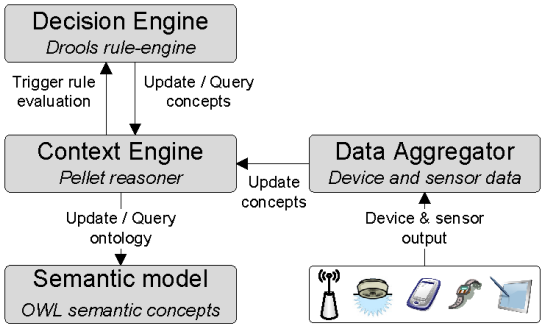


Figure 1: The layers of the reasoning framework of the ASTUTE project focusing on the importance of the semantic model used by the rest of the application.

The main purpose of the *Context Engine* is the low level domain model definition and inference through the use of rules. These rules are responsible for inferring knowledge from new data flowing into the system. The *Decision Engine* captures domain knowledge in the form of rules in order to determine which information needs to be send to whom at what moment. It relies on the *Context Engine* for delivering the interpreted raw context data.

4 Enriching a rule-based engine with semantic reasoning

This section details the encapsulation of a semantic model into the rule-based reasoning of a Drools engine.

4.1 Motivation for integrating semantic reasoning into rule-based engines

Rule-based engines such as Drools (Bali 2009) use forward chaining providing an integrated platform for rules, workflows and event processing. However, despite its light weight paradigm, Drools lacks support for a formal model definition enabling inference of knowledge at runtime through reasoning on the model.

Semantic technologies support the definition of a domain model by capturing in a formal way the required context between different parties in a machine-

processable common vocabulary also known as an ontology. A typical ontology language is OWL (Web Ontology Language) (McGuinness et al 2004), which is a well-defined vocabulary for describing a domain having a foundation in description logics. An OWL ontology can be created using the Protégé Editor (Stanford 2011) which provides support for OWL, RDF and XML Schema enabling the design of ontologies through a graphical interface. Additional knowledge is captured using rules defined through SWRL (SemanticWeb Rule Language) expressions and built-ins (SWRLB) such as comparisons (less/greater than) and math functions (Horrocks et al 2004).

This formal domain allows the use of existing frameworks, such as the OWL-API (Horridge and Bechhofer 2011) and Jena (Carroll et al 2004), which provide a programmatic environment for RDF(S), OWL, SWRL, SPARQL and can be extended with reasoning engines enabling common operations on ontologies. Supported description logic reasoners such as Pellet (Sirin et al 2007) realize the execution of data transformations, query processing and knowledge inference.

Two main concerns of the semantic approach are that it lacks a definition of temporal constraints in the SWRL rules and the execution of actions as result of a rule. The latter is particularly important in case a specific event should be triggered. Therefore, we aim at integrating the benefits of both approaches, a rule-based engine and a semantic reasoner, into an application supporting the invocation of events based on an underlying semantic domain model.

4.2 Automatic Java Beans generation from semantic concepts

A main requirement for working with a rule-based engine such as Drools is the use of Java Beans. It should be possible to define rule conditions on Java objects in the following way: FireFighter(temperature>39). Due to the Java Bean nature of the objects, the background query uses the getTemperature method of the FireFighter object. Our goal is to define concepts such as FireFighter and BodyTemperature through an ontology in order to enable semantic reasoning and at the same time trigger Drools rules.

The querying of a semantic domain model usually requires the configuration of a reasoner such as Pellet and the manual encapsulation of the necessary concepts into Java classes in order to update and query their properties in a more general domain independent way. This manual work may be feasible for limited models but for larger use cases such as an emergency dispatching scenario the amount of manual work becomes difficult to maintain. Apart from the necessary testing, one needs to manually update the Java classes each time the ontology changes in order to keep the system synchronized with the domain model.

We automated this process through the adaptation of the code generation library of the Protégé Editor[2]. This tool automatically generates Java classes from semantic concepts translating their properties into class methods. The translation

[2] http://protegewiki.stanford.edu/wiki/Protege-OWL Code Generator

of the FireFighter concept having a BodyTemperature property to a Java object with corresponding convenience methods is presented in Table 1.

Table 1: Translation of semantic concepts and properties to Java classes and convenience methods.

Semantic Concept	**Concept property**
FireFighter	hasBodyTemperature(FireFighter, BodyTemperature)
Java Class	**Convenience method**
FireFighter()	List<BodyTemperature> getHasBodyTemperature() boolean hasHasBodyTemperature() addHasBodyTemperature(BodyTemperature) removeHasBodyTemperature(BodyTemperature)

Clearly the translation is now here near a Java Bean format and needs additional tweaking. The requirements from the proposed emergency response approach are:

1. Automatic generation of Java Bean-compliant classes, so that i) the code is easily updated when the model is updated and ii) the instances of these classes are consumed by the other architectural components, in particular the Drools implementation of the **Decision Engine**.
2. Integration of the **Decision Engine** into the generated code, so that its rules are evaluated whenever a Java Bean is updated or the model changes due to inference by the Pellet reasoner in the **Context Engine**.
3. Handling automatic classification of the domain concepts as result of necessary conditions or SWRL rules defined in the ontology.

In order to meet these needs, we adapted the code generation as follows:

1. Insertion of additional methods to the code generation template in accordance to the bean formatting. For example the following methods are automatically generated for the property hasCommander(FireFighter, Commander) which specifies that a FireFighter has a Commander:

```
public interface FireFighter extends User {
    /*
     * Property http://localhost/ASTUTE.owl#hasCommander
     */

    // Gets all values for the hasCommander property.
    Collection<? extends Commander> getAllCommander();

    // Gets the value for the hasCommander property.
    Commander getCommander();

    // Checks if it has a hasCommander property value.
    boolean hasCommander();

    // Adds a hasCommander property value.
    void addCommander(Commander newCommander);

    // Removes a hasCommander property value.
```

```
    void removeCommander(Commander oldCommander);

    // Sets a hasCommander property value.
    void setCommander(Commander newCommander);
    ...
}
```

This also shows that all property definitions starting with has are automatically translated into methods without it. E.g. getBodyTemperature() instead of getHasBodyTemperature() from the property hasBodyTemperature.

2. Insertion of arguments for each object and data property. E.g. the FireFighter has an argument Commander additional to the generated methods which can be queried and updated by the application.
3. Insertion of the Pellet reasoner into the generated code. This enables the querying of the inferred axioms as result of the automatic reasoning on the domain model whenever object methods are invoked.
4. Integration of the **Decision Engine** into the code generation essential during object updates. This supports the automatic synchronization between the reasoner and the rule engine. Whenever an object is updated not only the corresponding semantic concept in the model is updated, but the Drools engine is also triggered to evaluate its rules. In this way the changes in the semantic model are propagated all the way up to Drools.
5. Automatic creation and removal of objects due to classification of concepts by the Pellet reasoner as result of SWRL rules or necessary conditions.
   - A concept is classified by the reasoner through inheritance from another concept as result of a predefined rule. For example, a SWRL rule can be stating that in case of several conditions such as high temperature and heart rate a FireFighter is a StressedUser. This means that the concept FireFighter should also be of the type StressedUser. As the reasoner automatically infers this in the ontology, the **Decision Engine** is also notified through the creation of a StressedUser out of the FireFighter object.
   - Necessary conditions are conditions that a semantic concept must fulfill and thus inherent to his domain specification. An example of a necessary condition is hasSolution (FaultyLightSensor, DoNotUseDataValue) defining that a possible solution to a faulty light sensor is simply not using its output data. Due to this, the moment there is an object FaultyLightSensor, the concept DoNotUseDataValue is automatically created if not present. This enables the **Decision Engine** to query for solutions to this event in a similar way the reasoner performs inference.

   In case the necessary conditions or classifications disappear, the classified individuals are removed automatically propagating up to the **Decision Engine**.
6. Java classes not only extend a specific class but also implement several interfaces allowing for multiple concept inheritance as supported by an ontology.
7. All data and object properties lacking a referenced property subject are automatically added to a main super class Thing extended by the rest of the classes. This resembles the equivalent Java Object class.

The result is the automatic translation of the semantic domain concepts into Java Beans that are used by Drools just like regular Beans. However, there is a slight change in the mentioned query: FireFighter(temperature>39). This is not possible as Temperature is also defined as a semantic concept and thus also translated into a Java object. In order to retrieve the specific temperature value, one should query its data property value hasValue and thus use: FireFighter(bodyTemperature.getValue()>39). On the other hand, as data properties specify value type definitions, it is possible to use them in the following way: BodyTemperature(value>39).

5 Illustrative example to an emergency response application

In order to validate the proposed approach, a scenario is designed capturing the state of a person such as a fire fighter walking through a building on fire. For this purpose, we developed a basic ontology, partially visualized in Figure 2(a), defining concepts such as users, devices, medical measurements and the relationships between them. Figure 2(b) presents the description of a fire fighter that can be a user having several properties such as location, activities (extinguishing fire), and medical measurements among which temperature, heart rate, oxygen level. Due to the specification of several types of context, such as physical, task, medical, one can define the criticality of a task or the level of a medical measurement. For example the activity ExtinguishingFire that is performed by fire fighters is defined as a Task with High Criticality as specified by the necessary condition below:

```
class ExtinguishingFire
        Superclasses: Task
                hasCriticality value High
```

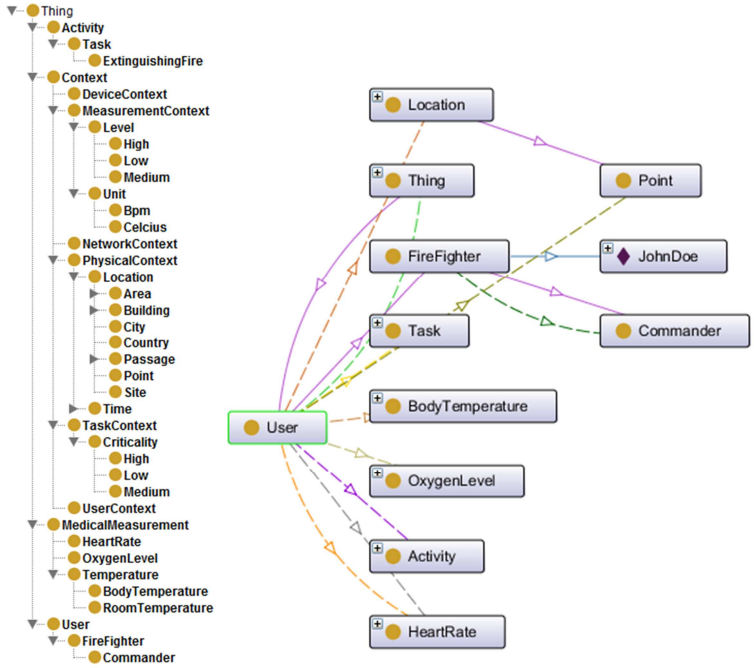
Using these definitions one can define SWRL rules inferring the thresholds for high temperature or heart rate. The following rule defines that a BodyTemperature above 38 degrees is High.

```
BodyTemperature(?bt), hasValue(?bt, ?btv),
greaterThan(?btv, 38) -> hasTemperatureLevel(?bt, High)
```

We could also specify personalized thresholds per user where one can define a maximum heart rate specific for each person. The following rule defines a user HeartRate higher that his personal defined maximum as too High.

```
HeartRate(?mhr), HeartRate(?uhr), User(?u),
hasHeartRate(?u, ?uhr), hasMaxHeartRate(?u, ?mhr),
hasValue(?mhr, ?mhrv), hasValue(?uhr, ?hrv),
greaterThan(?hrv, ?mhrv) -> hasHeartRateLevel(?uhr, High)
```

The results from inferring these rules are combined into additional rules. For example, we can define the rule that a user who performs a highly Critical Task having High HeartRate and BodyTemperature and located in a Room with High RoomTemperature is Stressed.



(a) Partial ontology defining a user and device context.

(b) Specification of several user properties such as medical measurements, activity, location.

Figure 2: Basic ontology defining concepts such as users, devices, medical measurements and the relationships between them.

```
Activity(?a), hasCriticality(?a, High),
User(?u), hasActivity(?u, ?a),
BodyTemperature(?ht), HeartRate(?hh),
hasBodyTemperature(?u, ?ht), hasHeartRate(?u, ?hh),
hasHeartRateLevel(?hh, High), hasTemperatureLevel(?ht, High),
Room(?r), RoomTemperature(?hr),
hasRoomTemperature(?r, ?hr), hasTemperatureLevel(?hr, High),
hasLocation(?u, ?r) -> isStressed(?u, true)
```

These rules enable the tracking of a fire fighter's state during the fire fighting scenario. The environmental sensors sending various measurements such as temperature, location and heart rate register these values via the **Data Aggregator** in the **Context Engine**. With each new update the **Context Engine** fires the rules in the **Decision Engine**. If the following Drools rule is defined that alerts the commander that the fire fighter is stressed, it will be triggered evaluating the condition of the fire fighter.

```
rule "Firefighter stressed"
no-loop
  when
    $p : FireFighter(isStressed==true)
  then
```

```
    $hmi.sendMessage($p.getCommander().getName(),
    "Firefighter " + $p.getName() + " is stressed", "ALERT");
end
```

The moment the **Context Engine** receives a new update, inferring that the fire fighter is actually stressed because of for instance elevated heart rate, the **Decision Engine** fires this rule and the commander is alerted of his team member's state.

6 Conclusions

This paper presents a novel approach to an emergency response application used in scenarios such as performed by a fire department. The approach implements the integration of a semantic reasoning engine into an event-based system supporting the use of a formal domain definition. The semantic model describing the users and device context is used to automatically generate corresponding Java Bean objects. These objects are consumed by the rest of the application just like normal objects with the exception that the underlying model is updated together with the object updates. Additionally, inference on the model performed by the semantic reasoner is automatically synchronized with the other architectural components resulting in the triggering of events based on scenario specific conditions.

The approach is validated on a fire fighting scenario where the state of a fire fighter is constantly monitored based on new device and sensor measurements such as body temperature, heart rate, and location. While the reasoner keeps track of the fire fighter's context, the event-based engine issues alerts to the rest of the team in case his state deteriorates.

Future work should incorporate an extensive evaluation of the proposed scenario consisting of capturing the state of a complete team of fire fighters using real-time device and sensor readings during an emergency.

Acknowledgement

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Digital Photogrammetry and LiDAR Techniques to study the Evolution of a Landslide

Tomás Fernández[1], José Luis Pérez[1], Carlos Colomo[1], Emilio Mata[1], Jorge Delgado[1], Javier Cardenal[1], Clemente Irigaray[2] and José Chacón[2]

[1]Department of Cartographic, Geodetic and Photogrammetric Engineering, Campus de las Lagunillas, University of Jaén, 23071 Jaén, Spain, e.mail: (tfernan, jdelgado, jcardena, jlperez, emata)@ujaen.es

[2]Department of Civil Engineering, Campus de Fuentenueva s/n, University of Granada, 18071 Granada, Spain, e.mail: (clemente, jchacon)@ugr.es

Abstract

In this work the evolution of the Almegíjar landslide (Granada, Spain) is presented. It is a rock slide developed in the last 50 years, settled in the Alpujarras region, a steep and rocky area with a high density of landslides. To establish its evolution, five datasets and flights corresponding to years 1956, 1992, 2001, 2008 and 2010 were surveyed. The most recent 2010 flight, combined of digital camera and LiDAR sensor, was oriented by flight data and control points, and a high-precision digital elevation model was built and edited. The other flights were oriented using second order points extracted from the first flight, and the corresponding DEM were elaborated by automatic matching and later edition from stereoscopic models, taking the 2008 model as reference. The landslide evolution was analyzed by comparing between DEMs, obtaining differential models, volumetric calculus and longitudinal profiles. The obtained results show that the movement was triggered after 1956 and since then evolved in an irregular pattern with periods of variable activity. On average, the land surface dropped over 8 m in depleted zones and raised near 4 m in the accumulation zones. The total volume of the mobilized mass is about $300x10^3$ m^3, moderately large, and the average velocity was very slowly along a long time span which results in a degree VIII of diachroneity.

1 Introduction

The use of aerial photographs from historical flights is the best technique that currently allows reconstructing the kinematics of landslides in time intervals significantly large (Walstra et al 2004, Prokesova et al 2010). Photogrammetric techniques have been used in many previous works (Walstra et al 2004, Cardenal et al 2006, Kasperki et al 2010), in some cases combined with other techniques such as LiDAR (DeWitte et al 2008, Corsini et al 2009), GPS (Brückl et al 2006), digitizing of older maps (Corsini et al 2009) and electrical resistivity tomography (De Bari et al 2011).

In photogrammetric studies, the flight orientation is based on triangulation and block adjustment by bundles (Walstra et al 2004, 2007, Brückl et al 2006, Cardenal et al 2006, DeWitte et al 2008, Kasperki et al 2010, Prokesova et al 2010, De Bari et al 2011), using a small number of control points captured by means of GPS techniques for all the considered campaigns. Then DEMs are obtained by automatic correlation or matching and two types of approaches can be made: on one hand, quantitative analysis such as differential DEMs between campaigns, profiles, volumetric calculations and in some cases determination of displacement vectors (Walstra et al 2004, 2007, Brückl et al 2006, Kasperki et al 2010); on the other hand, qualitative but very valuable observations are extracted (Walstra et al 2004, Prokesova et al 2010, Brückl et al 2006, DeWitte et al 2008, Prokesova et al 2010, de Bari et al 2011).

The application of LiDAR techniques allows the accurate positioning of the points of a high resolution point cloud, from which DEMs can be derived, after a classification and edition process. These models and those obtained by photogrammetry can be compared to determine vertical displacements or volumetric changes (Corsini et al 2000) and to obtain parameters characterizing landforms and landslides (Glenn et al 2005, Kasai et al 2009).

In this paper photogrammetric and LiDAR techniques are combined to establish the evolution of a landslide, following a methodology based on referencing the historical flights data to a recent and accurate flight, combined of LiDAR and camera. Historical DEMs are built editing the most recent DEM, obtained from LiDAR data, over the stereoscopic models of corresponding flights. This procedure has allowed a more robust but simpler referencing, reducing noise and runtime.

The obtained results are applied to the identification of several landslides parameters such as velocity, activity, diachroneity and intensity patterns.

2 Study zone and image data

The study zone is located in the Alpujarras region, a mountain area at the South of Granada province (Spain), affected by many landslides processes (Figure 1) (Fernández et al, 2003, Chacón et al 2010, Jiménez et al 2011).

Two photogrammetric flights from 2008 and 2010, combining digital camera (Z/I DMC) and LiDAR sensor (Leica ALS50-II), with GPS/IMU systems for direct orientation, were available. In addition other flights from 1956, 1992 and 2001 (Table 1) were used in the analysis.

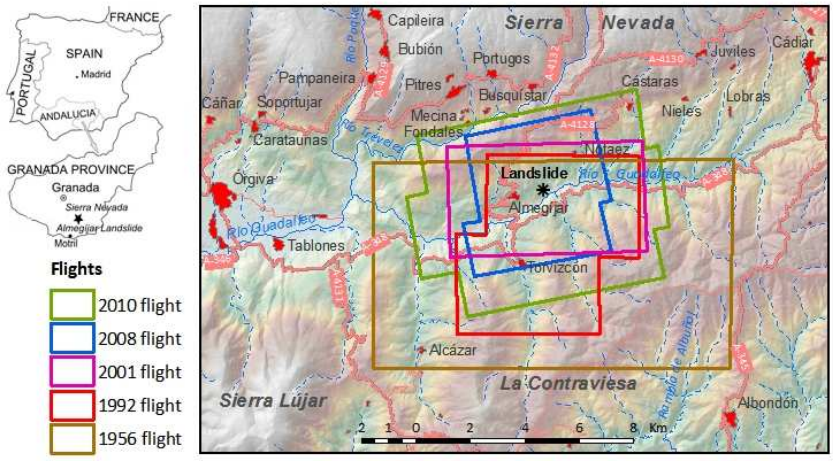

Figure 1: Location of study area and available aerial flights.

Table 1: Properties of datasets and flights.

	Bands	Format	Pixel size	GSD	LiDAR
1956	Panchromatic	Film	15 mm	0.60 m	No
1992/2001	Panchromatic	Film	15 mm	0.30 m	No
2008/2010	RGB-NIR	Digital	12 mm	0.20 m	Yes

3 Methodology

Digital photogrammetry is a step forward to evolutionary studies of terrain morphology (Walstra et al 2004, Brunsden and Chandler 1996), among which are those related to landslides. The methodology developed by the working group and calibrated in some previous works (Cardenal et al 2006, Fernández et al 2011) includes the following steps:

1. Digitalization of analogical photographs.
2. Definition of the reference system.
3. Orientation of historical flights.
4. DEM building.
5. Comparison of models and calculus.

Thereafter the calculus, we proceed to the interpretation of the results in terms of landslides velocity, activity, diachroneity and intensity.

3.1 Digitalization of analogical photographs

The older flights corresponding to 1956, 1992 and 2001, require scanning that has been made using a Vexcel Ultrascan 5000 with a pixel size of 15 microns that give the image resolutions shown in the Table 1.

3.2 Definition of the reference system

The most recent flight was taken as a reference because of its higher accuracy and resolution. This photogrammetric flight was oriented using the flight data (GPS and inertial) and, additionally, control and tie points. The orientation parameters and results are shown in Table 2.

On his hand, the LiDAR raw data were oriented adjusting the different strips and obtaining a single point cloud. Finally, both datasets had to be matched in height. This operation is critical as they were used as reference of other data.

3.3 Orientation of historical flights

The rest of flights corresponding to other campaigns have been oriented by means of second control points extracted from the photographs of both reference and historical flights. The results of the orientation are also shown in Table 2.

This procedure allows reducing the number of control points and ensures immediately that points will be observable, accessible and unequivocally recognizable in both flights, which it is not always possible in those methodologies based only on points measured in the field.

3.4 DEM building

The reference DEM was directly obtained from LiDAR data after they had been processed and edited through the viewing of contour lines overlaid on the corresponding stereoscopic model (Figure 2).

To build historical DEMs, the reference DEM is observed over the stereoscopic models of historical flights and then edited or recalculated by automatic matching in those zones where matching between surfaces fails (Fernández et al 2011). This procedure preserves the resolution and accuracy of the most recent DEM in the historical ones and avoids introducing noise in areas where there have been no changes (Figure 2).

3.5 Comparison of models and calculus

It has been made in different ways:

1. Vertical distance calculation, subtracting the values of each two models (differential DEMs) (Figure 3).
2. Volume estimations to identify the accumulation and depletion zones.
3. Obtaining longitudinal sections or profiles (Figure 4).

Once obtained these parameters and graphics, some observations about the landslides and its activity can be deduced.

Table 2: Results of flights orientations (RMS x,y,z are measured in m).

Campaign	Photo	Control points	Tie points	RMS pixel	RMSx (m)	RMSy (m)	RMSz (m)
1956	36	15 xyz, 4 xy, 1z	195	0.529	0.165	0.198	0.100
1992	9	8 xyz	82	0.246	0.095	0.109	0.042
2001	3	8 xyz	14	0.363	0.169	0.081	0.213
2008	4	7 xyz	21	0.423	0.120	0.225	0.067
2009	3	8 xyz, 4 z	14	1.038	0.363	0.434	0.269

4 Results

As first results, some qualitative aspects can be highlighted. As shown in Figures 2 and 4, the studied landslide does not appear in the 1956 model, although it is located in a global unstable zone, with some evidences of older instability upslope. After 1956, the slide was triggered and some evidences are observed in the next models, such as a main scarp, stepped slope, minor scarps, accumulation zone and open cracks.

The comparison between the 1956 and 2010 DEMs shows two very different areas, the depletion zone usually in the upper part and the accumulation zone in the lower part (Figure 2 and 3). DEM subtraction reveals significant vertical displacements with a decrease of ground surface of 8.5 m average in the depletion zone (0.16 m/year of annual rate) and a rise of the surface of 3.9 m average (0.07 m/year of annual rate) in the accumulation zone (Table 3).

By the considered periods, the more useful comparison is between annual rates in which significant differences are observed. So, the higher displacement rates occur in 1992-2001 and 2008-2010 periods, both in depletion and accumulation zones, although especially in the first; the lowest displacement rates are observed in the 2001-2008 period with non-significant changes; and finally, a rate similar to the whole analyzed time interval is found in the longer period of 1956-1992.

The analysis of volumetric changes shows similar results, with a depleted volume of almost $300x10^3$ m^3 and an accumulated volume about $120x10^3$ m^3; the difference of about $175x10^3$ m^3 corresponds in losses of material (wasting), evacuated by the river channel (Table 4).

By periods, we find similar results to those of the displacements, with maximum relative values in 1992-2001 and 2008-2010 periods and minimum in the 2001-2008 period; meanwhile, in the period 1956-1992 it is observed a rate similar as that found in the whole considered time interval.

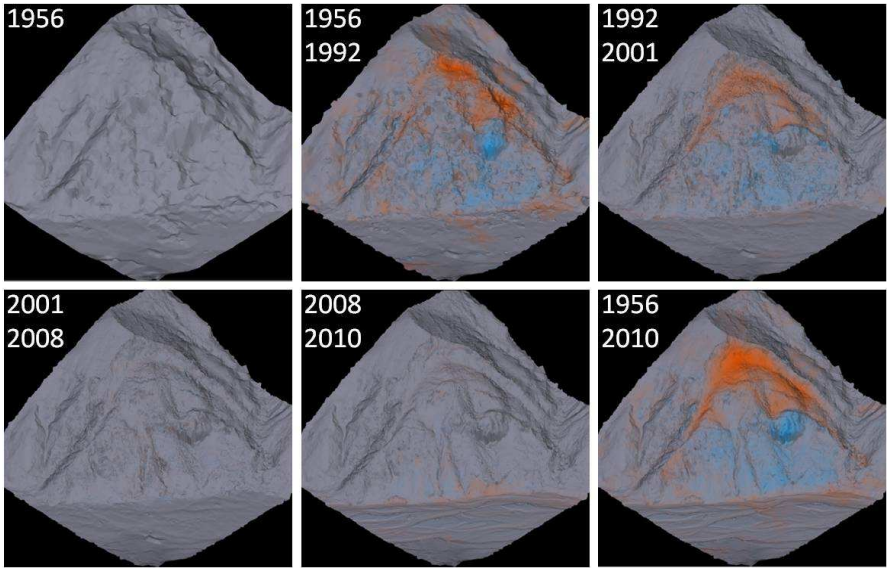

Figure 2: Evolution of the landslide (1996-2010): depletion zones are shown in orange and accumulation zones in blue.

Table 3: Vertical displacements (measured in meters), resulting from the subtraction of more recent model compared to older model.

Period	Absolute displacements		Relative displacements	
	Depletion	Accumulation	Depletion	Accumulation
1956-1992	-5.22	2.56	-0.15	0.07
1992-2001	-2.87	1.78	-0.32	0.20
2001-2008	-0.30	0.27	-0.04	0.04
2008-2010	-0.43	0.23	-0.21	0.12
1956-2010	-8.49	3.94	-0.16	0.07

Table 4: Volume calculations (measured in m3).

Period	Absolute volumes			Relative volumes		
	Depletion	Accum.	Wasting	Depletion	Accum.	Wasting
1956-1992	-178909	55697	-123212	-4970	1547	-3423
1992-2001	-85784	46182	-39602	-9532	5131	-4400
2001-2008	-9252	8705	-547	-1322	1244	-78
2008-2010	-18389	7124	-11265	-9195	3562	-5632
1956-2010	-292333	117707	-174626	-5414	2180	-3234

5 Discussion

The presence of landslide evidences in addition to other geomorphic features recently developed, such as gully erosion or ravines, reports about an important geomorphologic activity in this area that is also confirmed by the important losses of material evacuated during "rambla" flooding events. This activity is not only recent but dates back hundreds or thousands of years and extended along Late Neogene to Holocene landscape reactivation processes (Garcia et al 2002).

The obtained landslide parameters allow the identification of its dimensions, velocity, activity, diachroneity and intensity patterns, following published classifications (Cardinali et al 2002, Chacón et al 2010, Fell 1994, WP/WLI 1993, 1995). So, its volume of about $300x10^3$ m^3 is catalogued as moderately large, and its average velocity of a few centimeters per year was considered as very slow (Fell 1994, WP/WLI 1993, 1995) for a long time span of about 50 years. It leads to a degree VIII of diachroneity (Chacón et al 2010) during which a high sliding intensity (Cardinali et al, 2002) was attained.

From calculations, longitudinal sections (Figure 4) and other evidences, the landslide can be considered as translational with a sliding surface close to a plane and a thickness of a few tens of meters that partially flows in the front and is evacuated by the river.

The differences in annual rates of displacements and volumes during the considered periods suggest that the evolution of Almegíjar landslide is not uniform in time that agrees with other qualitative observations. So, in a previous regional study (Chacón et al 2010) this movement was then catalogued as degree VII of diachroneity that defines movements with an irregular activity alternating phases of low activity with reactivations, mainly due to heavy rainfalls that occur in the region every 10-15 years. It agrees with known climatic data in the area where the two last rainy periods occur in 1997 and 2010; however, this statement should be checked with more data and analysis that will become soon.

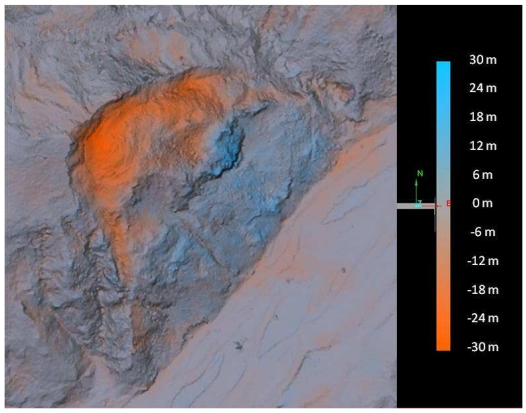

Figure 3: Vertical displacements in the whole considered period (1956-2010).

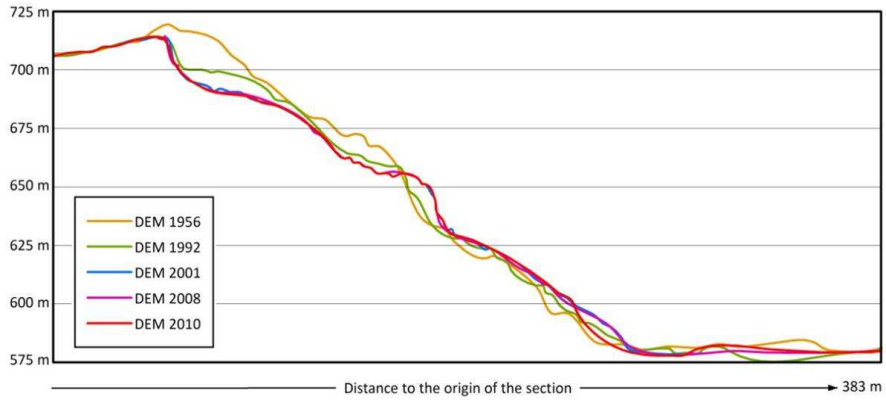

Figure 4: Longitudinal sections of the landslide.

6 Conclusions

Digital Photogrammetry techniques and DEMs building and editing are proving again as a very useful and fine tool to study landslide and its temporal evolution.

The proposed methodology is based on the fine orientation by means of control points and flight data on the most recent and accurate flight, that is taken as a reference; then the historical flights are oriented using second order control points extracted from the reference flight. This procedure ensures a good orientation and consistent data integration in the same reference system. Meanwhile, DEMs building taking as a reference LiDAR data from the most accurate flight reduces the time to DEM edition and avoids the noise in the automatic matching process.

Depletion and accumulation zones, with average vertical displacements around 8 and 4 m respectively and changes in volume over $300x10^3$ m^3, have been identified and quantified. Besides, some ideas about landslide description (translational slide) and its evolution not uniform in time can be deduced.

The moderately large Almegíjar landslide evolves with a very slow average velocity along a wide time span, resulting in a degree VIII of diachroneity during which a high sliding intensity was attained.

However, more flights and other techniques have to be used such as displacement vectors or the absolute distance calculation for a better knowledge of the landslide kinematics and activity.

The methodology is well suited to be employed in emergency situations detecting displacements and changes in the ground surface, since it is based on updating the model in areas where these changes are taking place. It will require the use of systems for quick data capture such as a terrestrial laser scanner (TLS) or light unmanned aerial vehicles (UAV).

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Cascading Effects and Interorganisational Crisis Management of Critical Infrastructure Operators. Findings of a Research Project

Thomas Becker[1], Marie Bartels[2], Michael Hahne[2], Leon Hempel[2] and Renate Lieb[2]

[1]Institute for Geodesy and Geoinformation Science, Technische Universität Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany, e.mail: thomas.becker@tu-berlin.de

[2]Center for Technology and Society, Hardenbergstraße 16-18, 10623 Berlin, Germany, e.mail: {hahne; hempel; lieb}@ztg.tu-berlin.de

Abstract

Geoinformation in crises is used to create a Common Operational Picture (COP) and enforce Situational Awareness by presenting and representing relevant information. As nearly all crises affect geospatial entities, geographical data representations have to support location-specific decision-making throughout crises. Due to the numerous interlinkages between utility networks, large interruptions might affect neighbouring systems as well and therefore lead to a citywide crisis. In such cases, an integrated COP is needed that does not consider systems as isolated but as mutually dependent in many ways. This forms the base for the collaboration of different utility operators in order to develop a joint coping strategy for the crisis. In order to facilitate the Situational Awareness of operators in conjunction with a COP, geoinformation about functional, semantic, and topographic aspects of urban features, their mutual dependencies and their interrelations are needed. This paper will give a brief overview of a project in which this information was firstly identified and secondly integrated into a common data model. Furthermore, specific challenges were studied that decision-makers face when confronted with cascading effects that arise from these interdependencies.

1 Introduction and motivation

The availability of water, electricity, natural gas, district heating, food, healthcare, transportation, and telecommunications services applies to most people in our society as a matter of course. Nevertheless, this implicitness is based on the proper operation of technical systems that in their complex structure are less banal than ubiquitous accessibility first promises. It is notable for infrastructure systems that they can be invisible, if they work. This is not only because of lack of clarity due to the physical size of the systems. No specialist would claim that he knows his supply network from start to finish. Supply networks are embedded in other structures, social arrangements and technologies, whose function is made possible and maintained only through them. Precisely because of this invisibility, functioning infrastructure systems are self-understood in modern societies, not just as a state of perfect technical stability, but also social stability - the widespread circulation of goods and communication with high social cohesion.

Thus, failures in those infrastructures are of major interest to the population and will have a large impact on social life and corresponding infrastructures.

Major incidents or major crisis events require the cooperation of different authorities and organizations such as police, fire workers, rescuers, utility network providers, and city administration, usually over a long period of time. A common understanding of the current situation, unfolding events, structures, processes and the available geodata (Becker et al 2011) is an absolute must in order to achieve coordinated action and to avoid misunderstandings in the moment of crisis. The necessity of the so-called Common Operational Picture (COP), (Steenbruggen et al 2011) arises through the need of a common visual presentation of the event site and its near surroundings. It enforces a common understanding of the current situation and supports the interactions between actors. A COP provides the needed information at the right time and in the right context by using maps, web services, etc., thus supporting the decision-making process during a crisis. In addition to the COP, a common understanding of "what is going on" is needed and is handled as Situational Awareness (SA) in literature; see (Endsley 1995). "*SA is viewed as consisting of a person's state of knowledge about a dynamic environment. It incorporates the perception of relevant elements, comprehension of the meaning of these elements in combination with and in relation to operator goals, and a projection of future states of the environment based on this understanding.*" (Endsley 1995).

Utility networks are highly complex systems. In today's technologically advanced society the dependency of every citizen and company on having a working infrastructure is extremely significant. Failures of critical infrastructure, such as the Italian blackout in 2003 or the power failure in wide parts of Europe in 2006, demonstrate the strong linkage of networks across borders and the effects of infrastructure failures. A COP in such a case requires the joint visualization of infrastructure assets, urban features, position of action forces, and much more. To give a motivation for the need of such a joint visualization a brief use case/scenario is

presented in the next paragraph that has been adapted from a real occurrence in the summer of 2008.

During construction work in Berlin in July 2008 an aircraft bomb from the Second World War was excavated. Immediately after excavation, different institutions with responsibilities for collecting precise information about the location and circumstances were called upon. Based on the address, the collected information, and the pre-existing knowledge of the operators, a security buffer zone around the bomb was established (Figure 1). It was decided to extend the number of the institutions involved by requesting the support of the fire department and external utility companies. The reason for this was due to the risk of a second area being affected, in addition to the primary impact area (orange hatched areas). The functional dependencies (red hatched areas) of utilities and the possible resulting cascading effects (Becker et al 2011) have made this scenario conceivable.

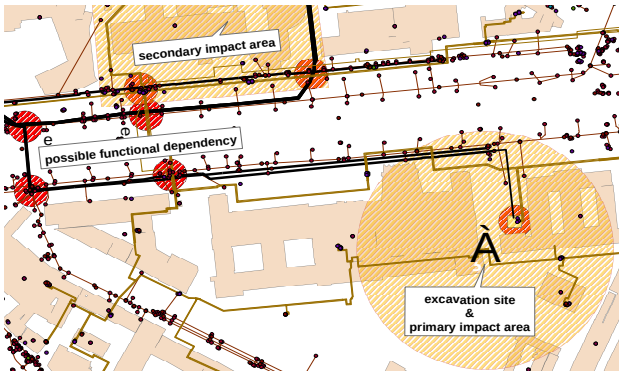

Figure 1: Scenario - excavation of a bomb from the Second World War and the resulting affected areas.

The nearby hospital, citizens, and workers were informed and instructed about an upcoming evacuation. The area around the bomb excavation site was blocked off for pedestrians, for nearby highways, for metro, bus, and urban railway lines, and for affected utility networks. Water, electricity, district heating and natural gas supply networks could also be affected. Central supply systems and, subsequently, transport, telecommunications and many other services threatened to collapse. A crisis team of representatives of four companies had to come together to deliberate and to make decisions. Moreover, the press demanded to be kept informed about the situation and actions that would be taken. Customers reported outages and damages. Between the supply system and beyond its borders domino and cascading effects arose that could be managed only by a cooperative undertaking. This case demonstrates the different aspects that were taken into account when developing a decision-support system for complex incidents:

- interaction points between the systems that can lead to cascading effects need to be identified;

- crisis managers in disaster response, mitigation, and recovery require reliable, current, and formatted information;
- visualizations have to be simplified and minimized radically while preserving as much information as possible, in order to allow handling the information provided under time pressure;
- not only are physical/functional processes relevant to crisis managers, but also a wide range of surrounding social factors has to be considered in order to present a problem in its entirety;
- a common model of the heterogeneous GIS systems will be of great use when a heterogeneous group of crisis managers has to cooperate.

The next sections will give an overview of the major project steps and will conclude with the main findings of the project.

2 Project overview

The starting point of the research project SIMKAS-3D was accident scenarios that bear effect on multiple supply infrastructures, thus making such scenarios more realistic and ameliorating the possibility of massive catastrophe. The project was part of the program "Research for Civil Security" of the Federal Ministry of Education and Research (BMBF). The project employs with its comprehensive analyses and scenarios, simulations, practice tests and trainings related to the various infrastructures, an unprecedented combination of interdependent supply infrastructure and the 3D city model of Berlin, especially concerning the problems of prevention and early detection of cascading effects. The aim was to enable operators to cope with crises by taking timely and correct action. Prevention and early detection of cascading effects regarding the failure of infrastructure have to be based on intensive system analysis and simulations on the base of geo-information. The joint modeling of Berlin infrastructure data, the 3D city model of the city of Berlin and the processing of interdependencies of infrastructure, were the basis for software developed during the project. The collaborative identification of failures, cascading effects and damages, and their effect on the urban environment became possible. The results are used to formulate recommendations for policy makers and to develop subject-specific and cross-sectoral trainings in the field of civil protection.

3 Survey of mutually dependent infrastructure systems

Knowledge of interdependencies is a prerequisite not only in defining the challenges to crisis managers but also to determine which requirements the intended decision support system must satisfy. The basic question at the beginning of the

project therefore was: what are the characteristics and internal dynamics of damage arising in an environment of closely networked urban supply systems?

Infrastructure systems are systems that can take on many complex forms in their technical components, network structures, and organizational and communications structures, especially in case of a catastrophe. The causes of failure of complex infrastructures are always varied and multi-dimensional. Until now, research has concentrated mostly on immediate dangers. It is a commonplace that infrastructure systems are especially dependent on the power supply. There are many studies on power failure, but without considering the interdependencies with other infrastructure operators, and therefore without taking into consideration the supply reliability for the population. Critical interdependencies between infrastructures are usually hard to see and even though infrastructure operators are aware of dependencies, they know little about possible interactions and cascading effects. This project aimed at looking into them in detail.

At first, forty interviews of several hours each were carried out with employees who are active in day-to-day operations in four participating utility operating companies. Further discussions were held with representatives from the fire department and local administration. The information obtained was analyzed and the joint linkage determined concerning the relationships of performance, communication and disruption. These relationships exist between relevant types of network components, organizational units and other relevant factors (nodes) that were determined and described during the system analysis as well. The result was a network model of 450 detailed individual relationships among 56 relevant nodes. These dependencies can arise because of the short distance between system components, as with cables lying next to and affecting each other through leakage current or washout. Other interaction points occur through physical media dependencies, media in this case being power, natural gas, water, etc. Communication relationships were also studied in detail, because the dissemination between organizations of information concerning malfunctioning plays an important role in cascade formation. Intensive collaboration can prevent failure propagation, especially in the early phase of a crisis. It must be anticipated if and when a registered malfunction can become relevant for another operator. It is necessary - and this is the difficulty - to communicate beyond one's own system boundaries. Successful coordination is an enormous challenge between organizations who are under time pressure, ignorant of the structure of neighboring companies, and facing constantly changing conditions. Experience shows that even small malfunctions cause important problems at the interfaces between operators.

In order to create a base for a Common Operational Picture these identified relationships had to be mapped into a common data model that enables the spatial determination of functional dependencies.

4 Integration and harmonization of infrastructures in an urban context

The survey of the existing GISs has revealed that clear similarities between different kinds of infrastructure systems exist that allow the development of a homogeneous and common data model for all infrastructures. The diversity of network entities makes the development of a data model necessary, that must be flexible and extendable. The Utility Network ADE of CityGML represents a first approach to extend the abstract model of a city by integrating utility infrastructures into the urban space and by making their network topology and topography explicit.

The core model (Becker et al 2011) of this application domain extension establishes the relation, or – to be more precise – the connection between aboveground and belowground urban inventory with respect to utilities. The core of this ADE defines the modeling environment by making relevant features and their mutual relations explicit and allowing the 3D topographical modeling of entire networks, sub-networks and network features as well as their graph representations. The consequent treatment of network features as abstraction of real world objects (topographic point of view) as well as a graph object, represented by its own network graph, makes the model more flexible than the models realized in existing GI utility systems. The module NetworkComponent (Becker et al 2012) of the Utility Network ADE extends the core concept by classes that will describe the entities of any utility network in a semantical-functional way. The possibility of modeling materials, commodity types, and the full interior of pipes and tubes, makes the data model almost complete. The decision to extend CityGML by utility networks will later enable the use of standardized services such as WFS, WMS and W3DS and it will give others the possibility of further extending the model.

The developed data model was brought into practice within the project SIMKAS-3D. The aim was to develop methods for the identification and analysis of the mutual interdependencies of critical infrastructures, including the simulation of cascading effects in the failure of supply infrastructures (see Becker et al 2011) for more details on the background).

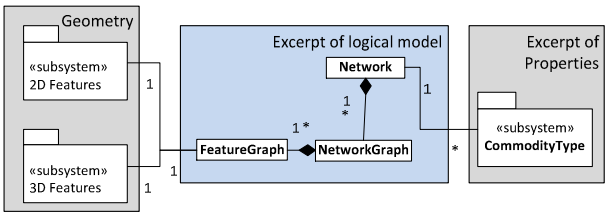

Figure 2: Implementation of the CityGML Utility Network ADE as a geodatabase model for ESRI ArcGIS.

In order to achieve the project goals a data model and geodatabase for the homogeneous representation of different utility networks such as water, gas, long-

distance heating, and power supply was developed. The integrated database facilitates a Common Operational Picture (COP) for disaster management as well as for the simulation of cascading effects in case of network failures.

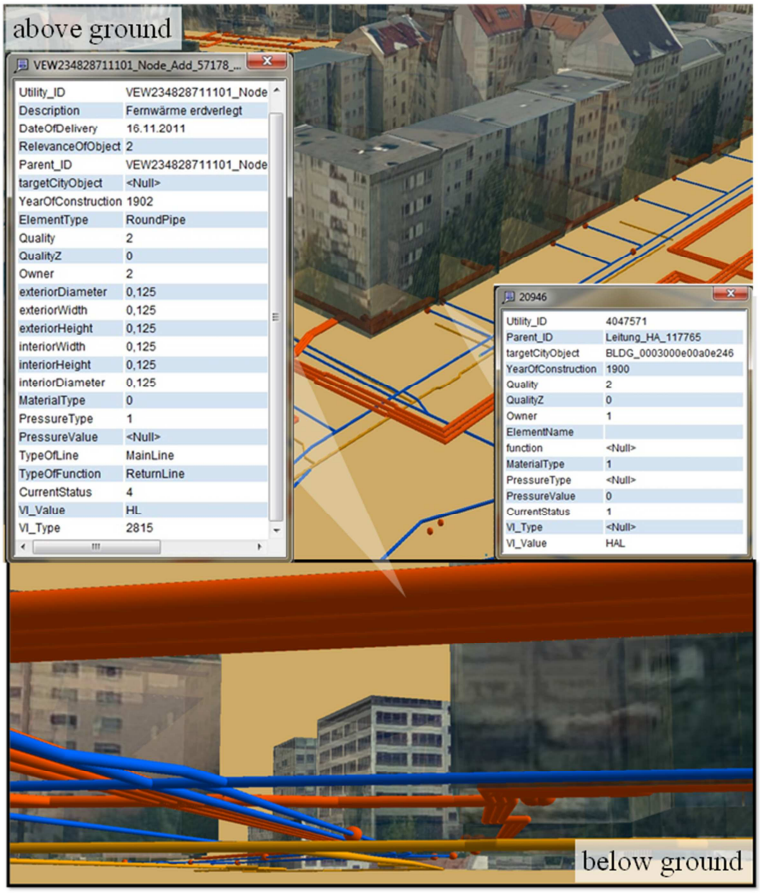

Figure 3 Embedded multi-utilities into 3D urban space in a perspective view (top = above ground; bottom = view from below ground).

The *NetworkCore* model, the *NetworkComponents* model, and the *NetworkProperties* model have been mapped to a relational database schema and are stored using the ESRI File-Geodatabase format. According to the three developed data models the database schema is partitioned into three major parts as well (see Figure 2). One represents the geometry of the network components in 2D (polyline, point) and 3D (multipatch), one represents the logical model - the core model - in tables, and the last one represents the network properties (commodity types) as a relation to the networks. The utility networks of the supply companies were converted into the geodatabase by customized FME workbench processes. The pro-

prietary GISs were the data source for the process and the created geodatabase has defined the destination writer type and schema.

The interdependencies between networks, network objects, as well as city objects were added. Figure 3 shows 3D visualizations of the available data and its embedding into the urban space. Each building of the dataset is logically connected to the available network. Thus, it is possible to perform complex analysis and simulations from producer (treatment plant) to the utility client (building) with respect to cascading effects, network tracing, and more.

On top of this database a decision-support-tool was developed. This system had to be adapted to challenges that arise when different organisations have to cooperate during crisis.

5 Requirements for the decision support system

Particularly critical components of the totality of the four systems can be identified on the basis of the overarching relationship network. Following the dependency links, event chains can be found that represent highly complex fault scenarios. They provided the basis for experimental crisis management tests, which in turn enabled the information requirements of operators in the case of crisis to be determined. These requirements had to be considered in development of the GIS.

Four crisis management teams were confronted in the course of one day with a cascade scenario. The attempt was made to create a realistic environment by providing the managers information on crisis development in the perspective of their organization, partly incomplete and with time delay. The course of the crisis made it necessary for the participants to develop a common solution strategy. They were able to use conventional communication methods (telephone, fax, e-mail) to exchange views and information on network conditions, repair measures, and prediction of further crisis development.

The protocol of the experiments was analysed to determine what the information needs were in the course of interorganisational communication. Almost all the provided and requested information belongs to one of the following categories: fault cause, fault location, measures taken, areas affected, impact on other facilities, expected fault duration, external representation of the event and provision of updates for changed situations. The test clearly showed that communication of such information presented crisis management repeatedly with the following challenges.

5.1 Spatial cascade

The names of the supply districts of each network operator have usually arisen historically and are seldom identical with official city district designations. In addition, network layout has arisen on the base of physical and historical circumstances and neither conforms to administrative borders nor corresponds to the lay-

out of neighbouring networks. Names are often oriented to prominent facilities or well-known buildings in the area. Within companies, this special area nomenclature is clear. In normal operation, it is not necessary to convey spatial information externally. A translation of internal names to standardized forms (e.g. post address, zip code, official district designations) has not been done.

This was the background to time-consuming discussions during the exercises on exactly where the faults or supply constraints had manifested themselves. Secondly - and potentially more dangerous - was the assumption that spatial designations between operators had been understood because of, for example, similar names being used in two different networks. In this way measures taken on the basis of assumed agreement were either useless or exacerbated crisis damage.

5.2 Time cascade

In case of a crisis when a disturbance occurs, the cause is usually not known immediately. The expected effects (affected areas and facilities) can be determined at a varying rate according to the system. Repair procedures are routine for the companies investigated, but they can be more complicated and protracted than usual in case of, for example, extreme weather, traffic problems, and personnel shortage, all of which occur more frequently in crisis situations. The time needed until normal operation can continue can be estimated roughly even when the situation overview is incomplete, but any estimates will be modified when further details, influences, partial causes or additional disturbances become known.

Important system facilities depending on a medium (e.g. power, cooling water, natural gas, diesel) are usually constructed to handle supply bottlenecks for a certain length of time, for example, with reserve storage or emergency generators. How long the corresponding redundancy holds varies widely and depends on many factors: importance of the facility for supply reliability, redundancy cost, worktime for maintenance of the backup system, frequency of supply failure, etc. For most facilities these buffer periods cannot be determined in advance, because they are dependent on current reserves, outside temperatures, customer usage, etc.

Both time values (time until supply is reinstated, redundancy) are predictions whose communication, reliability evaluation, and use as basis for decisions was perceived as a great challenge by the observed crisis management teams.

5.3 Escalating cascade

An unrecognized or under-estimated effect whose severity is much greater than the original disturbance can also lead to a cascade when the potential for escalation is underestimated. In this case the network component down the effect chain is much more important for the total system, for example when it affects more customers or additional facilities, or has additional effect on health, costs, time to return to normal operation, etc. Important are the criticality parameters to be assigned to every component failure in order to measure the degree of escalation.

The cross-sector assessment is a great communications challenge, because in order to identify an imminent escalating cascade failure it is necessary to have either a deep understanding of the mutual influences of the systems and their inner conditions, or early effective communication concerning escalation potential during the crisis.

5.4 Cascade because of suboptimal resource allocation

Till now we have discussed the types of functional dependency that become visible during disruptions. But there is also the problem that a chance of restricting the cascade may be missed when limited resources are used inefficiently during crisis handling. A careful use of means even beyond one's own network could, however, prevent time cascade for example. In extreme cases resources such as emergency generators or company personnel could be made available to neighbouring networks, in order to prevent or ameliorate a cascading effect. Support potential is not used either because the need or accessibility is not recognized, or because of lacking logistics.

5.5 Cascade because of overview loss

In the course of citywide crises every operator is confronted with an imminent threat to his or her own system. This threat tends to become the center of attention. These dynamics create a situation in which cross-sector communication can continue concerning main sites affected and the common operational picture. But beyond these hotspots other developments can be overseen whose complex interrelationships have not been recognized because of the one-sided focus. This specific problem of crisis management can lead to further expansion of the situation.

Before the project started the network operators had already formulated a need for a common visualization of cascading effects in order to support collaborative crisis management during a crisis. The experiment underscored this view and made possible a much more concrete formulation of the requirements concerning the communication problems identified.

6 Conclusions and recommendations

As utility networks are cross-linked in various ways more actors have to communicate and cooperate when disturbances occur. The systems are highly complex, thus not every crisis scenario is predictable. Actors have to be prepared to deal with unforeseen situations and scenarios and to exchange information across system borders. A realistic state analysis and prognosis based on them requires an integrated and simplified visualization, and an integrated and harmonized model.

The findings and the base for semantic classification of network entities into the essential entity types was based on empirical studies carried out at different utility providers. The integration with the CityGML standard facilitates the integration of multi-utility networks into the urban space or into 3D city models for joint visualization and analysis tasks. Furthermore, interoperable exchange of, and access to 3D multi-utility networks is enabled.

The developed data model represents 3D topography, 3D topology, and functional properties and interdependencies of the networks and their components. Hierarchical representations for both networks and components are supported as well. These characteristics allow performing geospatial analyses in order to determine the implicit interdependencies between network components within the same or different infrastructures, or between network features and other city objects based on spatial relations such as proximity. For example, collision detection would prevent many pipeline ruptures caused by excavation work.

The decision support system based on the data model makes possible a concurrent entry of disturbances during a crisis and thus also communication with access to a common view. This is in particular a long step toward common recognition and solution of geographical cascades by allowing entry of spatial effects of disturbances as areas and dots. The consideration of communication and disturbance relationships in the data model also allows other challenges to crisis management to be solved, for example, when for the other crisis management teams the disturbances are recognizably linked with their causes. Misunderstandings resulting from lack of knowledge about relationships, or from language and/or cultural differences can be avoided, or at least made visible.

As a result of the project we are able to formulate some recommendations to utility providers and authorities.

- To be able to handle interorganisational crises a knowledge base needs to be established in “times of peace”. The data model can be a sound basis for that, but additional insight into culture, language and logic of the neighbouring systems is required to succeed in communicating in moments of crisis. Therefore, staff of utility networks should be encouraged to exchange information on how their systems function on a regular basis.
- A “historical event database” of cascading effects can be fruitful firstly, in teaching staff about potentially disastrous dependencies, and secondly, in setting up crisis exercises for actors by using former events as realistic scenarios.
- Furthermore, it is recommended to discuss disturbances involving several networks as soon as possible after a crisis event to avoid misconceptions of the relevant factors that had effect, and thereby develop a common understanding of their intertwined networks.
- Even without a common database network operators have need for exchange and sharing of infrastructure geodata. It is strongly recommended to establish a standardized mechanism for data transfer between different utility systems.

Acknowledgment

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A Refuge Location Prediction System for Supporting Disaster Medicine

Akihiro Kawabe[1], Tomoko Izumi[2] and Yoshio Nakatani[3]

[1]Graduate School of Science and Engineering, Ritsumeikan University, Kusatsu, Shiga, 525-8577 Japan, e.mail: is013087@ed.ritsumei.ac.jp

[2]College of Information Science and Engineering, Ritsumeikan University, Kusatsu, Shiga, 525-8577 Japan, e.mail: izumi-t@is.ritsumei.ac.jp

[3]College of Information Science and Engineering, Ritsumeikan University, Kusatsu city, Shiga, 525-8577 Japan, e.mail: nakatani@is.ritsumei.ac.jp

Abstract

During the 2011 Tohoku Earthquake and Tsunami, DMATs (Disaster Medical Assistance Teams) could not rescue victims efficiently with accurate location data, because the local governments had lost refuge location data and resident registers due to damage caused by the tsunami. In this paper, to support DMATs, a refuge prediction system based on the characteristics of disaster, landscape, and victims' psychology is proposed, which can function even if local governments lose information about victims and refuge locations. As an example, this system deals with tsunami. We demonstrate the effectiveness of this system by comparing the data of the 2011 Tohoku Earthquake and Tsunami and our prediction system.

1 Introduction

All over the world, suffering is caused by various kinds of natural disaster, including typhoons, floods, volcanic eruptions, and earthquakes. Japan is particularly af-

fected by earthquakes, as the country is surrounded by four tectonic plates. According to recent statistics, magnitude 2.0 earthquakes occur in Japan about 10,000 times a year. For that reason, Japan is a country of frequent earthquakes and many earthquakes happen every year.

The 2011 Tohoku Earthquake and Tsunami occurred on March 11, 2011, killing more than 15 thousand people. This earthquake's magnitude was 9.0, which ranks fourth highest in global statistics of the past 100 years.

In this disaster, many hospitals and medical institutions were damaged by the tsunami, causing shortages of doctors. To solve this issue, DMATs (Disaster Medical Assistance Teams) supported the disaster area. In spite of the DMATs' early dispatch to the disaster area, they were not able to rescue with accurate location data, due to the fact that town office administration stopped because many coastal town offices suffered from the tsunami. There were no means of contacting victims, as the town offices had lost records of the sufferers' addresses. It is predicted that the probability of a Nankai or Tonankai Earthquake occurring in Japan within 30 years is over 60 percent. In future, when earthquakes occur, it is vital to know victims' addresses, conditions and ages in order to make full use of DMATs' abilities.

In this study, we propose a refuge prediction system for supporting disaster medicine from the viewpoint of disaster characteristics, regional characteristics and psychological characteristics, which can be used even when local governments are not able to acquire information on victims' addresses and conditions.

2 Related work

During a disaster, it is important to exchange disaster information. In the 2011 Tohoku Earthquake and Tsunami, DMATs were not able to acquire sufferers' addresses or refuge location information, as the local governments that should have performed this task were too damaged by the tsunami. In order to solve these problems, DMATs must establish who is in need of rescue, where they are, and acquire refuge location data. If information cannot be obtained from sufferers, we need to predict refuge locations in some way. In this disaster, such support was not provided.

Over the past few decades, a considerable number of studies have been conducted on predicting refuge locations. We briefly introduce such research.

In 2009, Asakawa et al proposed a system that shares the location information of the user by displaying it on a map. This system attaches these data to Google Maps using a mobile phone camera and GPS function. By sharing the data as map information, the system links between Google Maps and the physical world. Thus, Asakawa et al's system proposes an environment in which information can be exchanged as a reality.

In 2007, Tanida and Daito proposed a method for specifying victims' locations using IC tags when the telephone network fails in the damaged area, and demonstrated the system's effectiveness by simulation. In their system, a helicopter scat-

ters active type IC tags on the ground, and the system specifies victims' locations by trilateration with three fixed IC tags and the location-unknown subject's IC tag.

In 2011, Google constructed the "Google Crisis Response System" in response to the Tohoku Earthquake and Tsunami. This system displays refuge locations with markers in Google Maps, and displays the number of evacuees by marker color. In addition, this system can output refuge location data for all forty-seven Japanese prefectures in CSV and KML formats.

In 2011, Iizuka et al proposed a system that collects disaster situation information and shows it on a map when institutions such as universities are affected by disaster.

It is thus clear from the above research that it is effective to show disaster information on maps. However, sufferers were forced to take refuge in unexpected places by the Tohoku Earthquake's large tsunami, and rescue attempts by DMATs were hindered because the tsunami destroyed many designated refuge places. Therefore, a system is required that can predict refuge locations in advance, and give this data to DMATs, thus supporting disaster medicine

3 System construction

The purpose of this research is to predict disaster victims' refuge locations, with the system's user envisaged as a disaster countermeasures office. Based on the system's results, DMATs can go to the forecast locations, and start rescuing.

Other disaster countermeasures offices can use this system even if the relevant office has suffered damage from flooding or earthquake. In such cases, the only necessary items are a database and a PC terminal. Therefore, external support is possible.

We used Google Maps to display refuge locations. The process of the system consists of the following web application tasks.

- The user clicks the area in which an earthquake occurred on Google Maps, and the system indicates the hypocenter with the mark '×', displaying latitude, longitude.
- The user inputs the expected maximum tsunami height, and the system predicts refuge locations using these data, in cooperation with the refuge location database.
- Predicted refuge places are outputted as XML data, then, the system stores the XML data using JavaScript, and displays the refuge locations on Google Maps with markers.
- Markers are not displayed if tsunami height is higher than the refuge location's altitude. This system also shows refuge location names and the number of evacuees if a marker is clicked, as shown in Figure 1.

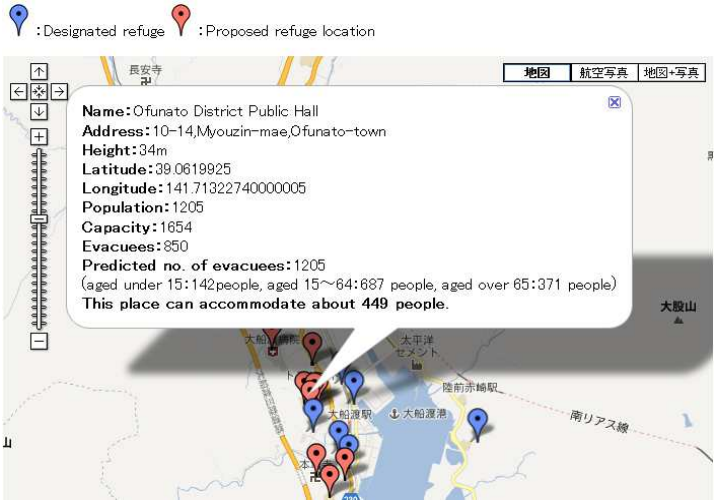

Figure 1: Output example: marker detail.

The disaster countermeasures office can predict refuge locations using the above system functions. The system architecture is shown in Figure 2.

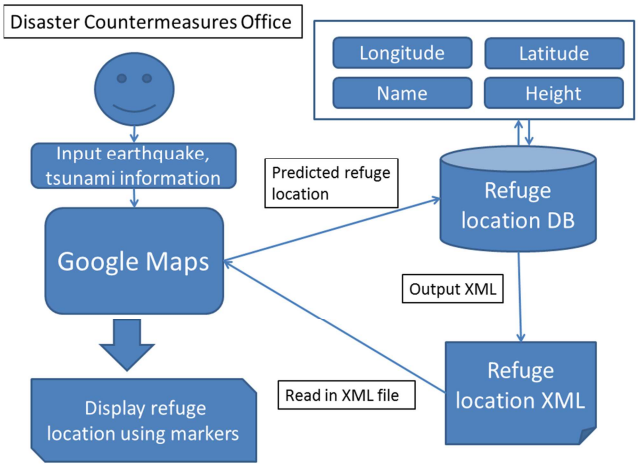

Figure 2: System architecture.

4 System evaluation

We conducted interviews with professionals in the field of fire department disaster prevention (Konan Fire Department, Kyoto City Fire Department), and we clarified issues by interviewing DMAT members about their problems and requirements.

4.1 System efficacy

We obtained opinions regarding this system's usefulness, which are summarized below.

- After an earthquake, there is no way to acquire victims' information, thus this system is useful because we can obtain victims' location data, and refuge location information.
- If this system can get exact population data and refuge location information, we consider the system's population estimation algorithm to be effective.
- There is some possibility of various applications (e.g. helping us to deliver relief goods to unknown places).

4.2 System improvements

Areas in need of improvement were pointed out by fire department disaster prevention professionals, and are summarized below.

- This system needs to make predictions that consider alterations to the maximum tsunami height.
- DMATs may not understand victims' locations only by using a map of the disaster area, as extensive damage can cause changes to roads and townscape.
- Refuge location prediction changes according to season, area and time of day, therefore this system needs to include these factors in prediction.
- To achieve reliable rescue by DMATs, we must obtain accurate information of municipal population and accommodation capacity when the system constructs the refuge location database.
- The system should display information regarding numbers and/or proportion of persons requiring rescue and those with injuries.

4.3 Future work

According to the results of the system's evaluation by Konan Fire Department and Kyoto City Fire Department, it would be useful in future to predict the number of victims, their locations and ages when DMATs are dispatched for early rescue in disaster medicine. Also, this system needs to predict based on town office resident data. However, there are some problems: for example, there is a lack of a framework in which resident data is exchanged with neighboring town offices, and

many town offices do not keep backups of resident data. This system must solve these problems in order to be ready for practice use.

Another issue of this system is that it needs real-time processing for disaster countermeasures offices to use the system. If DMATs visit refuge locations using this system, they can confirm the number of evacuees and their ages. However, it may occur that a DMAT may hear evacuees talk about a different refuge location which the system had not predicted. Consequently, this system needs to modify its data with real-world circumstances so that DMATs can get accurate information. Also, the system needs to incorporate a comparison of pre-disaster and post-disaster photos and location referencing with GPS, because it is difficult for DMATs to understand their positions when team members are not familiar with the region. In future, we aim to build a platform in which local residents can mutually register the information. For example, local residents could register refuge locations and places where in the past ground liquefaction had occurred. Thus, when an earthquake occurs, disaster countermeasures offices could extract information from this platform.

5 Conclusion

In this paper, we proposed a system that predicts refuge locations in times of disaster so that DMATs can rescue effectively based on this information. In large-scale natural disasters such as the 2011 Tohoku Earthquake and Tsunami, DMATs were unable to obtain victims' locations and refuge location information because local governments that held such information had suffered extensive damage from the tsunami. The purpose of this research is to support disaster medicine. As confirmed by evaluation from professionals in fire department disaster prevention, it is important for us to predict refuge locations. However, there are many problems. In future, we will improve this system in order to achieve greater reliability of refuge location prediction. Furthermore, as the current system can only predict refuge locations in the case of tsunami, we aim to improve the system to predict refuge locations in the context of various disasters, including fire and floods.

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Determination of Susceptible Areas for Flooding With Geographic Information System Based Multi Criteria Decision Analysis Method: Example of Istanbul European Site

Mustafa Yalcin[1], Fatmagul Kilic[2] and Saffet Erdogan[3]

[1]Afyon Kocatepe University, Department of Geomatic Engineering, Ahmet Necdet Sezer Kampusü Gazligöl Yolu, 03200, Afyonkarahisar, Turkey, e.mail: mustafayalcin@aku.edu.tr

[2]Yildiz Technical University, Department of Geomatic Engineering, Barbaros Bulvan, 34349, Istanbul, Turkey, e.mail: fkilic@yildiz.edu.tr

[3]Afyon Kocatepe University, Department of Geomatic Engineering, Ahmet Necdet Sezer Kampusü Gazligöl Yolu, 03200, Afyonkarahisar, Turkey, e.mail: serdogan@aku.edu.tr

Abstract

In this study, the preparation phase of disaster management has been approached with a GIS (Geographic Information System) based MCDA (Multi-Criteria Decision Analysis) (G-MCDA) vision and an example of determination of the susceptibility of the flood and overflow. Criteria that affect the flood and overflow were defined as; rainfall, elevation, slope, aspect, drainage density and size of sub-basins. Digital elevation data, data of the details for drainage, rainfall data, data for hydrologic soil groups, land cover data, boundary data (provincial boundary, land boundary, lake boundary), current orthophotos, flooding data that is produced in accordance with rational method have been used for preparing the data layers.SCS-CN (Soil Conservation Service-Curve Number) empirical model developed by USDA (United States Department of Agriculture) - which is one of the

precipitation-flow models - was used in order to create flow layer. Data layers prepared were normalized according to the Linear Scale Transformation - The Maximum Value method. AHP (Analytic Hierarchy Process) is used in stage of decision analysis of MCDA. Pair wise comparison method was applied in order to determine relative weights of the each criteria in the scope of the AHP. Consistency ratio was calculated to determine whether the comparisons, consistent or inconsistent and it was understood that they were consistent. The susceptibility layer was created via synthesizing the weights with normalized data layers. Susceptibility areas for flood were defined in G-MCDA after the susceptibility layer was classified using natural break method.Flooding susceptible areas of the European side of Istanbul; were determined by the G-MCDA method and compared with flooding areas defined by rational method. Susceptibility areas are showed similarity with a ratio of 97%.

1 Introduction

Spatial decision problems typically involve a large set of feasible alternatives and multiple, conflicting and incommensurate evaluation criteria. The alternatives are often evaluated by a number of individuals (decision-makers, managers, stakeholders, interest groups). The individuals are typically characterized by unique preferences with respect to the relative importance of criteria on the basis of which the alternatives are evaluated. Accordingly, many spatial decision problems give rise to the GIS-based MCDA. (Malczewski 2006).

With the integrated use of GIS with MCDA method, the location ensures the participation in decisions about optimization techniques. Also, the geographic information technology is made available directly to decision-makers for policy or scenario development (Eastman et al 1993, Malczewski, 1999, Jankowski et al, 2001, Ascough et al 2002).

G-MCDA approaches were most often used for tackling land suitability problems (Malczewski 2006). Determination of risk and susceptibility analysis in disaster management by using G-MCDA, has been one of the most widely used methods in recent years (Quesada et al 2007, Zerger 2007, Komac 2006, Rashed et al 2003, Ayalew et al 2004).

In this paper, the G-MCDA method was presented for flood risk analysis which will be required at pre-disaster phases of disaster management.

2 Method and material

In this paper, the G-MCDA method was presented for determination of susceptible areas of flooding. Project's flow diagram was depicted in Figure 1.

Figure 1: Project flow diagram

Initially, according to the specified purposes, literature researches were conducted and expert opinions were taken. As a result of these, criteria were defined as flow, elevation, slope, aspect, drainage density and size of sub-basins for flooding.

Data layers were prepared for each criteria, using as a base belonging to the Istanbul European Side boundaries (Figure 2).

Figure 2: Working area.

Elevation, slope, aspect, drainage density and size of sub-basin criteria were derived from 1/25000 scale digital topographic maps and flow criteria were derived

from soil groups maps, annual rainfall values and it has been defined with the SCS-CN method. The SCS-CN method, which was developed by USDA, is one of the methods in rainfall-runoff modelling. The result of the pixel sizes in the raster data were selected as '10 meters' optionally.

After the data layers were normalized, weighting and simple additive weighting stages were carried out respectively in the scope AHP method. Classifications and comparisons were made over the synthesis of data, and as a result of these, final recommendations were composed.

2.1 Normalization

During normalizing data layers, "Maximum Value" method is used in order to synthesise of all layers in the same denominator. The formula shown in (1) was applied in the flow, size of sub-basin and drainage density data layers. As these values of data layers increase, the risk flooding increases. Thereby, new pixel values of all data layers are defined varying between 0 and 1. The values which are converging to 0 are insignificant in data layers and the values which are converging to 1 are significant in data layers.

$$x_{ij}^{'} = 1 - \frac{x_{ij}}{x_j^{\max}} \tag{1}$$

In contrast, as the values of pixels related to the layers of elevation, slope and drainage density increase, the risk flooding decrease. Hence, the formula shown in (2) is applied to the layer to provide that as the pixels of the new values converge to 1 they get more significant and as the pixels of the new values converge to 0 they get more insignificant.

$$x_{ij}^{'} = \frac{x_{ij}}{x_j^{\max}} \tag{2}$$

Normalized layers of criteria in Figure 3 are also shown for each criteria.

2.2 Weighting

Weight values were constituted by decision makers according to their importance to synthesize among each criteria. All criteria were compared in pair groups with pairwise comparison method (Table 1). Consistency of the weights was determined to check whether the comparisons were consistent or not. Consistency Ratio was calculated as: 0.017 for 6 criteria. This value was less than 0.10, thus, the weights were found to be consistent.

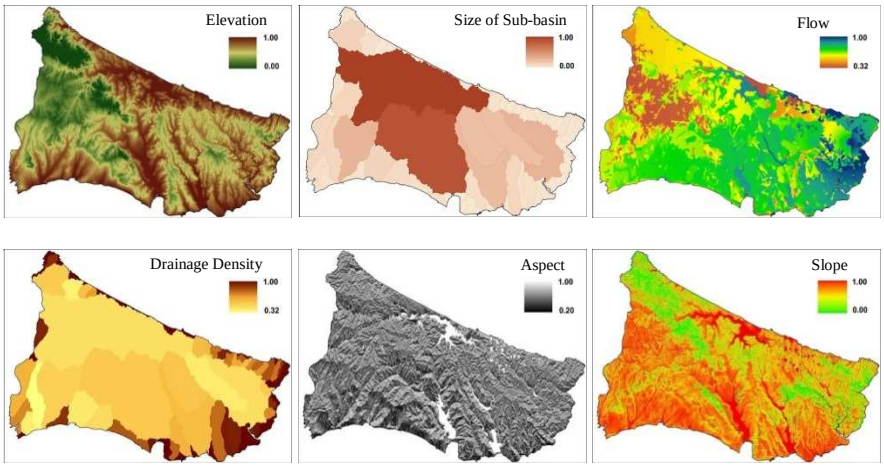

Figure 3: Normalized data layers.

2.3 Synthesize

The entire data was multiplied by their weights deriving pixel based value and then the synthesis layer was produced by adding these pixel based values on top of each other. Finally, susceptibility layer was created via synthesizing normalized data layers with their weights.

Table 1: Pairwise comparison matrix of assessment criteria and calculated weights.

Pairwise Comparisions	Flow	Elevation	Slope	Aspect	Size of Sub-basin	Drainage Density	Weight
Flow	1	3	3	4	3	2	**0.35**
Elevation	0.33	1	0.50	2	1	0.50	**0.11**
Slope	0.33	2	1	3	1	0.50	**0.15**
Aspect	0.25	0.50	0.33	1	0.50	0.33	**0.06**
Size of Sub-basin	0.33	1	1	2	1	0.50	**0.12**
Drainage Density	0.50	2	2	3	2	1	**0.21**

2 Results

3.1 Classification

Classes are shown with different colors, created a more open and understandable data integrity about the risk area on the layer result and more comfortable ability to comment gained. Synthesize map was classified with five classes (very low,

low, medium, high and very high) by using natural break method. Susceptibility areas for flood were defined as high and very high classes. Here the red and orange areas demonstrate low risk areas, green areas demonstrate medium risk areas and blue and dark blue areas demonstrate susceptible areas (Figure 4).

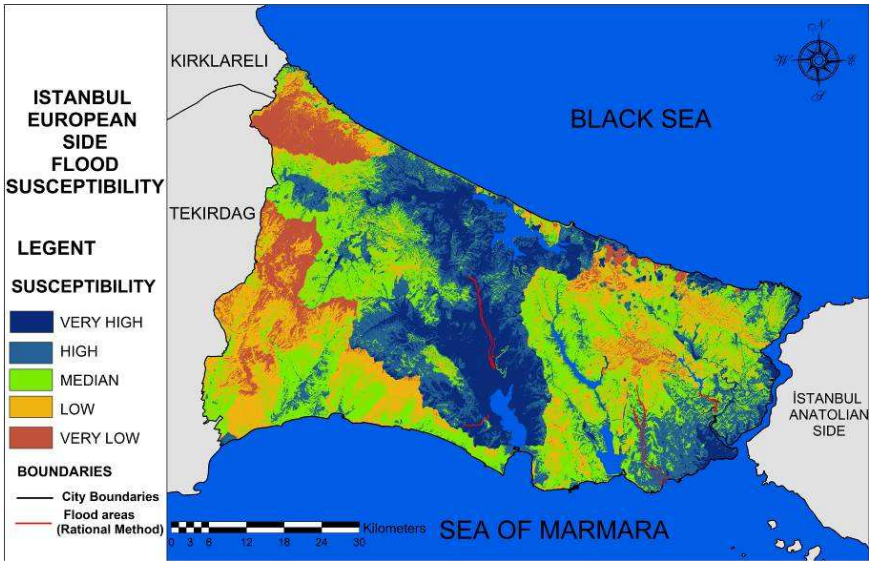

Figure 4: Classification maps.

3.2 Comparisons

Results of the study were compared with Rational Method which is empirical method to estimate peak flow. The Rational Method provides for the assessment of the peak discharge rate for design storms, but does not provide a reliable basis for the determination of runoff volume, hydrograph shape, or peak discharge rates from storms in the past (25,50,100,500 years). Five-hundred-year flood areas were calculated with rational method according to the maximum precipitation level that might occur in every 500 years by relevant Turkish Agencies.

Susceptibility areas which were obtained with MCDA were compared with flood areas defined by rational method to four river basins (Alibey River, Sarisu River, Ayamama River, Ciftlikkoy River) in Istanbul European Side (Figure 5). Percentage value of classification determined with G-MCDA method are shown in Table 2. These classes are also within Rational Method flood risk areas in Istanbul European Side.

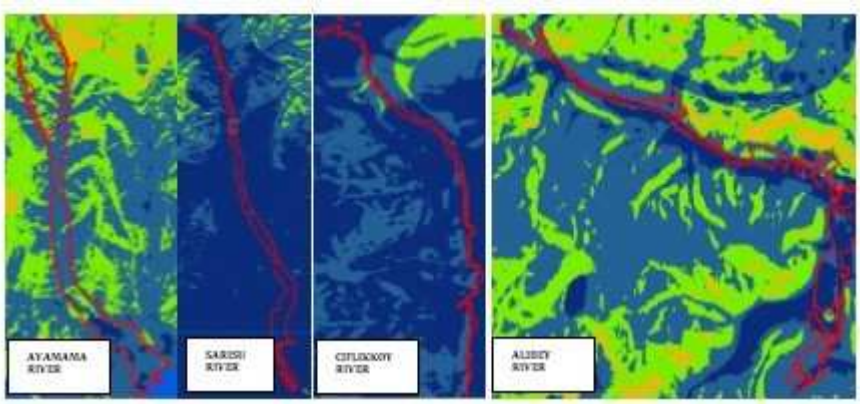

Figure 5: G-MCDA's flood susceptible classes within the boundary that was calculated by Rational Method.

Table 2. Percentages of G-MCDA's Flood Susceptible Classes within the estimated flooding area boundary determined by Rational Method for four river basins.

	Ayamama River	**Sarisu River**	**Ciftlikkoy River**	**Alibey River**	**Avarage Of Rivers**
Very High	% 53	% 97	% 88	% 55	% 74
High	% 38	% 3	% 12	% 41	% 23
Medium	% 6	% 0	% 0	% 4	% 2
Low	% 3	% 0	% 0	% 0	% 1
Very Low	% 0	% 0	% 0	% 0	% 0

The results of comparisons show that %53 very high, %38 high, %6 medium and %3 low flood risk area in Ayamama River, %97 very high, %3 high flood risk area in Sarisu River, %88 very high, %12 high flood risk area in Ciftlikkoy River, %55 very high, %41 high, %4 medium flood risk area in Alibey River that determined by G-MCDA Method within flood boundaries determined by Rational Method. Avarege of rivers, %74 very high, %23 high, %2 medium and %1 low flood risk area that determined by G-MCDA Method within flood boundaries determined by Rational Method.

4 Conclusion

This paper, aims to create flood susceptibility maps via the use of MCDA and with the help of GIS in European Side of Istanbul for pre-disaster actions.

In this process, definition of the problem, criteria selection, identifying for criteria weight with method of pairwise comparison, normalization, creation of results data with AHP method, classification, and comparisons were described in de-

tail. Synthesis of data obtained with AHP method, were organized with classification and comparison with the Rational Method.

The criteria selection and weight determination are subjective matters. Therefore, criteria and weights may vary according to the opinions of the decision-makers and the characteristics of the study area.

As a conclusion, the paper presents an application of G-MCDA by applying the determining flood vulnerability in the European Side of Istanbul in Turkey. The analysis results were compared with the Rational Method. Susceptibility areas are showed similarity to each method with a ratio of 97%.

As a result, the model suggested in this research can also be designed for earthquakes, landslide, avalanche etc. and using these models any kind of decision problems on GIS base which is developed in the scope of the research.

Similarly and in the first place, middle or small sized research should be conducted for disasters such as earthquakes, landslide, avalanche, etc. and then more detailed and bigger sized research should be conducted in the areas prone to disasters.

In this small scale research, susceptible areas have been detected and these susceptible areas are expected to lead for bigger scale researches. Compared to the other methods this study is much more economic in terms of cost and timing.

Acknowledgement

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Review of Grid Navigation Research in the Context of Emergency Routing

Lei Niu[1] and Sisi Zlatanova[2]

[1]GIS Technology, Delft University of Technology, Jaffalaan 9, 2628 BX, Delft The Netherlands; Department of GIS, Faculty of Surveying and Spatial Information, Henan University of Urban Construction, Pingdingshan 467036, China, e.mail: l.niu-1@tudelft.nl

[2]GIS Technology, Delft University of Technology, Jaffalaan 9, 2628 BX Delft The Netherlands, e.mail: s.zlatanova@tudelft.nl

Abstract

Gird-based navigation is one important approach for path finding besides the more often used network navigation. This paper makes a review of different approaches of grid navigation in the context of emergency routing, for grid navigation has many advantageous aspects and could be applied for indoor navigation in emergency routing. We also identify several future research directions for grid navigation applying in the emergency routing.

1 Introduction

As the emergency responding needs a path plan to guide the responders like fire fighters to the hazard scene, we have to consider the introduction of some navigation technology to support the emergency response. One promising candidate for this task is the grid navigation, which is currently used in the field of robotics navigation, computer game and simulation of human movement, indoor and outdoor human navigation. We may find grid-based navigation also essential for the emergency routing, such as directing a fire-fighting robot to explore a room on fire and utilizing the emergency simulation for training fire fighters. Therefore, we review

the current grid navigation approaches, point out gaps in existing research and propose future developing trend of grid navigation for emergency routing.

Grid navigation is defined as "a navigation system related to a reference grid instead of the true north for the measurement of angles" (Parker 2003). Although this definition may not be strictly followed in the real work, we can still perceive that only the research contributions that represent the route environment in lattice form and utilize these lattices to finish the path-finding task could be labelled as "grid navigation related works". From this point of view, we organize the current grid navigation approaches into three main categories. They are grid navigation in the robotics field, computer game and simulation of human movement field, and indoor/outdoor human navigation field. The review of papers is organized with respect to this categorization.

The paper is organized as follows: in this section, we formulate the three categories with the context of emergency routing. In the second section, a comparison of the three main categories of grid navigation is provided. In the third section, we discuss the applicability of current grid navigation approaches in emergency routing. Finally, we shortly conclude the grid navigation development and propose research targets for addressing the grid navigation need in a complex public building under emergency situations.

1.1 Robotics approaches

The robot navigation is among the key part of a robot system to allow robot to operate in specific environment, and is also important for emergency routing. For example, when the fire and plume block several floors of the building, we have to rely on fire-fighting robots to search and rescue the survivors in this area.

Robots move in a style quite different from human beings. Human can perceive the surrounding environment fast in a unique cognitive way. On the contrary, robots have to clearly address many issues to gain the navigation ability. The first issue is how to utilize sensors to scan the surrounding environment and keep the scanned data in the robot storage system (Lidoris et al 2009). The second problem is how to locate the robot position in the scanned environment to provide the start position of the navigation route. Thirdly, after the path plan is generated, the robot still has to control its velocity and posture to follow this plan and avoid collisions with obstacles. Besides these topics, there is another crucial issue existing in the whole navigation process for robots. That is how to address the dynamic feature of the emergency navigation environment. The clue for solving all these problem could be found in the existing robot navigation approaches.

The localization and position task for robot in the emergency scene could be tackled by the Simultaneously Localisation and Mapping (SLAM) solution proposed by Smith et al and Durrant-Whyte (Smith and Cheeseman 1986, Smith et al 1990, Leonard and Durrant-Whyte 1991). These pioneer SLAM works provide a foundational theory that defines how a robot could recognize the surrounding environment and locate its own position in this environment. In order to finish the navigation task, SLAM needs to be combined with the "occupancy grid" method

to organize the acquired traversable information by robot sensors from the environment (Elfes 1987, Elfes and Matthies 1987, Elfes 1989) (Figure 1).

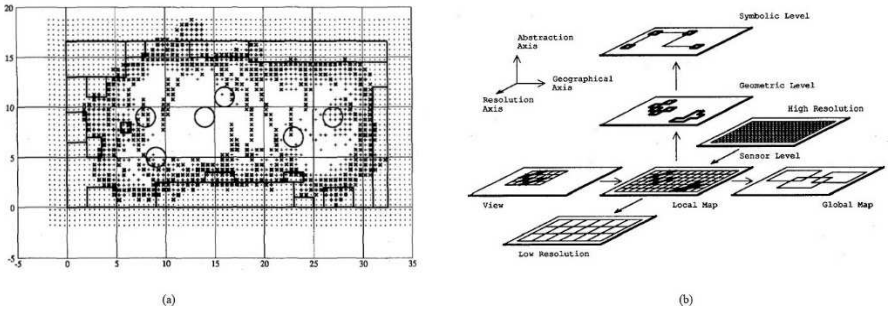


Figure 1: (a) The occupancy map generated by the sonar sensors of robot; (b) the multiple application axis of this map (from the work of Elfes 1987).

During the emergency management, it is common that not complete navigation information of the environment is available, and robots have to acquire some navigation data by their own. Thus a solution to generate workable paths with occlusion is proposed (Saitoh et al 2009). This solution firstly initializes current unknown area for sensors with an intermediate moving cost value to secure the existence of an autonomous drivable path, and secondly updates the routing environment with the new sensor information to receive a true optimized path. There is another interesting navigation approach that utilizes the theory of physical diffusion to handle the uncertain routing environment for robot (Stopp and Riethmuller 1995).

Providing flexible navigation path to robot is indispensable for the emergency routing, as the previous generated path plan could be unfeasible during emergency development. One option is to introduce the level-of-detail idea into the robot grid navigation, and the robot could receive both a nearly-optimized path and a minimum routing cost of computing resource (Figure 2) (Hornung and Bennewitz 2012). Another option is to produce a mixed navigation route, which provides path segments in a topological graph form in the safe area and path segments in metric description in the hazard spreading area (Thrun and Bücken 1996, Konolige et al 2011).

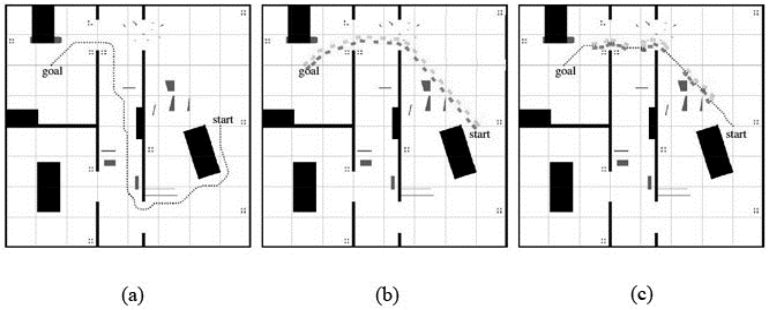


Figure 2: (a) A grid-based optimized path for the experiment area; (b) a footstep path for the same area; (c) an adaptive level-of-detail path for the same area (from the work of Hornung and Bennewitz 2012).

The context-related social costs concerned by human beings are also crucial to allow the robot working in an emergency scenes with people activity like fireman and evacuating people (Kruse et al 2012). Therefore, we have to analyze the human behavior in depth, such as people would reduce the velocity of movement instead of adapting path when possible collision among them would happen. Only with this knowledge robots could predict the next movement of human and avoid collision with a move efficient alternative path.

There also exist approaches that consider the introduction of 3D voxel grids to improve the robot navigation performance. These efforts enable the robot to function properly in an emergency scene with many irregular 3D obstacles (Marder-Eppstein et al 2010, Kläß et al 2012). In these solutions, the voxel map could be provided by committing a ray-surfel intersection detection algorithm on the 3D environment (Figure 3a, b).

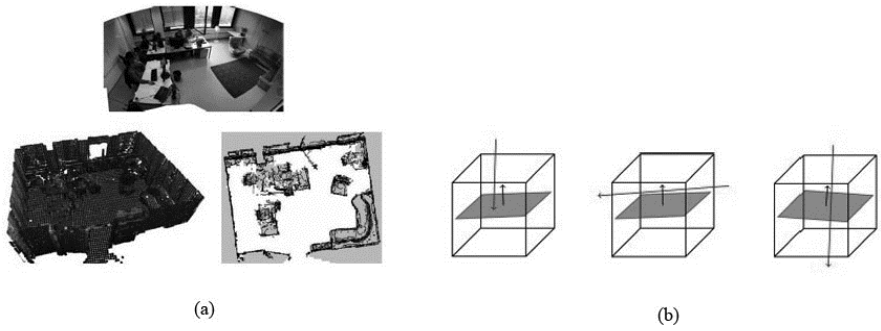


Figure 3: (a) Voxel and 2D occupancy grid demonstration for an office; (b) three typical scenes of voxel occupancy by detecting the relationship between its passing ray and containing surfel (from the work of Kläß et al 2012).

When the hazard covers the space surrounding the building, we have to supply the robot with the outdoor navigation information. Thus, the robot grid navigation should also consider several traversability-related elements for robot moving on rough outdoor terrains (Chilian and Hirschmuller 2009, Neuhaus et al 2009). And we have to evaluate the DEM data from the point of the degree of danger for robot movement, which is a weighted sum of the slope value, roughness value and step height value in the environment (Figure 4).

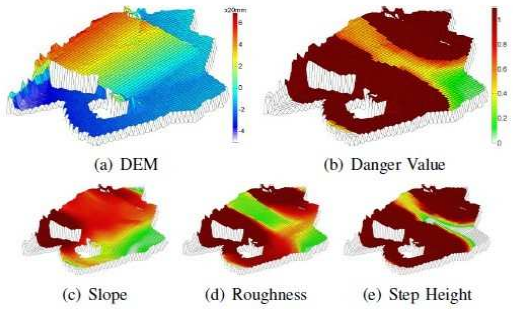


Figure 4: (a) DEM of the experiment area; (b-e) danger value and its composing elements value for the example area
(from the work of Chilian and Hirschmuller 2009)

1.2 Computer game and simulation of human movement approach

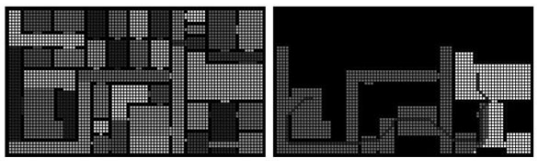
Besides the grid navigation application in robot field, there also exists a major grid navigation developing approach in the field of computer game and simulation for human movement. These research contributions could be utilized to build the virtual reality training system for fire brigade by using 3D gaming technology or to analyze the evacuation routing plan by executing an emergency simulation program for specific building.

This approach has many similarities and differences with the robot navigation approach and human navigation approach. On the one hand, during the simulation or game playing, because of human motion simulated nature, the agents or game characters could move more like real human than robots. For example, the agents or characters can climb up the low obstacles or even crawl through the wholes on walls if allowed. On the other hand, all these moving ability and the collision avoidance have to be explicitly defined during the program design process, for the activities of simulated agent or animated character are totally controlled by corresponding codes. Furthermore, the proper solution for changing between known environment and unknown environment is also appreciated in this approach. It is common that in an emergency simulation a former passable path will become unfeasible to use, when an expected fires appears.

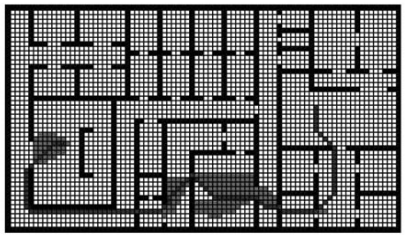
A typical research topic in this field is to project all the obstacles of the animated scene to a 2D bitmap to accelerate the process of forming path plan (Kuffner 1998). But this method lacks many other important navigation elements in emer-

gency simulation, such as the simulated vision and character movement along Z axis.

The game map research contributions could also be taken to improve the path-finding efficiency on emergency routing maps (Björnsson and Halldórsson 2006). We can use both the research fruit along this trend, such as the "dead-end" heuristic algorithm and the "gateway" heuristic algorithm. The first algorithm eliminates the map regions not used for the specific routing operation before executing path-finding; the second algorithm introduces connecting areas between separate map regions to reduce the computing cost of routing (Figure 5). Besides improving the routing algorithms, the introduction of hierarchical data structure to large scale grid maps is also required in emergency routing (Botea et al 2004). Because using multi-level indexes for the large grid map could minimize the path-finding area, and accelerate the routing speed for specific request.



(a)



(b)

Figure 5: (a) (b) Using dead-end heuristic algorithm and gateway heuristic algorithm for the same navigation task on a game map (from the work of Björnsson and Halldórsson 2006).

To mimic the human action in the emergency scene, committing human motion simulation is also crucial (Bandi and Thalmann 1998). In order to do this, we have to discuss many important topics affecting motion simulation for humans, such as the "forbidden region" and borders of holes in the navigation simulation (Figure 6). More important, we have to clearly formulate why some path results generated without considering these restricted areas are not feasible under the complex 3D emergency situation.

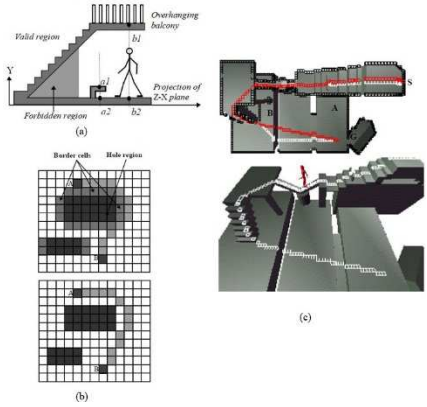


Figure 6: (a) Multiple evaluation elements in human navigation; (b) the effect of hole regions and its border cells in navigation; (c) generating and smoothing path considering these elements(from the work of Bandi and Thalmann 1998).

When there are restricted area for movement in the emergency environment like one-direction doors and corridors, we also have to evaluate the influence of these guidance fields into the crowd simulation under emergency (Patil et al. 2011). Therefore, every agent should be given a specific evacuation path by considering both the guidance field effect and crowd effect in the simulation (Figure 7).

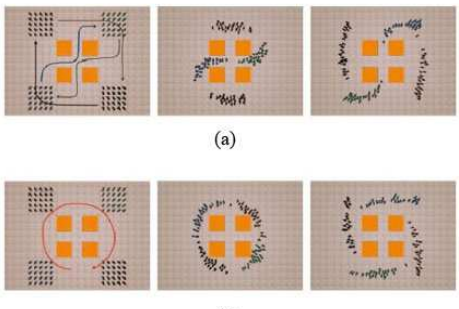


Figure 7: (a) Crowds movement with each group of agents assigned different guidance fields; (b) the movement with all groups of crowds having a same global guidance field (from the work of Patil et al 2011).

1.3 Indoor and outdoor navigation for human approach

As is well known, human are intelligent and able to solve the navigation problem more easily than robots or simulated agents. For example, people can fast change kinematic posture according to the dynamic routing situation, such as jumping over unexpected ground obstacles without reducing the moving speed. Under most

situations, all these actions are only feasible for human body instead of robots and simulated agents. Moreover, people can also adapt their route flexibly according to the changing environment. For example, they can easily perceive which route will lead to a dead end with the emergency development and quickly abandon this route, compared to the robots or simulation program searching to the dead end and then turning back.

With a unique intelligent and kinematic ability, people usually only need crucial path information like significant directional change between path segments to adjust their map in mind and solve all the unexpected problems along movement by their own. Nevertheless, this does not mean we could ignore the requirements from some special groups of people, such as blind people and wheelchair using people.

Public buildings like supermarket and office draw attention of the navigation researchers. There is a navigation solution for supermarket that could be used to implement the emergency evacuation guide. It utilizes a grid map of the supermarket and user positions located by WiFi signal strength to finish the routing job, and takes a handset to guide users with voice instructions during the movement (Bhattacharya et al 2011). For the emergency evacuation in the office, we could use a 3D-to-2D projection to receive the floor grid plan, and applied the context-relative searching technology to construct the optimized path and simplify the preliminary path result (Lyardet et al 2006).

Besides the 2D-projection navigation solution, we should also introduce the 3D object to indoor emergency navigation to more accurately describe the route environment, and receive an evacuation path by considering the 3D shape of obstacles. The usage of virtual 3D bricks originated from the famous toy vendor "LEGO" may be sounding to properly organize the indoor navigation space(Figure 8) (Yuan and Schneider 2010). Although this model is successful on introducing the effect of width and height of user into navigation consideration, it still has some limitations on providing workable moving plans for disabled people.

When emergency spreads to the building surrounding area, the navigation assistant for people in large outdoor space is also necessary. Unlike the limited space of the indoor environment, the outdoor space normally has a larger spatial coverage. Therefore, how to efficiently subdivide the outdoor space is crucial. For navigation on a middle spatial scale, Bemmelen et al. provided an extended raster approach to finish the navigation tasks for cross-country movement (Bemmelen et al 1993). This method abandons the usage of center node to represent each raster cell during the path-finding process and received a better route than classical solution (Figure 9). For navigation on a global scale, Stefanakis and Kavouras utilize square grids or triangular grids in tessellations to solve the path-finding problems (Stefanakis and Kavouras 1995). The implementation of this solution divides the routing space to a graph containing finite spots, and then initialize each spot with the accumulated moving cost from the start position. Thus, the path-finding problem is translated into a weighted graph searching question.

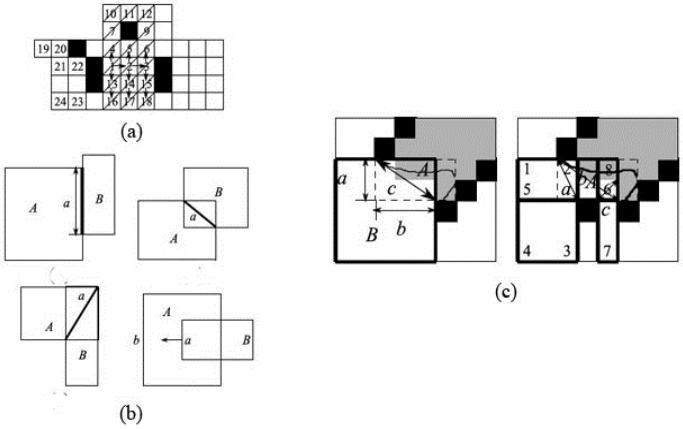


Figure 8: (a) Merging cubes to generate large blocks; (b) four typical types of connector between two blocks; (c) connectors between plane block and stair block without and with the consideration of obstacle effect
(from the work of Yuan and Schneider 2010).

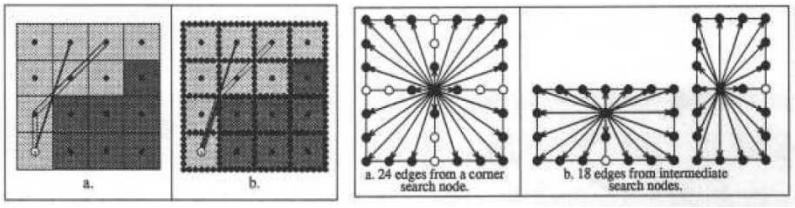


Figure 9: Left is the demonstration of solving path intersection and fusion by using nodes on raster cell sides; right is an illustration of using various number of intermediate nodes during path searching
(from the work of Bemmelen et al 1993).

2 Comparison between the different approaches

The three main application fields of grid navigation have their own features, and this could attribute to the difference of their central research target. The robotics navigation has used the metric grid in the routing process most frequently, because robot needs to periodically update the routing environment data and control the body to follow the free space to avoid collisions with obstacles. The grid navigation of computer game and simulation for human movement also needs a fine grid subdivision of the environment to avoid obstacles. Thus, by using grid the agents or characters in programs will behave more like humans to change their route, when possible collision would happen.

Whilst the application pattern of grid in the field of indoor and outdoor navigation for people are quite different from the two previous fields. The reason is that people naturally have the ability to handle the posture control and collision avoidance with ease. Thus they only need a coarse route guidance, which could provide key information along the optimized path. Therefore, the provided route for people only need to cover the important path segment changes like turnings of route.

Besides the different research target for three main fields, there are many other differences existing on spatial scale, route accuracy, human-based optimization and interactivity between the navigation and dynamic environments. The divergence of three fields is likely to continue existing.

Although three fields differ significantly by nature, they can also share same advanced technologies for grid navigation in emergency routing. For example, with the intention to behave more like human, the robotics research and simulation research tend to introduce the social cost field of humans in their navigation process; the navigation for human also tends to evaluate the step limitations of blind people or wheelchair users, which are commonly considered in the robotics and simulation navigation research.

3 Applicability for emergency response

The current approaches of grid navigation are successful on addressing many path-finding problems in the robot field, simulation field and human navigation field. Nevertheless, there is still room for improvement of grid navigation to the emergency response. According to our understanding, there exist two main issues for applying current grid navigation approaches in emergency response.

The *first issue* is the insufficient research of current grid navigations to meet the dynamic demand of path-finding in changing environments. We have observed that the current approaches by robotics research applied a preliminary solution to consider several dynamic routing restrictions in the environment, such as a simple changeable occupancy attribute of the grid (Stopp and Riethmuller 1995, Thrun and Bücken 1996, Saitoh et al 2009, Hornung and Bennewitz 2012). Nevertheless, a large amount of these solutions do not properly handle the all dynamic element in emergency routing, for example quickly changing environments as the activity of people or obstacles quickly moved by wind waters, etc. For example, during the robot navigation if a person currently stands in one grid and soon move to another grid, should we assign the two related grids with free attribute or occupied attribute? Besides the insufficient consideration of fast moving obstacles, the research focuses on the static state of restricted regions in the surrounding environment. For this reason, the “update” meaning for routing environment generally equals to reset new cost values for grids that are blocked by obstacles or just around the corner in the previous environment scanning (Stopp and Riethmuller 1995, Marder-Eppstein et al 2010, Hornung and Bennewitz 2012). Thus these solutions could not face the routing problems in changing-state environment, such as a scene with the increasing impassable area caused by the fire spreading in buildings.

What can be learned from the analysis of the inefficiency of path-finding solutions under dynamic emergency situations is that the consideration of multiple changing elements in the navigation process is required. According to our view, we have to add both the local variable navigation element like people activity and global variable navigation element like emergency spreading in the routing environment. Thus, we have to introduce a modifiable moving cost that will place a dynamic weight on route evaluation and produce a flexible route result, which could update path segments with the emergency development. Furthermore, according to the non-navigation-expert feature of most emergency responders, this dynamic path result also has to be produced by adapting the formerly-generated optimized path instead of directly re-planning a whole new path, when the previous route is not feasible (Kruse et al 2012).

The *second issue*, which draws attention of the grid navigation research for emergency response, is how grid navigation could use efficient data structures to hold the routing data generated by scanners from the real 3D world. Due to that the complex 3D world could bring a large volume of navigation data. The solution for this issue may cover two key topics. They are the usage of 3D hierarchical data structure and a promising subdivision method of the routing environment data.

In our opinion, the introduction of 3D hierarchical data structure could provide us with a more efficient organization for routing data. Unfortunately, mere preliminary structures for 3D grid data organization in navigation are observed (Neuhaus et al 2009, Marder-Eppstein et al 2010, Kläß et al 2012). We believe that a promising 3D hierarchical data structure should be neither a simple array to hold the accessible state of voxels, nor an oversize data object to store more gird attributes than navigation need. This is because an array could only keep over-simplified occupancy information. And the usage of a data object with non-navigation grid information like geometric representation would probably bring a significant increase on storage space consumption. Therefore, what we suggest is a data structure that could hold both the position of each grid and a proper amount of additional route-related information like the degree of traversability in every grid.

The efficient organization of the 3D routing data also contains the proper subdivision of the routing scene. After a careful study of the current works, we have perceived that the word “subdivision” really has two meanings in the grid navigation (Bemmelen et al 1993, Stefanakis and Kavouras 1995, Thrun and Bücken 1996, Botea et al 2004, Björnsson and Halldórsson 2006; Lyardet et al 2006, Yuan and Schneider 2010). The first meaning is to tessellate the whole routing environment with specific types of grid, such as triangles and squares; and the second meaning is to aggregate the tessellation result of the first level to generate a spatial index. Only a very limited number of approaches implement the voxel tessellation of 3D environment (Bandi and Thalmann 1998, Yuan and Schneider 2010), and no mature solution for efficiently organizing large number of 3D grids into spatial indexes are observed.

We believe the quality of research on these two key topics directly determines the success for the future development of the grid navigation for emergency routing. Thus we try to propose three promising future research topics to overcome these limitations in Table 1.

Table 1: Promising solutions to cover the gaps in current grid navigation development.

Limitations of current approaches	Solutions		
	Dynamic path-finding method	Hierarchical 3D data structures	Flexible subdivision method of the environment
Dynamic routing environment	Need	Probably need	Probably need
Large volume of 3D grid data	Unknown	Need	Need

There are still more topics that needs to be covered in order to allow the navigation application to be operational under emergency situation. For example, how to provide the emergency responders like fireman with fast navigation data support? To answer this question, firstly we may have to locate the position of fireman, and secondly fetch the specific amount of the navigation information to this fireman to finish search and rescue task. Another issue is how to re-discover the former known environment with hazard spreading like a building floor being filled with fires and plume. Under this situation, the fireman may need some portable sensors to update the existing grid map in order to search for survivors (Ramirez et al 2009).

4 Conclusion and future work

The distinctions in research target and application field finally determine the different developing trend of the grid navigation in the robotics, computer simulation and navigation guide for human. Nevertheless, they still can face same bottlenecks when applied for indoor navigation in case of emergencies. What we believe is that they will exchange some key technologies and keep their unique features in such a way that the emergency routing will take benefits from all of them.

Applied for emergency response grid navigation will need to consider larger and more complex environments as in real cities. This implies that approaches for grid navigation should consider several additional aspects:

- hierarchical 3D data structures to organize grid. The grid in whole building may become very complex and will require a sort of 3D levels-of-detail approach for fast computation;
- Subdivision method for complex routing environment. Complex buildings with many obstacles will require a dedicated method for surface gridding.

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Part III: Best Practices

i-Bridge: from Innovation to Added Value in Crisis Management

Rob Boots[1] and Relinde van Bladel[2]

[1]IVENT, Ministry of Defence, P.O. Box 90822, MPC58A, 2509 LV The Hague, The Netherlands, e.mail: RFHJ Boots@mindef.nl

[2]Innovatie in Veiligheid, The Netherlands,
e.mail: Relinde@innovatieinveiligheid.nl

Abstract

i-Bridge is a Dutch investigation program offering an innovative platform for public safety organizations to test and evaluate new technologies. During the third phase of the i-Bridge project several new technologies have been integrated as Proof-of-Concepts on the i-Bridge platform and tested and evaluated by public safety organizations on their added value. By integrating and combining these new technologies the common operational picture and shared situational awareness of the disaster or crisis are improved, allowing for more effective and more efficient crisis management. The Proof-of-Concepts were built by MOD NL, NVBR, Geodan, Vigilance, Nieuwland, Compumatica, Layar, IGI Group, Talkto, RadioAccess, Intemo, Citygis, Wandy, Fox-IT and Netage.

1 Introduction

In 2008 the Dutch government initiated social innovation programs in the fields of water management, safety and security, health care and energy. The goal of the programmes was solving major social issues. In the safety and security program the input of know-how, innovation and entrepreneurship for solving social issues was the central subject. i-Bridge started as a collaboration between the Dutch Min-

istry of Defene and the Dutch Ministry of the Interior (Now: Ministry of Security and Justice), within the Civil - Defense cooperation Program.

i-Bridge is based on the concept that communication components can be linked in various combinations using internet protocols. By using internet protocols secure, real-time collaboration and logging in becomes possible. Internet protocols also solve a number of bottlenecks, as identified in the roadmap of the Social Innovation Agenda Safety, including the build-up of an integrated common operational picture.

The objective of i-Bridge is threefold: showing innovations in the public safety domain, involving (NL) industry in these innovations and finding a practical use that may lead to possible industrial activity.

Between 2008 and 2012 i-Bridge started more than 10 projects that all met these criteria and delivered Proof-of-Concepts.

The Minister of Economic Affairs, Maria van der Hoeven, complimented the i-Bridge project for being successful in bringing different safety organizations and industry partners together to collaborate on innovations. This paper contemplates on the reasons for this success.

First the i-Bridge program is described. After that we discuss the concept and finally the i-Bridge projects. Lastly we elaborate on the role of location and building a common operational picture within the i-Bridge concept.

2 i-Bridge concept and architecture

In 2005 the Advisory Committee Coordination IT Disaster Management published a report on the status of information management in the public safety sector. The report described a fragmented and greatly compartmentalised organisation, poor national direction and funding. Information was not shared in an efficient manner and quality of the information was poor. The report was a stimulus to improve information management and to work towards a common operational picture. Central to this was the netcentric philosophy as used by the Ministry of Defence. It is against this background that the first Civil Military Collaboration and later the Intensification of this Civil Military Collaboration were realised in a series of programmes. i-Bridge became part of these programmes.

The goal of the i-Bridge program was to improve crisis management by developing, testing and evaluating new (IT) technologies on their usability and added value. i-Bridge offers a platform to the security sector with the possibility to test and evaluate these new (IT) technologies. The focus of i-Bridge is on the Safety Regions, fire brigade, police, (para-)medical services and municipalities. These organizations are in a constant struggle how they get the right information to the right people and how to integrate new functionality with existing platforms. i-Bridge brings representatives from these disciplines, with their specific needs and questions, and industry partners, with their new and innovative technologies, together (Figure 1). In this way i-Bridge is an intermediary for demand and supply

and supports the translation from operational requirements of first responders into functionality by using new technologies.

Innovations are field tested, which means that:

- innovations are used by one or more safety regions in a field exercise. Usability, usefulness and added value for crisis management and daily use are evaluated;.
- interoperability of a new product or technology with the existing platform is being tested. Existing functionality can be expanded using new technologies.

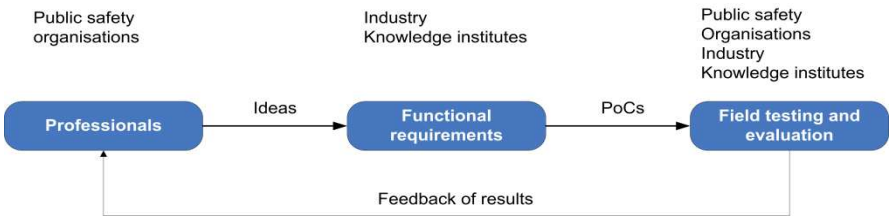

Figure 1: Generic i-Bridge process.

The most important factor of the i-Bridge program is the availability of the i-Bridge platform where all innovations are integrated.

The i-Bridge platform is mainly built with Commercial-Of-The-Shelf (COTS) software and re-uses software for specific Proof-of-Concepts. Principally the i-Bridge platform is an empty box, which is capable of handling a variety of IT standards. In this manner the i-Bridge platform is interoperable with a variety of platforms and systems and is used as a broker between these platforms and systems. The i-Bridge platform can be re-used in different contexts. The basic technical architecture is depicted in Figure 2 below.

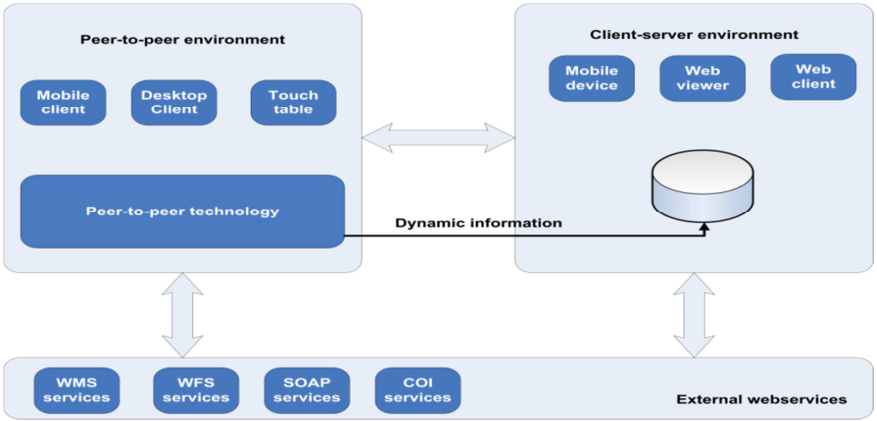

Figure 2: Basic architecture of the i-Bridge platform.

A control room may use an Emergency Management System (EMS) to conjoin operations of sectors, and multiple cities (multiple control rooms) can be joined to facilitate joint command, communications and linked data supporting decision-making when larger or more complex incidents can benefit from interoperability.

3 i-Bridge 1.0 and 2.0

At first the Proof-of-Concept i-Bridge 1.0 was developed. During demonstrations and exercises (Combined Endeavour 2009, Voyager 2007 and other exercises) it was proved that the five core functionalities that are required to act effectively and in a coordinated way during a disaster, both individually and in every required combination, can be supported with the i-Bridge concept.

These five core functionalities are:

- (ad hoc) collaboration. Concerns secure ad hoc online collaboration;
- reporting. Concerns activities with regard to logging and scenario plotting;
- geo harmonisation. Concerns synchronising geographic information in various forms and applying this information again for each context;
- voice harmonisation. Concerns Voice Interoperability, whereby all forms of speech are converted into IP and harmonised with IP through software;
- crypto harmonisation or access management and protection of information. This makes it possible to connect different domains under predefined conditions. Open and closed information can be added to the process and analysed and feedback can take place to the participants on the right security level.

In i-Bridge 2.0 these core functionalities and mutual links and integrations were further extended. For instance the Proof-of-Concepts for an ad hoc data infrastructure and an independent GSM network were tested and evaluated for their added value on ad hoc collaboration. During the multi-national exercise Combined Endeavour in 2009 these developments were shown for the first time in an exercise where the civil military collaboration was tested.

4 i-Bridge 3.0

During the third and last phase of the i-Bridge program the following (IT) technologies are made available as Proof-of-Concepts and integrated on the platform:

1. cloud computing;
2. ad hoc (data) infrastructure for exchanging information;
3. secure collaboration;
4. crowd sourcing;
5. intelligent maps;
6. wildfire modeling;
7. unmanned aerial vehicles;
8. personal sensor and location system;

9. augmented reality.

The sections below briefly describe these innovations. In detail the different Proof-of-Concepts of the used technologies, the tests and evaluations are described in the i-Bridge 3.0 booklet distributed at the Gi4DM conference 2012.

Ad 1: Cloud computing. The definitions, obstacles and advantages of cloud computing have been described in many papers (e.g. Armbrust et al 2010). In the case of i-Bridge the goal of the cloud computing project is to research the benefits of cloud computing for disaster management. The main goal is to be independent of the organizational infrastructure. Second goal is to test benefits of cloud computing, like scalability.

The use case for this innovation is twofold. Firstly a crisis center prefers not to be dependent on one location, where all IT infrastructure is implemented. Relocation, even cross-border, of the crisis center during a crisis is a realistic scenario. The cloud offers a secure environment where all the necessary data is available. Secondly a cloud infrastructure has the ability to scale in case of escalation of the crisis. Use of a cloud environment is not only a technological innovation, but also a financial innovation since cloud is pay-per-use.

Cloud computing could be deployed in the cloud or in a private environment, e.g. in a container containing mobile cloud servers. The advantage of the latter is that the cloud can be moved to wherever it is needed and connected to the network available. This network can even be an ad hoc network.

Ad 2: ad hoc (data) infrastructure for exchanging information. Fighting wild fires is one of the core tasks of the local fire brigades. The operational fire fighters are dependent on existing communication networks, like UMTS and 3G, for sharing information. The range of these networks is often poor in the areas vulnerable for wild fires. And in case of a crisis these networks might get overloaded or malfunctioning. In these situations the fire brigades need guaranteed communication networks.

In cooperation with the safety region Gelderland-Midden (VGGM) an ad hoc wireless mesh routing network has been developed based on the open source Optimized Link State Routing Protocol[7] (OLSR). The i-Bridge adhoc router running the OLSR software is installed in the fire trucks. The adhoc router has several possibilities to communicate with the back bone and with other adhoc routers. Adhoc routers within range of each other form a mesh network and exchange relevant information. A communication truck with satellite communication and present nearby the incident is the node to the crisis center.

This ad hoc network guarantees real-time information sharing providing a common operational picture and situational awareness. The ad hoc network is tested and evaluated during a wild fire exercise and in an urban environment.

Ad 3: Secure collaboration using the “Telestick”. While the cloud computing solution can solve the accessibility to crisis management systems from outside there is still the need for a secure access to the cloud systems or the internal network when working remote. The Dutch Ministry of Defence developed a flexible

[7] See: http://www.olsr.org

and secure solution for getting access to the cloud or internal systems called "Telestick".

The current secure solutions for remote access at the Ministry of Defence are very expensive to provide to all employees of the Ministry. Beside this there is a growing need to access information any time, any place and with any device.

The "Telestick" is a solution using open source software on a USB stick to establish a connection with the network of the Ministry of Defence or the network of the safety regions. This connection is highly secured and approved by the Security Authority of the Ministry of Defence.

The open source character of the innovation potentially allows for an unlimited amount of users to connect in a secure and cost-effective way to the network of their public safety organization.

Ad 4: Crowd Sourcing. During incidents and disasters people use social media like Twitter and Facebook to exchange information. In the Proof-of-Concept Crowd Sourcing, functionality is developed and integrated with the i-Bridge platform to filter information from social media. Two types of information gathering can be distinguished. First unstructured information, like Twitter, and second structured information, through platforms like Ushahidi[8].

Goal of the Proof-of-Concept is a common operational picture based on information from the public and from first responders. Filtering and analyzing tweets give crisis managers an idea of the opinion and feelings of the public. Information from the public can be used in the primary crisis management process or as an input for crisis communication.

Ad 5: Intelligent Maps. Maps and other location information are essential for effective crisis management (ref maps). Maps offer a quick overview of the situation, e.g. the location of the incident, the surroundings and deployment of first responders.

The goal of this Proof-of-Concept is to provide the first responders with the right information. Using techniques and standards like semantic web (Xu and Zlatanova 2007) and the Resource Description Framework (RDF) it is possible to present only the necessary information aligned with location, context and role of the first responder. For example if an incident occurs in a tunnel, information will be shown about current and expected traffic, escape routes, safety systems, etc.

Ad 6: Wild Fire Modeling. Modeling and simulating the progress of wildfire is important for effective firefighting and the safety of first responders and citizens. Together with The Netherlands Institute for Safety (NIFV) and two safety regions a fire behavior model has been integrated on the i-Bridge platform. The software used by the NIFV is based on the FARSITE[9] software.

Fire behavior models were already available but difficult to use by first responders and not integrated with other crisis management functionalities. Based on research from NIFV and Efectis a cloud service has been developed which has been integrated with the i-Bridge platform. The system uses a detailed national topographical dataset (Top10NL) as input for the modeling together with parame-

[8] See: http://www.ushahidi.com

[9] See: http://www.firemodels.org/index.php/farsite-introduction

ters specific for Dutch situations. The result of the model can be visualized in the crisis management functionality and first responders can act upon the outcome.

4.1 Unmanned aerial vehicles

Ad 7: Unmanned aerial vehicles. A so-called helicopter view is essential for safety regions and first responders to have an overview of the situation and operate accordingly. In some cases literally a helicopter view is needed to get an overview. Using a manned helicopter is expensive and time-consuming. Unmanned aerial vehicles (UAVs) can be deployed on a very short notice, are less expensive and flexible. The goal of this Proof-of-Concept is to test and evaluate if the use of UAVs in crisis management proves added value. The collection and distribution of the still and motion imagery is based on a series of NATO standards as used within the MAJIIC program (Multi-sensor Aerospace-ground Joint ISR Interoperability Coalition).

Still motion imagery gives a real-time view on the situation and the deployment of the first responders. Combined with maps real-time imagery is a valuable source for improving decision making.

Ad 8: Personal; sensor and location system. Fire fighters are exposed to extreme risk when entering a building on fire. If the building collapses or the fire fighters are not able to leave the building a commander wants to know where his men are.

On the other side sensors are getting smaller and it is possible to carry body sensors, which communicate with for example ad hoc routers in vehicles outside a building. In this Proof-of-Concept Chirp Spread Spectrum (CSS) and Ultra-Wide Bband (UWB) sensors are used as a source to determine the location of people in buildings, without mapping the building beforehand. The technology seems also capable of communicating with other body sensors like temperature, oxygen or nitrogen. The location is visualized on the GIS interface of the i-Bridge platform.

Ad 9: Augmented Reality. In the Netherlands approximately one third of the population has a smartphone. In the Proof-of-Concept Augmented Reality new ways to present information to the public and first responders has been tested and evaluated during the cultural festival “Zwarte Cross” in 2011.

The application consists of two applications: a layer in the AR app Layar for citizens and a secured layer in a dedicated AR app from Layar for first responders. The application augments the reality with relevant information for both groups. For citizens visiting the festival this can be the location of toilets, beer booths or emergency exits. For first responders this can be the same, but also the location of other first responders or the location of incidents. The AR app is updated with the latest information from the crisis management system. In case of an incident the AR app for the public can also be used for crowd control.

5 Location

In the past several publications have stressed the importance of geo-information for crisis management and disaster response (NRC 2007, Zlatanova and Fabbri 2009, Brooijmans et al 2009, Neuvel et al 2012).

Geo-information, location and visualization is needed to create a common operational picture, to acquire shared situational awareness and as a means to communicate effectively and efficiently.

In the i-Bridge concept and philosophy geo-information and location plays an important role. Almost all Proof-of-Concepts are integrated on the i-Bridge platform through the aspect of location.

This can be put in a theoretical framework as described by Scholten et al (2009). Scholten et al (2009) describe three different frameworks to use Geo-ICT: geodatabase, geomodel and geomap. Two frameworks have been added: the organizational framework to incorporate the boundary condition and the infrastructural framework supporting the other frameworks. This overall theoretical framework in Figure 3 shows the different frameworks.

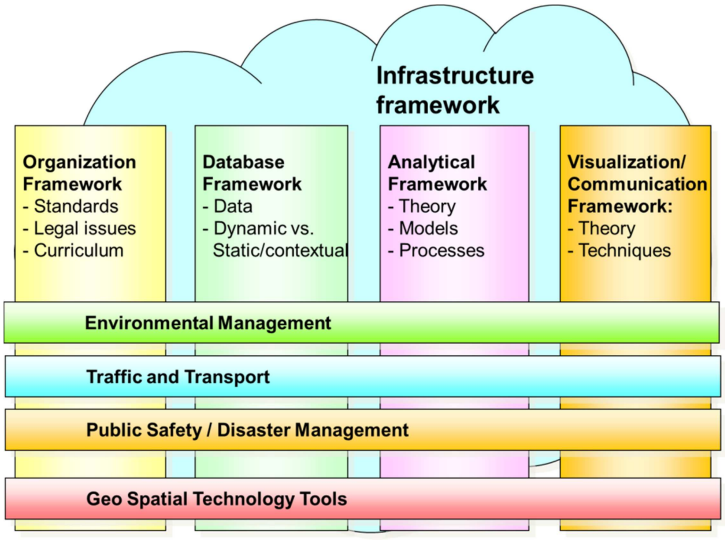

Figure 3: Generic Geo-ICT framework (adapted from Scholten et al 2009).

In Figure 4 the i-Bridge 3.0 Proof-of-Concepts are projected on the theoretical framework from Scholten et al (2009). The i-Bridge Proof-of-Concepts contribute to all aspects of the Geo-ICT framework.

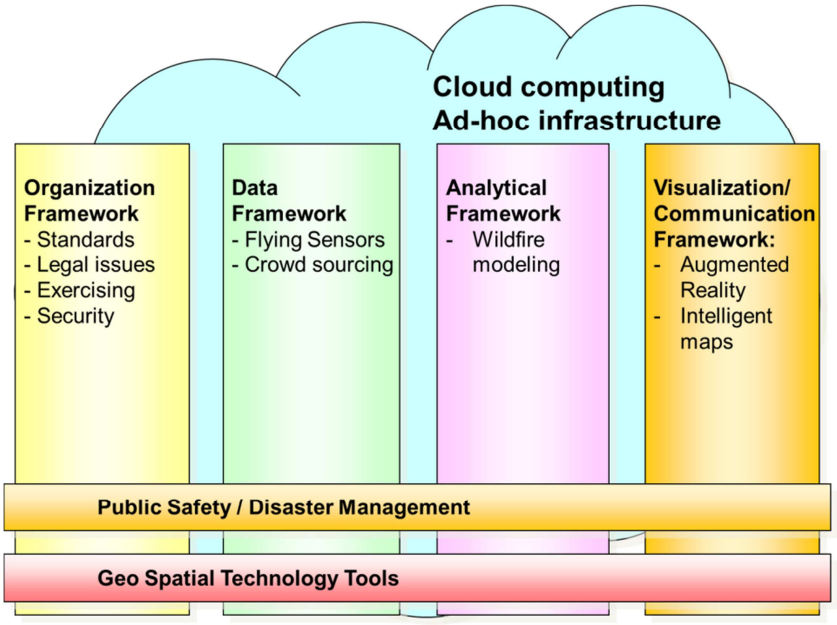

Figure 4: i-Bridge 3.0 Proof-of-Concepts mapped on the generic Geo-ICT framework.

Distribution of information during a crisis or disaster is important for an appropriate emergency response, to ensure that all parties have the same operational picture, that parties can cooperate in a coordinated way and that the public can be kept informed.

The netcentric approach is a theory, a concept and a doctrine to be able to share information to the right persons at the right time. The information flow does not follow the hierarchical lines, but information is distributed to all actors involved.

The i-Bridge platform has the ability to test and evaluate the netcentric approach. This is supported by the implementation of a peer-to-peer network in combination with a client-server network. Better information sharing leads to better shared situational understanding, which leads to better decisions and better actions.

6 Conclusions

The i-Bridge program has been successful in bringing safety organization, industry partners and science together in designing Proof-of-Concepts that could be tested and evaluated for their added value in crisis management or daily work of the safety organizations.

The concept of collecting ideas from operational experts, using and combining innovative technologies as Proof-of-Concepts and testing and evaluating the added value by public safety organizations using scientific approaches has proved to be useful. The Proof-of-Concepts are integrated on the i-Bridge platform and made available to first responders for testing and evaluating their added value for crisis management but also for their daily work. In this way the added value of innovative technology can be tested and evaluated in a relatively short time.

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Situational Awareness and Crisis Management Systems: can Situational Awareness be improved, using a Different Textual and Spatial Visualisation in Crisis Management Systems?

Jaap Smit

Safety Region IJsselland, Zeven Alleetjes 1, 8011CV Zwolle, The Netherlands,
e.mail: J.Smit@veiligheidsregio-ijsselland.nl

Abstract

Micha R. Endsley (1995) formulates a generally accepted theory of Situational Awareness, SA, with three levels of SA: Perception, Comprehension, and Projection. The SA-SWORD method (SA-Subjective Workload Dominance) of Vidulich and Hughes (1991) is used, to measure differences in situational awareness for the three levels of SA. This method is used for different visualisations of textual and geospatial information in a Crisis Management System. First, the visualisation techniques of Crisis Management Systems currently in use in the Netherlands are aggregated to produce a standard visualisation technique. Next, based on insights from scientific literature regarding the cognitive processing of visualisation, an improved visualisation is developed. Observers judged the difference in situational awareness for both visualisations and for separated details of these visualisations. The results are recommendations regarding the improvement of textual and spatial visualisation in a Crisis Management System. Professionals in the field of crisis and disaster management tested the on-line survey. LinkedIn-groups with experienced workers in the field of crisis and disaster management and in the field of geographic information systems, GISs, are currently completing the on-line survey; the first 100 completed surveys have been analysed for this paper; the overall results will be presented at the 8th International Conference on Geo-information for Disaster Management in December 2012. Results are: 1) SA is important for crisis management systems, 2) measuring of the difference in Situational Awareness for visualisation of textual and spatial information in crisis management systems is possible, 3) the results of the first one hundred reactions are; out of ten examples of textual and spatial improvement, eight are real improvements, one is

only partly an improvement, and one example is no improvement of SA. The central question “Can Situational Awareness be improved using a different textual and spatial visualisation in crisis management systems?” is thereby affirmed. Based on closer analysis of the textual and visual designs, specific recommendations are made regarding how current Crisis Management Systems can be improved to facilitate better situational awareness.

1 Introduction

This paper is part of a Master in Science dissertation in Geographic Information Science at the VU University Amsterdam. The study is still ongoing so this paper is limited to the description of the research design and the evaluation of the first one hundred completed surveys.

1.1 Organisation of crisis and disaster management

Crisis and disaster management in the Netherlands is a multidisciplinary job for a multi-level organization. The emergency services are the Fire and Police departments, (Para-) Medical aid, and the Municipalities. The response to large incident starts at the incident location, with the units of the emergency services coordinated by the COmmando Plaats Incident (COPI), or Command Post Incident Location, offering relief in the source area. To support this, a Regional Operational Team, ROT, located at the Regional Coordination Centre, controls the area affected beyond the initial site of impact, in anticipation of the decisions taken by the Municipal Policy Team. In case of an incident extending beyond the borders of a single municipality, a Regional Policy Team is also active.

1.2 Required information

All these teams require access to information about the incident location, the object(s) involved, the nature of the incident, its development, the dangers and risks, the people that are likely to be affected, and the existing, possible, and desirable actions to handle the incident. This information must be relevant, accurate, up to date, complete and available in an appropriate format to all those involved in managing the incident. To share this information, the emergency services use a Crisis Management System. These systems provide a textual and a geospatial visualisation of the information.

1.3 Crisis Management Systems

Currently (October 2012), there are different Crisis Management Systems in use by safety regions in the Netherlands; one is used in many safety regions and five regions have their own system. By project, a National Crisis Management System replaces the regional systems.

1.4 Problem definition, hypothesis, and methods

The central question of the thesis is "Can Situational Awareness be improved using a different textual and spatial visualisation in crisis management systems?" The thesis focuses on crisis and disaster management in the Netherlands and on the situational awareness, SA, of an individual person. Examples of textual and spatial visualisation fit the level of a Regional Operational Team, (the scope of the study). The following hypotheses are tested:

1. situational awareness is important for crisis management systems;
2. measuring of the difference in Situational Awareness for visualisation textual and spatial information in crisis management systems is possible;
3. better textual and spatial visualisation improves situational awareness.

The used methods are a literature review, interviews, and on-line surveys.

2 Literature review

This review focuses on information management for disaster management, the theory of SA, possibilities to measure SA, textual and spatial visualisation and the interviews. These items are succinctly reported in this paper. More detailed information will be presented during the presentation at the 8th Gi4DM and in the final thesis report.

2.1 Information management for disaster management

Disaster management in the Netherlands used to be a job for the civil defence. In the 1980s, disaster management became a task for the emergency services. Despite the emergence of computers systems at that time, they initially copied the existing methods of using a hand-written 'Situation Report' for text and a 'Situation Plot' on a paper map. This plot existed of drawn symbols, lines and a few coordinates on a plastic sheet overlaying a paper map. Evaluations of these methods during the 2000s revealed that crucial information was either not available or are not shared (ACIR 2005, National Research Council 2007). The Dutch Association for Fire Service Care and Disaster Relief, NVBR, together with the Ministry of Home Affairs, took the initiative to improve the information architecture: Brand-in (NVBR 2006).

During the Gulf War in 1990-1991 the US military developed a doctrine called 'Network Centric Warfare', NCW (Osinga 2003). This network enables the collecting and distributing of operational information to all teams and units. This approach was later adopted for risk and disaster management in the USA and other countries, including the Netherlands. Based on this doctrine, the disaster management teams and units share information by network-centric systems with a distributed infrastructure instead of sharing it in a hierarchical way (Van Capelleveen 2005, Neuvel and Van den Brink 2006, Brooijmans 2008, Neuvel, Scholten and Van den Brink 2010, Scholten and Van der Vlist 2011). A chain with the following links can represent the benefits of NCW: better networks, better information sharing, better-shared understanding, better decisions, better actions, and better effects. In the last years, safety regions in the Netherlands have introduced crisis management systems for network-centric sharing of textual and spatial information between the emergency services and teams.

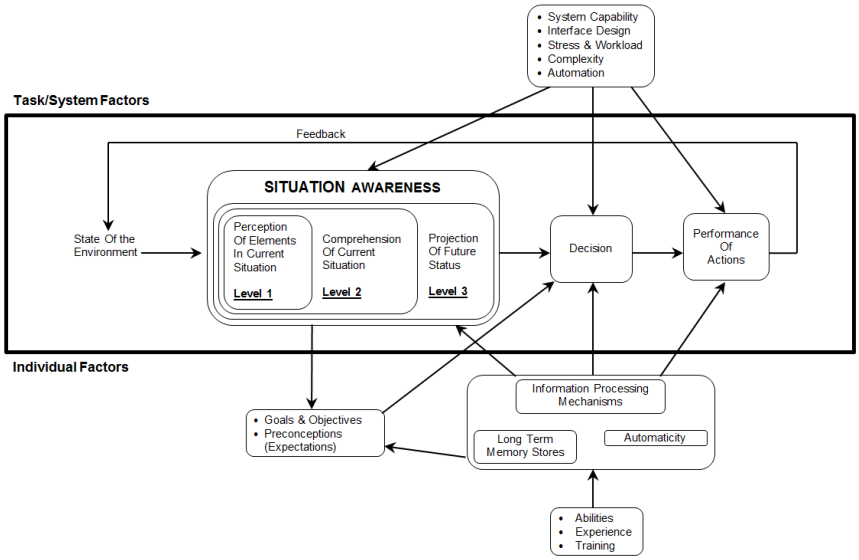

Figure 1: Model of situation awareness in dynamic decision-making (source: Endsley 1995, p. 35).

2.2 Situational awareness

Since the 1980s, SA has developed as a major area of study within human factors research. Mica R. Endsley has defined SA as: "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future" (Endsley 1988, p. 97). This involves the following SA levels: 1) perception or observation, 2) comprehension or understanding and 3) forecasting future situations, see Figure 1. The

theory of Endsley about SA is widely accepted within human factors research (Alfredson 2007).

The model (Endsley 1995) defines Level 1 SA as: 'Perception of the Elements in the Environment'. The decision maker distinguishes the relevant elements in the environment, and its status, attributes, and dynamics. For crisis management: the ROT members must monitor all messages to signal relevant information. Examples are: nearby storage of flammable liquids, an expected explosion and possible vulnerable objects in the affected area. Level 2 SA is 'Comprehension of the Current Situation'. Based on the awareness of the level 1 elements, the decision maker creates, together with other information, a picture of the situation comprehending the meaning and the importance of those elements. For example, when a tanker with liquefied toxic gas is exposed to an open fire, the staff members must be aware of all possible scenarios, just like the effect of inundation of a residential area. Level 3 SA is 'Projection of Future Status'. At the highest level, the decision maker needs skills to translate the properties of the elements into future meaningful situation. For all expected scenarios, timelines must be available for when and where impacts are likely to take place and of what severity. Jones and Endsley investigated the types of SA errors that occur in aviation. Of the errors identified, 76.3% were Level 1 SA errors, 20.3% were Level 2 SA errors, and 3.4% were Level 3 SA errors (1996, p. 507). Figure 1: Model of situation awareness in dynamic decision-making (source: Endsley 1995, p. 35).

It is important to keep in mind that SA is not an active process of seeking information from the environment, but the result of that process. Decision-making and performance are the next steps after SA, so they are not elements of SA. Elements that influence SA are goals and objectives, preconceptions, information processing mechanisms, system capability, interface design, stress and workload, complexity, and automation (Endsley 1995).

Emergency services manage the unexpected disturbances that result from crisis and disasters. Before the teams of those services can make decisions, they need an image and judgement of the actual and the suspected situation. Therefore, the conclusion is, SA is an important aspect of crisis and disaster management.

2.3 Measurement of SA

The SA-model is very helpful because a lot of methods have been developed for its measurement, methods that can be divided into following groups:

1) Measurement based on observation of on-going activities
   - 1.a) The process indices, where SA is measured psychophysiological.
   - 1.b) Performance measures, based on the postulates that an appropriate SA was created and it had a beneficial impact on performance.
   - 1.c) Behavioural measures, where some behaviours are the result of more or less appropriate SA.
   - 1.d) Observer rating, where the impartial observer observe the person under study.
2) Direct measurement

2.a) The think aloud technique, where a person tells what he is actually thinking about while performing a task.
2.b) The freezing technique, where queries were addressed during a pause in task execution.
2.c) The real-time probe, where queries were addressed without stopping the on-going activity.

3) Retrospective measurement techniques
3.a) The recall awareness technique, with a questionnaire after the activity.
3.b) The recall situation technique, where the state of the map of a situation at a given time must be rebuilt (Jones 2000, Breton and Rousseau 2003).

Between all those methods only one paired comparison technique is available: SA-SWORD, Situation Awareness Subject Workload Dominance. This self-rating technique does not measure the SA but the difference in SA for different combinations of factors such as display (Vidulich and Hughes 1991, Gieselman and Craig 1998, Jones 2000, Stanton et al 2004). This technique is very easy to learn and use, is useful in any domain, and is very appropriate for comparing different interface designs. Disadvantages of this technique are that it does not provide a direct measure of SA, that there is limited evidence of the use of this technique in scientific literature, and thus limited validation evidence, and that the technique has no underpinning theory (Stanton et al 2005). Gieselman and Craig documented the SA-SWORD to evaluate a panoramic night vision goggle for aircraft (1998). The conclusion is that SA can be measured, just like the difference in SA for paired comparison.

2.4 Textual and spatial visualisation

Today the crisis and disaster management systems used in the Netherlands, exist of two different registrations, one for textual and one for spatial information. Members of crisis management organisations register textual information as free text for a few subjects. Safety regions have not implemented geographic information systems well in their activities, neither for daily use nor for crisis management, and almost no geo-information decision support systems have been adopted. Yet, scientific assessment of trials in which these tools were used demonstrate that the tools can improve the effectiveness of disaster management (Neuvel and Van den Brink 2006, Neuvel, Scholten and Van den Brink 2010, Scholten and Van der Vlist 2011). Because of the lack of practical experience, users of a crisis management system, only plot a limited amount of spatial information. The functionality of some systems is limited to a few colours and patterns, so the available geo-information is not visualised optimally (MacEarchen 1995, Monmonier 1991).

However, because of the implementation of crisis management systems, the awareness of emergency services of the importance of a good spatial visualisation of information is growing. (Successful response starts with a map 2007, Brooijmans 2008, Van Rijk 2009, LCMS 2010).

3 Interview and on-line survey

An element of the research was interviewing professionals working in six safety regions. This interview exists of three parts: a) registering of two different incidents in their crisis management systems according to the given incident descriptions, b) filling out a questionnaire and c) answering general and evaluation questions. The questionnaire was a beta version of the on-line survey, to test and improve this. The interviews and literature study result in a "standard" and an "improved" visualisation of textual and spatial information, used in the on-line survey.

The survey uses the SA-SWORD method (Vidulich and Hughes 1991) for comparing the SA for the three levels of SA. This survey has a standard format of presenting a standard visualisation, 'A', and an improved visualisation, 'B'. The person filling out the survey, has to judge the visualisations for three or six questions with the following rating scale: 1: 'A' is the best, 2: 'A' is better than 'B', 3: 'A' and 'B' are equal, 4: 'B' is better than 'A', and 5: 'B' is the best. The following combinations are tested:

1. an overview with a standard and an improved text visualisation, see Figure 2 and 3;
2. an overview of a standard and a spatial visualisation and improved text and spatial visualisation, see Figure 2, 3, 4, and 5;
3. a standard and an improved text visualisation, for five different text visualisations;
4. a standard and an improved spatial visualisation, for five different spatial visualisations;
5. Repeating of situation 2.

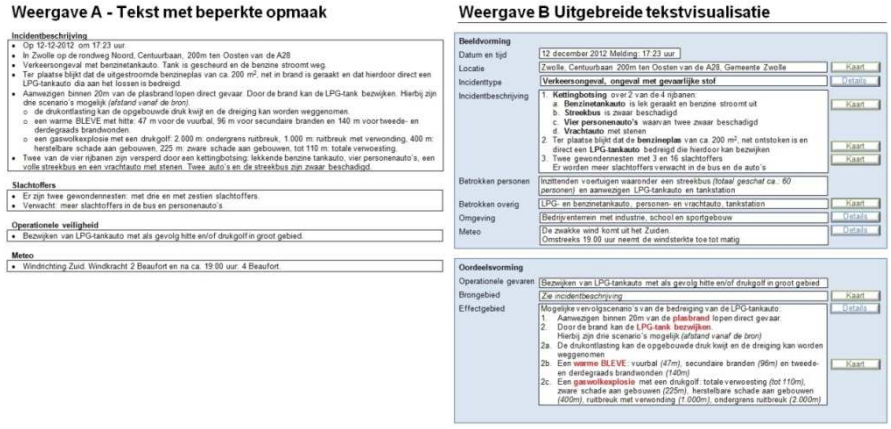

Figure 2: Standard text visualization. Figure 3: Improved text visualisation.

Because a user can overlook elements of the improved visualisation, the different elements of the textual and spatial visualisation improvement are also meas-

ured separately for the three levels of SA, in combinations 3 and 4. To measure the influence, the second situation of the questioner is repeated as combination 5.

The questions used to measure the levels of SA for the different combinations are given in Table 1.

Figure 4: Standard spatial visualization.

Figure 5: Improved spatial visualisation.

Table 1: Questions used for different situations. **Questions / Combinations**	**1**	**2**	**3**	**4**	**5**
1. With which visualisation the information is best observed?	X	X			X
1.1 Which view is the clearest?			X	X	
1.2 At which view the key points are best visible?			X	X	
2. With which visualisation the information is best understood?	X	X			X
2.1 Which view best shows the significance of the information?			X	X	
2.2 With which view can you best interpret the situation?			X	X	
3. With which visualisation the future situation is best projected?	X	X			X
3.1 Which view best shows the current situation that is to occur in the near future?			X	X	
3.2 Which view gives the clearest impression of the future development of the situation?			X	X	

The five textual improvements are:

a) textual information is registered in a form with labels instead of free text for a few subjects with limited layout;
b) important information is visualised in bold text and the most important text in bold red text instead of a plain lay out;
c) data is translated in information for a ROT member instead of data is not translated;
d) the user can consult links next the text, thus allowing him/ her to present more background information;

e) tn the form, the user can consult links next the text, thus allowing him/her to present the related situation on a map, next to the textual visualisation.

The five spatial improvements are:

a) a map with coloured polygons for building blocks, important roads and open water area and with street names and house numbers instead of a large scale map with only lines in one colour;
b) a low contract base map with thematic information instead of a high contract base map with thematic information
c) a roadblock with the visualisation of the blocked roads instead of a roadblock only;
d) a limited amount of affected areas with labels about their meaning instead of many affected areas without labels;
e) a map with a submap with other relevant effect areas instead a single map.

The comparison of the visualisation exists of questions that measure the difference in SA for the three levels of SA. Professionals in the field of crisis and disaster management tested the on-line survey before it was distributed among the target respondents. The online survey was distributed via LinkedIn-groups with experienced workers in the field of crisis and disaster management and in the field of geographic information systems, GISs. Completing the on-line survey requires approximately 30 minutes.

4 Results

A. Situational Awareness is important for crisis management systems.
B. Measuring of the difference in Situational Awareness is possible for visualisation textual and spatial information in crisis management systems.

As the on-line survey is currently (October 2012) still running, only, the first one hundred reactions are evaluated here. All reactions are visualised in graphics. Almost all graphics show a clear preference for visualisation method B. To prove the response on paired comparison is not evenly distributed, the method Chi-squared is used (Bolle, Lenoir and Van Loon 1974). With this method, the probability of all five results of each SA level are equal is calculated.

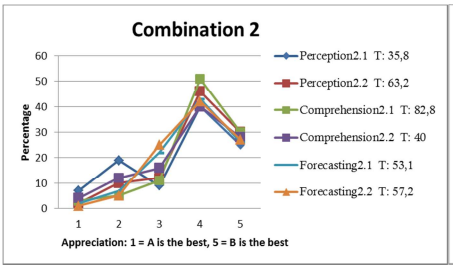

Figure 6: Results of combination 2.

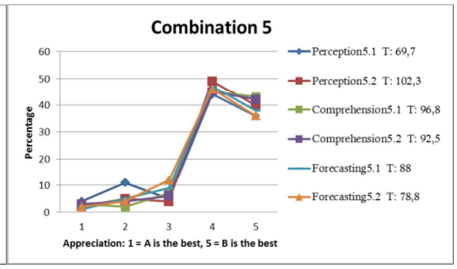

Figure 7: Results of combination 5.

For almost all measures, the probability that they are equally distributed, is lower than 0.001, see Figure 6 and 7 for the results of combination 2 and 5 with the review class, T.

For T > 18.5, the probability of value 1 up to 5, to be equal, is lower than 0.001, for T > 7.78 the probability is lower than 0.1, and for T > 5.39 the probability is lower than 0.25. For the third improvement of text visualization, data versus information on the level of a member of the ROT, the probability of SA level 1 is 0.25 but the SA levels 2 and 3 scored both 0.001, see Figure 8.

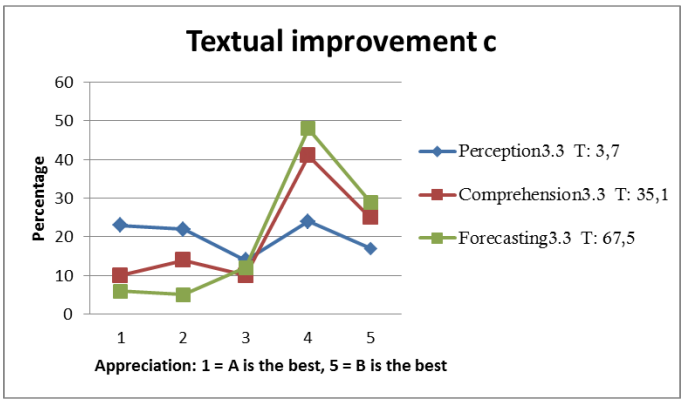

Figure 8: Results of textual improvement c.

Figure 9: High contrast base map.

Figure 10: Low contrast base map.

The second improvement for spatial visualisation (see Figure 9 and 10), scored the lowest for all SA levels with probabilities of: level 1: 0.1, level 2: 0.25 and level 3: 0.25, see Figure 11.

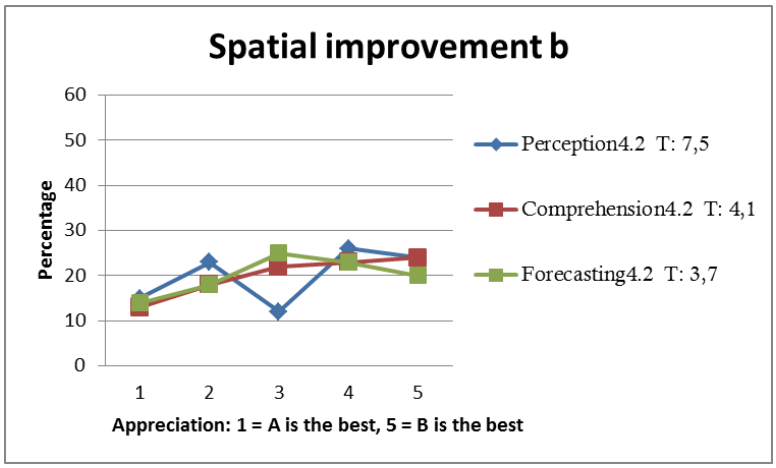

Figure 11: Results of spatial improvement b.

The results indicate that out of the ten improvements, eight are real improvements, one is only a partial improvement and one does not improve the SA.

Therefore, the central problem "Can Situational Awareness be improved using a different textual and spatial visualisation in crisis management systems?" is proven. In general, the study realized several contributions for different fields. The study makes a scientific contribution by:

- extending the framework of SA and of the measurement method SA-SWORD, to the field of crisis and disaster management;
- using the framework of SA and of the measurement method SA-SWORD to come to better textual and spatial visualisation.

The study makes a social contribution by:

- increasing the awareness of the value of spatial information for crisis and disaster management;
- increasing the situational awareness to improve textual and spatial visual information for crisis and disaster management.

This study makes a practical contribution by:

- developing principles that help to make work processes easier and faster, and thus more efficient;
- informing the safety regions about the needed time to visualize information, limitations of crisis management systems, use of thematic and basic maps and different methods to improve the use of crisis management systems.

Acknowledgement

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Interoperability and Interchange of Geographical Information in Emergency Management: Views from the Netherlands

Rob Peters[1]and Frank Wilson[2]

[1]VRK, Zijlweg 200, Haarlem, The Netherlands, e.mail: RPeters@vrk.nl

[2]IDL, 6-8 Underwood St, London, UK, e.mail: fwilson@i-d.co.uk

Abstract

This paper presents progress in the Netherlands in using maps and map object attribute data as the core of interoperability of emergency management systems. First-responders concerned with security of citizens and infrastructure commonly use Geographical Information (GI) to share a rich Common Operational Picture (COP), and the COP is usually based around a layered map image with supporting data such as video, still images and text documents. The paper examines a range of initiatives, and the key issues identified for future research and development are seen to be interoperability, maps and standardization, maintenance of sources such as registries, and feedback from users. The examined work exposes the need to support first responders by preserving local semantics where necessary (essential icons), standardizing where possible (shared semantics), and translating where common standards cannot yet be achieved (semantic interoperability).

1 Emergency management and GI support

First-responders concerned with security of citizens and infrastructure commonly use Geographical Information (GI) to share a rich common operational picture (COP - Steenbruggen 2011).

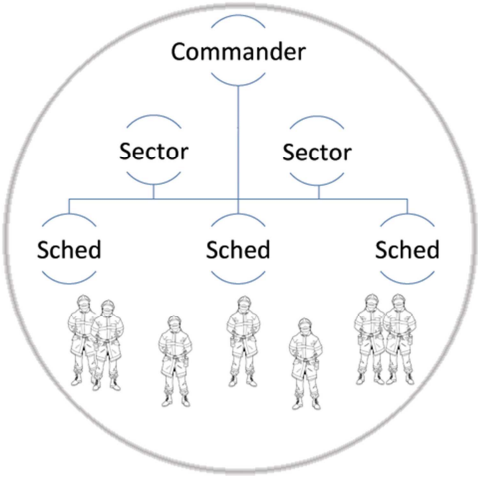

Figure 1: Local and single column view.

Figure 1 shows the typical Dutch approach referred to as 'within the kolom' (column) and adheres to explicit non-intervention to avoid confusion. The overall commander and sectorial commanders use GI and decision support to determine and convey, via schedulers, the operational decisions.

Commanders at different levels can interact with other agencies for information to enrich the COP, but ensure the model of non-intervention by using Information Managers (IM) to acquire necessary information such as map data, or critical attribute data (e.g. chemicals in a railway truck, or passengers in a crashed airplane). IMs may collaborate with IMs at other first responders (e.g. a fire brigade may work with police and ambulance in the field – see Figure 4 later).

2 Joint operations using GI

Emergency Management Systems (EMSs) are used to support joint operations between fire, police and ambulance, and/or between multiples of these separate forces. A control center typically uses a map wall to allow command staff to share the common view of the incident location, any victims or affected buildings/infrastructure, and the first responder staff and vehicles. The COP can also be supported by video feeds and still images (e.g. from ground crew and helicopters) plus information bulletins showing the status of tasks in the field.

Figure 2: MICK control room (VRK, Haarlem, NL).

A control room may use an emergency management system (EMS) to conjoin operations of sectors, and multiple cities (multiple control rooms) can be joined to facilitate joint command, communications and linked data supporting decision-making when larger or more complex incidents can benefit from interoperability.

Figure 3: LCMS, the Netherlands National Emergency Management System.

The three main strategies evident in current practice in joint operations are:

- cooperative information exchange;
- net-centric awareness;
- interoperability.

These are discussed so as to expose the GI issues identified in the Netherlands.

2.1 Cooperative information exchange

Even when command systems are joined by EMS (as in Figure 3 above), there may be a critical need for collaboration with external agencies (e.g. public health experts, cargo data holders, or other EMS – see Figure 4 below).

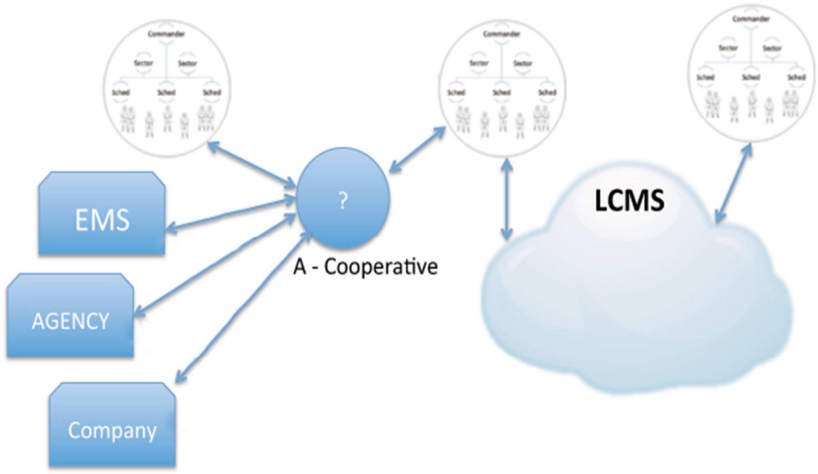

Figure 4: Adding value to LCMS in cooperation.

Sharing information ensures the common operational picture, used by distributed command activities, gives a common reference through identical display of relevant operational information. In recent incidents such as Turf Fires (see later), first responders cooperated with, and used GI data from, a variety of information sources shared by more than one command for shared planning and situational awareness (e.g. position of firemen, vehicles, and infrastructure such as roads). Appropriate information is presented to decision makers and their supporting officers, and the use of maps, overlaid symbols, still and video images, plus status bulletins, assist command at all levels (referenced at A in Figure 4 above).

2.2 Net-centric awareness

The previously mentioned liaisons with external agencies provide significant benefit to Crisis Management, and enable exchange of GI and metadata, plus supporting information. To extend capacity further, the information officers use social media and any net-accessible sources to further improve awareness. The Dutch "net-centric" approach to situational awareness (Boersma 2010) employs many useful sources such as News-feeds from TV, Radio and Internet, plus messages via Twitter, and videos via YouTube, etc. (at B in Figure 5).

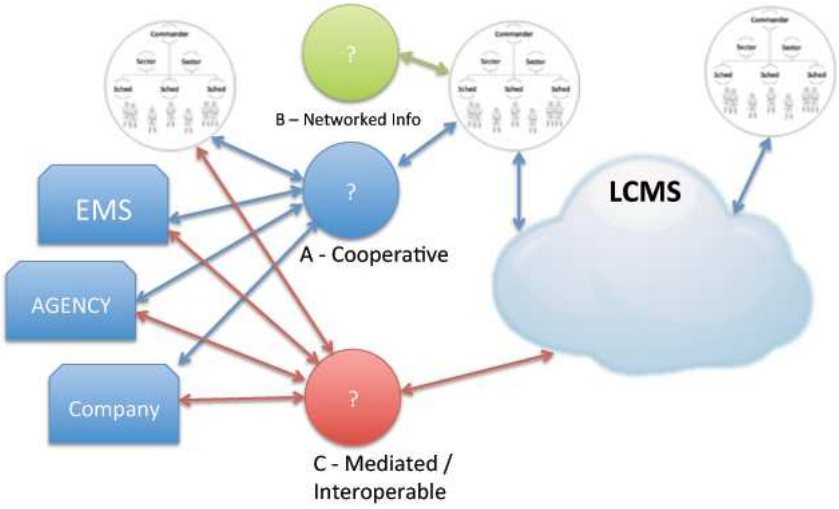

Figure 5: Cooperation (A), Net-centric awareness (B), Interoperability (C).

The considerations thus far indicate that the Dutch LCMS is a very powerful way of supporting a limited approach to interoperability by linking LCMS users together, and allowing LCMS users to exploit cooperative and net-centric strategies to increase connectivity and awareness. Extended interoperability is required.

2.3 Widening interoperability: DISASTER program

The Dutch LCMS is already a leading example of interoperability of EMS, and can conjoin command and communications for complementary services (fire, ambulance, police), as well as several control rooms. However, not all relevant agencies in the Netherlands use LCMS, and for cross border working there is no opportunity to introduce LCMS to other Member States. For these reasons, there is significant interest to find ways to allow interoperability between LCMS and other EMS, and also between LCMS and other information systems (i.e. non-EMS).

Interchange between information systems is increasingly of interest in all major IT sectors, and while interchange mechanism and translators such as Smooks (Jichen 2009) are increasingly used in the commercial sector (e.g. in Enterprise Service Bus – ESB), they typically require constant creation/updating of interchange patterns/mappings. Security is of such widespread importance that a stable and reliable mechanism is more desirable than a solution requiring constant reworking. For this reason VRK has elected to collaborate with a European consortium aiming to develop a middleware solution for interoperability of EMS, with a significant focus on GI and metadata (DISASTER 2012), supported by the EU FP7 Security program (FP7 Security 2011).

This approach requires support for organized and systematic interaction between command units: seeing each other (who is there); knowing what linked data is available (discovery of GI and metadata); determining access control (rights).

Making linked data discoverable and accessible in controlled ways requires a better understanding of the various information and communication strategies illustrated in Figure 5 (A and B), so as to develop clear technical and operational requirements for interoperability (C). This approach ensures that, unlike separated information-gathering actions (A and B), all information is shared in the richest common operational picture (COP).

3 Example case study - Cross-Border Turf Fire

Turf (Peat) is an accumulation of partially decayed vegetation under moorland, historically used to fuel fires, and even to smelt iron. It can generate significant heat and, once ignited by summer brushfires, can smolder below the surface for months, or years. After a moor fire, deep peat fires pose risks to road, infrastructure, people and property.

Figure 6: Firemen dealing with deep turf fire.

In June 2011, a peat fire in the cross-border region between Enschede (NL) and Ahaus / Gronau (DE) involved 130 hectares of protected bog and heathland. Around 350 fire officers from 2 countries were manually cutting into burning ground to access the deep fire layer for water treatment (Moorbrand in Gronau 2011). These officers had to move across an area where the heat could suddenly approximate a furnace. Ministry level collaboration provided thermal imaging from helicopters to show high-risk areas, but systems on each side of the border were not interoperable, and so these images could only be accessed by some of the

operatives on the ground. Commanders from Veiligheidsregio Twente and from the NordRhein Westfalen were challenged in specifying exactly where men were positioned, and found it difficult to share information about progress, or to ask for assistance. Text and radio message exchange was not sufficient. Subsequent analysis suggests a need for shared map information, with added (tagged) layers such as thermal images, first responder placements, video streams, and translation of terminology (common ontology).

The meaningful (semantic) exchange and the presentation of information must be improved in future to ensure safety, and so exchange of GI, metadata and attribute data between different systems requires a reliable middleware translator / transformer.

4 Interoperability challenges and solutions

The emerging Dutch model follows some of the ideas of the European INSPIRE initiative (INSPIRE Directive 2007). Inspire aims to create a spatial data infrastructure for environmental planning (Joint working of DG Environment, Eurostat and JRC), and has thematic working groups, similar semantic challenges and the notion of a common infrastructure (commons) for use in different tasks and regimes. Extension of such a model to a "safety commons" could add value.

However, experts in the Netherlands agree that there cannot be one ***centralized*** solution for all relevant information. A centralized model was previously tried with the SHERPA police database but did not work, because of maintenance challenges associated with managing data from multiple sources. Relevant experts must maintain the different information types, and so knowledge of sources and mechanisms for exchange are key to improving practice.

The key discovery in Dutch EMS usage is that the best ways to share information is to use maps and map services, using text to support where necessary (e.g. chemical info). Maps present common ground between people who may not know they have interests in common. Crisis management teams agree that the best focus for the common operational picture is map based presentation supported by other graphical, video, or text based sources for explanation and nuancing.

The high level requirements identified so far suggest needs to:

- make linked data discoverable and accessible in a controlled way;
- identify the relevant categories of linked data and communications to be supported;
- define the middleware and common data models (taxonomy, ontology etc.) required to facilitate semantic interoperability in a service oriented architecture framework (SOA) as can be seen developing in LCMS and in other EMS across Europe.

The key challenge is to discover how to help multiple command nodes act as an organized whole to maximize security of citizens and the first responders who go to their assistance.

4.1 Dutch safety and security architecture

In response to the abovementioned needs, the Netherlands has initiated its Veiligheidsregio Referentie Architectuur (VERA – the public safety and security reference architecture) using SKOS (Simple Knowledge Organization System), OWL (Web Ontology Language) and WFS (Web Feature Services) to support semantic formats for interchange and interoperability (see Figure 7 following).

VERA has a number of purposes, including avoidance of fragmentation and stimulation of standardization, and was approved by the Council of Fire Brigade Commanders and the National Security Council in 2012 to overcome problems in older standards (IOOV, IASV) that failed to address the link between administrative data processes, preparative data, and crisis information. A key issue is 'approachability mapping' whereby the route and the obstacles for approach to a location are accounted for to ensure regulations regarding arrival time are addressed.

In recent years the many mappings, objects and routing information (preparative data) have been combined with 'preventive data' (permits and inspections), standardized and converted to GIS technology so as to provide detailed object oriented mapping of entire regions.

Key work in the Netherlands is aimed to design the fit between regional data and the new National emergency management system, and so the (digital) map has been the connecting paradigm during these developments. The information model for preparative data (i-DBK) has been configured in line with standards designed by the same experts who supported the INSPIRE European Geo-infrastructure (GEONOVUM 2012).

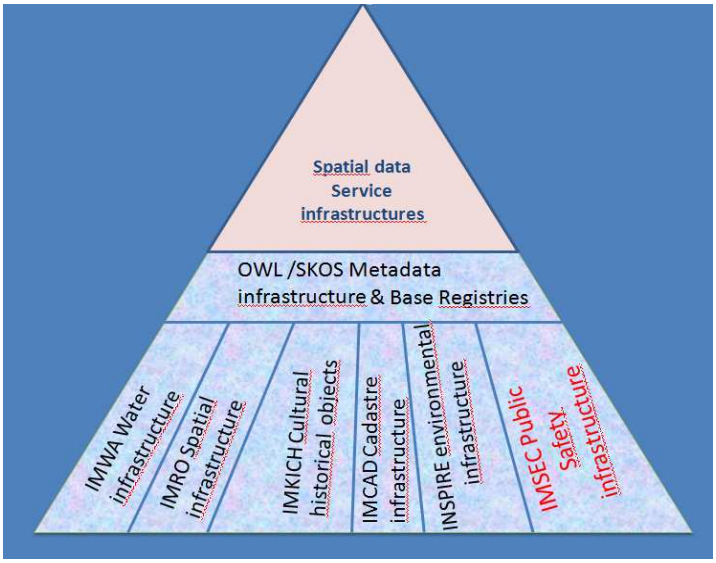

Figure 7: The Dutch framework for Spatial Data Infrastructures including Disaster Management based on NEN 3610, IMGEO2 and SKOSS/OWL.

The VERA architecture has become part of the larger family of Spatial Data Infrastructure (SDI's) in the Netherlands as far as geographic information is concerned (Bregt 2011). And so the national emergency management approach now focuses open connectivity with external sources for integration with map layers (e.g. from transport & roads authorities, from railways, and from major private players such as Schiphol Airport). This approach will allow the Dutch CIO's of safety regions to combine national systems with regional and other object oriented geographic information systems.

4.2 Base registries and feedback mechanisms

It is recognized that a sophisticated and integrated architecture, as described above, is not feasible without proper feedback mechanisms to avoid systems becoming outdated. This requires that all geographic nodes in the geographic data network benefit from a common set of standards and a common governance of feedback mechanisms. VERA is using the base registries as the key to achieving such governance.

The launch of VERA and the overall geo-based infrastructure is only possible because of the huge effort made by all cities and a number of inistries to create the base registries for addresses, for waterways and all other infrastructures (referred to as BAG and BGT in Holland). Users and data suppliers benefit from there being a unique address identifier per object, to be used as URI in Service Oriented Architecture (SOA) web-service environments, and there is a compulsory feedback on false addresses or object attributes under Dutch law to ensure quality of data. Cities, environmental agencies, regional authorities, police force personnel and others are obliged by law to send a message about mistakes or mutations or otherwise remarkable attributes.

Key actors within government understand that VERA and associated infrastructure can only survive if it is properly maintained. And so it is also recognized that the same feedback mechanism could be enlarged to cover all other relevant data, including storage of dangerous goods, size of ventilation openings, maximum load of bridges, etc.

It is also recognized by police, fire brigade and ambulance architects that standardization of feedback mechanisms is driven by usability - the men in the field will only provide feedback if the mechanism is user friendly and if the value of feedback is made abundantly clear to all. This notion has initiated a number of pilots testing of tablet-based and map-based feedback forms.

4.3 Icons and symbols

Map-based feedback and information sharing relies on standardization or mapping of symbols and icons to help people from different domains or different languages to understand each other's intent. The need for semantic interoperability based on harmonization of icons on maps has been a key reason for VRK participating in

the European DISASTER project. The teams involved were aware of the need for immediate common understanding in command and control rooms when multiple organizations are involved, such as during the Turkish Airlines 'polder crash' (Winkelhagen 2010) where discussions about the exact location of the crashed airplane in 2009 (and therefore the best access routing and the best approach plan) took valuable minutes from the 'golden half hour'. The Manager of the Control & Dispatch Room of Kennemerland clearly stated that she believed in icons, not text. The crash inspection report (IOOV 2009) emphasized the need for enhanced information sharing.

4.4 Other future work

At national level, the harmonization of symbols and icons used in the regional and preparative data for Fire brigades could be a valuable contribution for the European GMES initiative which is based on Galileo satellite imaging. This would enable top down and bottom up data processing for crisis management teams, and so officers equipped with vehicle information systems using tablets could use the new PRS positioning system in combination with images and map layers to generate a common operational picture in more languages and for different teams.

However, the DISASTER initiative also requires preservation of local images and semantics, and so interoperability may also have to be supported by mapping through semantic interoperability to allow different organizations to preserve icon and symbol culture. These two approaches are not incompatible.

Other future work in Kennemerland will aim to use embedded software in all public space objects run by the city of Haarlem's technicians. Lighting, gas pipe valves, traffic regulatory systems, bridges and road blocking devices are increasingly subject to remote control, but each has a separate controlling system. Systems designed to integrate control, such as IBOR (Den Ouden 2011) could be of great benefit when, for example, evacuating a number of people from a city center.

All of these considerations emphasize integration of command and control, and suggest a common operational picture represented within a map.

5 Summary of the Netherlands' perspective

In emergency and crisis the safety and security of staff and citizens in the field is paramount. Current trends in governance of safety and security emphasize integration and interoperability for improved safety and security. Previous centralization initiatives proved unsuccessful and showed that preserving and interoperating distributed knowledge, expertise and information is crucial to success. The common operational picture can be informed by many sources, and where standards of representation differ, middleware for semantic interoperability is necessary (translate meaning). At national level, interoperability initiatives such as VERA ensure consistency in management of multiple spatial data infrastructures (SDI) exploiting

open connectivity. Cross-border collaboration can be supported by initiatives such as GMES for shared image data, and the development of cross-border (and inter-EMS) interoperability is addressed through the DISASTER initiative. Together these approaches allow the Netherlands to improve systems at ground level, integrate operations at National level, and prepare the way for cross-border interoperability.

The key issues identified here for immediate address in research and development are interoperability, maps and standardization, maintenance and feedback. The work in progress also emphasizes the need to support first responders by preserving local semantics where necessary (essential icons), standardizing where possible (shared semantics) and translating where common standards can not yet be achieved (semantic interoperability). In the near future, smart icons may support a range of needs.

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UAV Surveillance using Multihop ad hoc Wireless Networks: a Demonstrator

Daniël Heimans[1], Maurits de Graaf[2] and Gerard Hoekstra[3]

[1]Department of Electrical Engineering, University of Twente, Enschede, The Netherlands, e.mail: d.heimans@student.utwente.nl

[2]Thales Nederland B.V., Huizen, The Netherlands and Department of Department of Stochastic Operations Research (SOR), University of Twente, The Netherlands, e.mail: maurits.degraaf@nl.thalesgroup.com

[3]Thales Nederland B.V., Huizen, The Netherlands and CWI, Probability and Stochastic Networks, Amsterdam, The Netherlands,
e.mail: gerard.hoekstra@nl.thalesgroup.com

Abstract

Festivals, public parades, and sports events are a common happening that attract a large amount of people to one location at the same time. To improve the safety at such crowded events, the event organization could use static and mobile sensors that sense and detect situations which require the attention of the security personnel. Camera surveillance of large areas is traditionally a costly endeavour, requiring either a large camera infrastructure or a lot of manpower. However, presently consumer electronics have evolved to the point where quadrotor toys with cameras and wireless connectivity have become affordable. In the meantime, the same has happened with consumer-grade wireless routers. In this paper, we describe a demonstration of a scalable aerial surveillance solution using consumer off the shelf quadrotor drones and wireless routers to create an ad hoc network based on optimized link state routing, extending the operational range of the drones.

1 Introduction

Critical infrastructures such as power plants, large industrial areas, harbours, railway emplacements, but also people-rich structures like railway stations, are essential enablers of our economy and way of living. The number of threats that may disrupt the normal functioning of these infrastructures is growing and it is not likely to diminish in the coming years. The aim of the COMMIT Sensafety project is (1) to offer real-time automatic analysis of potential hazardous situations and detection of important events and (2) to give support in these situations to first responders to guarantee the safety of the general public as well as of the responding authorities. To improve safety, traditional surveillance methods are based on fixed camera systems or surveillance personnel on the ground. One of the main issues is that as the scale of the surveillance operation increases, more cameras and manpower are needed to cover greater areas, increasing costs.

In recent years, flying robots equipped with cameras, often referred to as drones, have been used to overcome the limitations associated to fixed camera systems. Drones are capable of flying over obstacles and provide a bird eye's view of the situation and can move easily while still being able to provide a stable video platform. An example use of this is seen at music festivals, where aerial footage is used for surveillance as well as for commercial purposes. Drones used are usually small and manoeuvrable, using four to eight rotors.

The downside of these drones is their limited range. Existing approaches are based on a single point of transmission, which automatically imposes limits to the scale to which they can be used. A solution to this problem can be found in the use of multihop ad hoc networks: these are networks that consist of many transceivers sources, called nodes in the network. These nodes can enter and leave the network at any time while maintaining a connected, decentralized network via a routing protocol.

In this paper we propose a scalable aerial surveillance solution using consumer off the shelf quadrotor drones and wireless routers to create an ad-hoc network based on optimized link state routing, extending the operational range of these drones. An extended version of this paper, with a focus on the analysis of the scalability of ad hoc networks and on the drone control framework appears as (Heimans et al 2013).

2 Demonstration overview

In our demonstration, we use a Parrot AR.Drone (http://ardrone.parrot.com/parrot-ar-drone/en/technologies) 2012 (see Figure 1). It provides wireless connectivity and video footage of up to 640 by 480 pixels. The demonstration shows a drone sending a video stream to the command centre. The drone is part of the ad hoc network, which enables both the control of the drone as well as the video stream to be sent over an ad hoc network. The drone runs low-level control firmware providing stable take-off, landing and hovering. The firmware takes high-level

control commands and converts it to low-level control. An example of a high-level command is 'move forward at 50% speed'. The high-level control commands are sent over a wireless LAN connection. By default, the user connects to the access point the drone provides. In our experiments the drone is integrated in the OLSR network, so it can take commands from anywhere in the network.

Figure 1: The Parrot AR.Drone used for demonstrating camera surveillance over ad hoc networks.

olsr.org OLSR daemon

Configuration | Routes | Links/Topology | All | About

OLSR Routes in Kernel

Destination	Gateway	Metric	Cost (ETT)	Interface
192.168.4.0/24	192.168.6.206	2	42455.000	wlan0
192.168.4.204	192.168.6.206	2	42455.000	wlan0
192.168.6.0/24	192.168.6.206	1	19573.000	wlan0
192.168.6.206	192.168.6.206	1	19573.000	wlan0
192.168.9.0/24	192.168.6.206	4	74092.000	wlan0
192.168.9.209	192.168.6.206	4	74092.000	wlan0
192.168.10.1	192.168.6.206	3	56521.000	wlan0

(C)2005 Andreas Tønnesen
http://www.olsr.org

Figure 2: The (linear) topology of the network consisting of nodes 192.168.6.206, *.204, *.9.209, and *.10.1, as seen by the command centre. The drone (with IP address 192.168.10.1) is 3 hops away from the command centre and functions as a router. The ETT values indicate the cost of the links based on delay and loss.

By default, the drone is controlled using a smartphone which connects to the drone's wireless network. Once connected, the user can issue commands on the smartphone which are constantly being sent to the drone. For example, the user

can tilt his phone forward, making the drone fly forward. During the time that the phone is tilted, it constantly sending commands to the drone, indicating it should move forward at the angle the user is holding the phone. In our demonstration we have replaced the phone with a laptop generating the same commands the phone would, using a gamepad (see Figure 3). We refer to this as the command centre. By default the drone is controlled by a steady stream of commands coming from the controlling device - be this a smartphone or the control centre application. The drone sends back two streams: one containing the video stream and one with navigation data. Navigation data contain (amongst others) battery level, orientation, altitude, and speed.

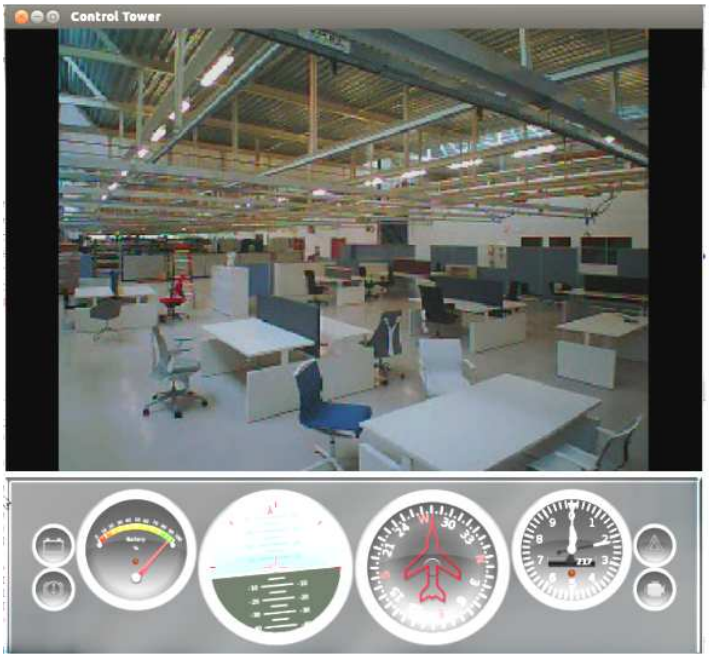

Figure 3: Impression of the AR Drone Control Centre, to which the AR Drone streams the images over the multihop ad hoc network.

Commands are sent every 30ms when controlling the drone as specified in the AR.Drone SDK (Piskorsi, Brusez and Parrot 2011). Commands are always smaller than 1024 bytes but are usually between 20 and 60 bytes. This constant sending of commands is called the control loop.

UAV surveillance applications are characterized by a continuous video stream from the drone to the command centre and an intermittent stream of time-critical control commands to the UAV. We use the Optimised Link State Routing protocol (OLSR) (Adjih et al 2003) as topology control protocol. This protocol sends frequent network probing messages to keep an up to date routing table in every node. In addition, it has a mechanism to prevent broadcast messages from flooding the

network called *multipoint relay* (Qayyum, Viennot and Laouiti 2000) Scalability issues of the OLSR, related to this specific application are investigated in (Heimans et al 2013).

The hardware of the stationary nodes in our network are TP-link WR1043ND routers. They run a custom firmware called openWRT (https://openwrt.org/ 2012) which allows for the installation of non-default packages, such as OLSR. The network we are using is laid out linearly to allow experiments for different amount of hops. The maximum amount of hops between the drone and the command centre in our network is four (see Figure 2).

We have installed OLSR with link-cost extension (olsr-lc) (http://sourceforge.net/projects/olsr-lc 2010) which is based on OLSR version 0.6.0 on the drone and the routers.

3 Conclusion

In this paper we describe a demonstrator for site surveillance using unmanned aerial vehicles in a multihop ad hoc wireless networks. This provides a scalable solution using off-the-shelf consumer equipment. The paper describes a 'lab test' with of the shelve means particularly because of the efficiency and low investments. The paper shows that, in potential, simple means could give good results. Besides adding to the surveillance capacities, the flying nodes-in-a-network could help with network coverage problems in larger areas.

Acknowledgement

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Traffic Incident Management in Europe – Guide for Best Practice

John Steenbruggen and Peter Nijkamp

VU University, Department of Spatial Economics, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands, e.mail: j.g.m.steenbruggen@vu.nl, pnijkamp@vu.nl

Abstract

Road networks are part of a country's transport infrastructure and are therefore subject to general transport policies. Efficient road networks are increasingly seen by governments across Europe as being the key to supporting and sustaining economic growth, as they enable the movement of goods and services around the country. Traffic incidents have a significant impact on the normal operation of the road network. Economic constraints are causing National Road Authorities (NRA) to innovate, as they look for cost efficient ways to tackle congestion and develop more effective traffic Incident Management (IM) measures. This has led to an emphasis in many European countries being placed on better use of existing infrastructure and IM capabilities rather than investing in more costly systems, equipment and working methods. The level of IM implementation varies across Europe. The Trans-European Road Network (TERN) shows for example a wide range of differences in the deployment of road infrastructure for the detection of incidents. There is also considerable variety in the national road administrations in Europe. A recent EU white paper concludes that the fragmentation of research and development efforts in Europe for traffic safety is most harmful. The Conference of European Directors of Roads (CEDR) investigates how countries can develop their IM capabilities to support policy goals and the needs of road users. The purpose of this study is to facilitate the cooperation, on a European level, by exchanging experience and information. This will support countries across Europe to minimize the economic cost of incidents, improve road safety and, decrease mobility problems through the implementation of relatively low cost IM measures. This paper provides the state of the art from a European perspective on the spatial relevance of IM and related fields.

1 Introduction[10]

An 'incident' is defined as "an unforeseen event that impacts on the safety and the capacity of the road network that causes extra delays to road users" (EasyWay 2011). Traffic Incident Management (IM) is "the systematic, planned and coordinated use of measures and resources to safely handle an incident from discovery to restoration of normality" (EasyWay 2011). In practice, IM is a set of measures that aims to minimise the negative effects on safety and traffic flow conditions, by reducing the clearance time following an incident. The main goal of traffic IM is to manage and resolve incidents in a safe, effective and quick way considering the following needs (CEDR 2009):

- to ensure the safety of all involved IM responders, traffic safety and the safety of casualties;
- to limit the impact of incidents on traffic flow and return traffic flow to normality in the shortest time;
- to control the damage of the vehicles and load involved in the incident as well as the road infra structure.

IM can be broken down into phases of progression through which the timeline of an individual incident passes. There is no general written agreement on the different traffic IM phases and objectives (Steenbruggen et al 2012a). The phases of the traffic IM process can be visualised along a linear timeline (see for example Özbay and Kachroo 1999, Zwaneveld et al 2000, Nam and Mannering 2000, Corbin and Noyes 2003). This allows for some overlap between phases. With the exception of detailed planning, it is felt that the nature of these overlaps are not well defined, and therefore the cycle model could offer some clarity of these phases and the progression through them. The traffic IM cycle, adopted from England (UK FHA 2009), contains the following timelines (CEDR 2011): discovery, verification, initial response, scene management, recovery, restoration to normality and normality. Incident response time and clearance time are two critical components of the overall incident duration. Incident duration is generally defined as the time elapsed between the occurrence of an incident and the time at which a roadway is restored to its capacity (Garib et al 1997, Nam and Mannering 2000, Chung 2010). Strategies to prevent incidents occurring are of course in favour in terms of safety and mobility rather than developing strategies to respond to incidents. Incidents can be caused due a number and combination of reasons. In many cases human error or technical failure play an important role, e.g. driver distraction, alcohol abuse or motor breakdown (Wegman 2007). Some incident preventing measures for both primary and secondary incidents have previously been identified (CEDR 2011).

[10] Parts of this paper are based on: Steenbruggen, J., M. Kusters, and G. Broekhuizen, 2012. Best Practices in European Traffic Incident Management. In: Proceedings in Social and Behavioral Sciences 48, pp. 297-310. Transport Research Arena–Europe 2012. Athens Greece, April 23–26.

Traffic IM involves the coordinated interactions of multiple public agencies and private-sector partners. Road authorities, police, fire and rescue, and ambulance services can ensure safe and reliable transportation operations by helping to prevent incidents and rescuing accident casualties. On the other hand, the transportation network enables access to emergency incidents, and, increasingly, provides real-time information about roadway and traffic conditions.

The IM concept has been gradually introduced in the EU. Efficient road networks are increasingly seen by governments across Europe as being key to supporting and sustaining economic growth, as they enable the movement of goods and services around the country (European Commission 2001, 2011). The level of its deployment varies across Europe (CEDR 2011). Today the Trans-European Road Network (TERN) shows a wide range of differences in the deployment of road infrastructure for detection of incidents, and in the measures available to handle incidents. In the same operational environment, there are also differences between countries and regions. Many countries have some form of IM primarily covering motorways and main roads. Agreements are typically regional or local, and occasionally nationwide. Special consideration has to be given to the underlying secondary road network. The same IM measures should be applied there as well. The European dimension is to provide a common approach to IM on the TERN, thereby harmonizing national IM, as well as improving the conditions for cross-border IM activities and sharing IM experience and best practices. The harmonization of future deployments should take the form of: improved cooperation between road authorities and IM responders; similar European definitions of IM stages and evaluation methodologies; and road-user-oriented aspects, such as systems for incident detection and traffic information for road users (EasyWay 2010a). To support the process of IM, the need for (mobile) context-aware (spatial) information and supporting information systems will be a paradigm shift. In the next section we will describe the IM policies from an European level. In section 3 we look in more detail at the results of the CEDR 'Best Practice' survey. Based on these outcomes, section 4 will provide a best practice framework as a guide for countries to implement different IM measures. Finally, in section 5, we address the main developments related to information services in terms of standardization and information technology on a European level.

2 European policy

2.1 IM regulation on mobility and safety

For a long time, the European Community was unable to implement the common transport policy provided by the Treaty of Rome (European Commission 1957), because of the different and sometimes conflicting objectives of each Member State. This led to a mixed picture in terms of congestion problems based on the growth of transport in an enlarged European Union, with a resulting imbalance be-

tween different transport modes. The Treaty of Maastricht (European Commission 1992) reinforced the political, institutional, and budgetary foundations for transport policy which included the concept of the TERN. In 2001 this resulted in the EU White Paper '*European transport policy for 2010: time to decide'* (European Commission 2001), which includes 60 specific measures. In relation to traffic IM the most relevant are improving quality in the road transport sector and putting users back in the heart of transport policy by improving road safety. In 2011 this White Paper was updated as '*Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system'* (European Commission 2011). Since 2001 much has been achieved. The safety and security of transport across all modes have increased. However, the White Paper concludes that the fragmentation of research and development efforts in Europe is most harmful for traffic safety. A specific goal is to identify the necessary innovation strategies and deploy large-scale intelligent and interoperable technologies such as the '*Intelligent Transport Systems'* (ITSs) to optimize the road capacity and the use of infrastructure. Members States have a direct influence on EU legislation. For traffic IM, a number of different EU organizations have been established which deal with legal EU matters. The US (US FHWA 2010) identifies broadly the same communication and standard issues as in Europe. They conclude that the coordination among federal, state and local agencies or public safety and transportation agencies typically lacked cohesion. They conclude that to cope with this challenge, public and private sectors need to cooperate.

2.2 EU road organizations

There is great variety in the national road administrations in Europe. Examples of organizations are the Conference of European Road Directors (CEDR), the European Construction Technology Platform (ECTP), and the European Road Transport Research Advisory Council (ERTRAC). The Transport Research Committee (TRC) is another forum for strategic coordination in Europe. These organizations have defined strategies for effective traffic management and congestion. An example is the OECD/ECMT initiative of 2007 '*Managing urban traffic congestion*' (ECMT 2007). The main findings related to traffic IM are introducing:

- coordinated IM policies to reduce the incidence of non-recurrent congestion;
- systems for coordination and integration amongst the emergency services;
- automatic incident detection systems, and traffic surveillance by cameras.

In the US we find the same fragmentation. At the national level, there are several agencies involved in the development and research of highway IM. These agencies are the Department of Transportation (DOT), National Traffic Incident Management Coalition (NTIMC), Federal Emergency Management Agency (FEMA), American Traffic Safety Services Association (ATSSA), National Fire Protection Association (NFPA), and the Towing and Recovery Association of America (TRAA). Highway IM procedures and policies developed by these agencies focus on different aspects of IM (Illinois Center for Transportation 2011).

Recently, the Conference of European Directors of Roads (CEDR) developed the guideline 'Best Practice in Europe' for traffic IM (CEDR 2011). The purpose of CEDR is to facilitate cooperation on a European level by exchanging experience and information in order to make progress in the road safety and road transport sector (CEDR 2008). The main goal of IM is to manage and resolve incidents in a safe, effective, and expeditious way, considering safety, traffic flow and control damage (CEDR 2009). Traffic IM can be viewed as one part of an integrated service to road users, whose various parts are related to dynamic traffic management, information provision, and traffic IM. They contribute in different ways to the efficiency of the road system (CEDR 2011). By maintaining a balance between these elements, a more efficient use of network capacity can be achieved. Effective traffic IM can reduce both safety and non-safety-related costs by: reducing response and clearance times; reducing the risk of secondary incidents; ensuring the safety of incident responders; and maximizing the use of available resources (CEDR 2011).

Another initiative comes from EasyWay, who have created a long-term vision in their '*Strategy and Action Plan*' (EasyWay 2010c). The policy framework, defined from the road operators' perspective, constitutes high-level guidance for the period 2010 to 2020. A special roadmap summarizes the development and implementation steps to be taken, and defines the period in which this has to be done in order to fulfill the specific goals. They identify some main issues that the countries need to address in order to create a European framework for traffic IM which includes differences in the:

- organizational structure of IM responder units;
- level of agreements between IM responder units;
- involvement of road authorities and the private sector in IM;
- service levels (e.g. in relation to time of arrival and time of recovery);
- systems for incident detection and location;
- requirements/expectations of road users when involved in or influenced by an incident.

EasyWay implements most parts of the Intelligent Transport Systems (ITS) action plan (European Commission 2008). A new legal framework was adopted to accelerate the deployment of these innovative transport technologies, and is an important instrument for the coordinated implementation necessary to establish interoperable and seamless ITS services (European Commission 2010). EasyWay has defined its priority ITS services, known as the *core services*, to be implemented in the coming years. For traffic IM services the deployment guidelines *Incident Management* (EasyWay 2010a) and *Incident warning* (EasyWay 2010b) are relevant. Recently, these guidelines have been integrated (EasyWay 2011).

2.3 Road safety

In the last ten years a big effort has been made, by the European Commission and all Member States, to reduce the impact of road transport in term of fatalities and injuries. Initiatives in technology, enforcement, education and with particular at-

tention to vulnerable road users are the key to drastically reduce the loss of lives even further. The overall objective to halve the number of fatalities between 2001 and 2010 has not quite been reached but significant improvements have been made. In the last decade, thanks to the third Road Safety Action Plan, fatalities have decreased by 43 per cent but the total number of accidents decreased by only 24 per cent and the total number of injuries by 26 per cent.

Road safety strategies traditionally focus on reducing fatalities. Injuries, however, are overlooked, and have become a major health problem. Each year more than 1 million people worldwide die as a consequence of road accidents. Traffic injuries in the European region are a major public health issue. In 2011 around 30,500 people lost their lives on the EU road network, a figure which corresponds to a medium-sized town, while around 1.5 million were injured on the roads of the European Union, at huge economic and human cost to society[11]. Road traffic accidents should be considered not only a transport issue, but also a social and public health concern, and therefore a scientific and rigorous approach should be adopted. Reducing the number and the severity of road traffic injuries is one of the strategic objectives outlined in the '*Policy Orientation on Road Safety 2011-2020*', and a priority for EU action. The new European goal is a 'zero-vision' on road safety for 2050 (European Commission 2011.

The fifth ETSC (European Transport Safety Council 2011) report provides an overview of road safety performance in Europe. This analysis is based on the road safety performance index as an instrument to support European countries to make greater efforts to enhance road safety. By comparing Member States performance, it serves to identify and promote best practice. European roads are among the safest in the world. Sweden, the UK, Malta, and the Netherlands remain the safest EU countries for road use.

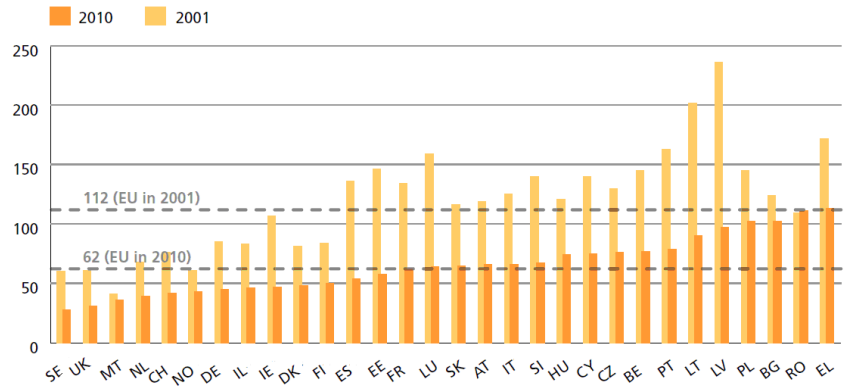

Figure 1: Road deaths per million inhabitants in 2010
(with road deaths per million inhabitants in 2001 for comparison).
Source: European Transport Safety Council (2011).

11 http://ec.europa.eu/transport/road_safety/specialist/statistics/trends/index_en.htm

In 2010 in the EU27, 62 people per million inhabitants were killed on the roads. However, the accident rates across Europe vary greatly as shown in Figure 1 above.

3 Results from an European survey on traffic IM

3.1 Research goals and methodology

The CEDR workgroup 'Traffic IM' followed the strategy of CEDR Strategic Plan (CEDR 2008). From April 2009 until March 2011 they produced the document "*Best practice in European Traffic IM*". The IM survey was designed as a secure, online web survey showing a mixture of multiple-choice and open questions. It was addressed to all CEDR members including the traffic IM workgroup and a couple of practitioners outside of Europe who had agreed to participate. The web survey was posted online and made available to all CEDR member countries for which an NRA contact could be identified, amounting to 21 European countries for a period of 4 months. During this time 7 countries provided detailed responses, and 2 others general responses. Three other countries provided information by e-mail or phone, other data for 6 other countries were obtained from other sources.

The survey was designed to interpret the context of IM techniques. The first part of the survey included a set of detailed questions to characterize each country, what they are currently doing well, and what plans they have for communications, data collection and incident prevention measures etc. The second part of the survey was about future thinking and long term plans in more general terms.

3.2 IM policy review

The survey asked the responders if they held multi-responder policy reviews and if so to provide details. The information provided indicates a preference for a Traffic Management Center (TMC) and the three emergency services over the secondary support services for the purposes of policy planning, as would be expected.

Country	**Group name**	**Meetings per year**	**Achievements**	TMC	Police	Ambulance	Fire	Recovery service	Media	Civil defense	Government
Austria		1	Point out deficiencies and identify improvements, with particular concern for tunnels								
Denmark			To align with Danish broadcasting about information								
England	ACPO	4	Issues and opportunities to enhance working partnerships								
Finland		1	Share information and develop cooperative actions								
Italy	COEM		To plan for major incidents and emergencies, big events and the seasonal exodus								
Latvia		2	Collaboration schemes, address EU regulation and support national legislative process								
Netherlands	IM council	4	Aim to reduce response times by 25 per cent by 2015								
Norway		2	Identify need for cooperation of routines and cooperation between stakeholders								
Slovenia		Ad hoc	Analyse major incidents to approve response times for each stakeholder, perform exercise in tunnels								
Sweden		5/6	Discuss problems handling accidents efficiently on the road network and achieve improvements								
Victoria State		4	Determine responsibilities, discuss improvements, improve coordination between agencies								

Figure 2: Countries policy reviews and respond.

3.3 Responsibilities in Traffic IM

The role of each National Road Authority (NRA) within its own country varies greatly across Europe and the rate of development of individual NRA's is an important factor. Some are government organisations, others are private companies. Some are tasked purely with maintaining the highway, while others are more involved with managing the traffic. Several workshops identified two key points:

- NRA's have differing levels of responsibility for IM, and in many countries the police have sole responsibility;
- countries have different IM priorities, dictated by geography, climate and driver culture.

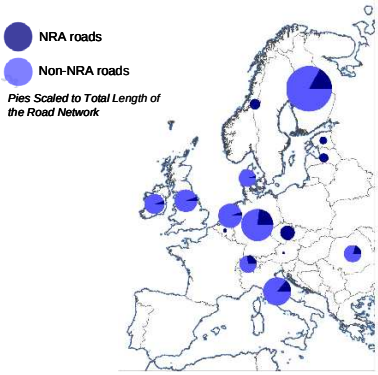

Figure 3: Extents of networks for which National Road Authority (NRA) are responsible (CEDR 2010).

These two points dictate the variation in terms of NRA budgets, size and legislative responsibilities. One key indicator of the scope of an NRA's responsibility is the size of the road network for which it is responsible. Figure 3 shows a selection of EU countries for which the size of the total road network is identified and the proportion of that network for which the NRA is responsible for. It shows that NRA's typically run between 10% and 25% of the total road networks. These are usually the most busy roads such as motorways and primary trunk roads. The leadership roles for traffic IM in terms of incident clearance, resulting congestion, diversion strategies, traveller information, responder leadership, monitoring and safety for traffic IM varies for each country. IM should at least be introduced on the roads belonging to the TERN network. The results have been tabulated for the countries that responded and are shown in Figure 4.

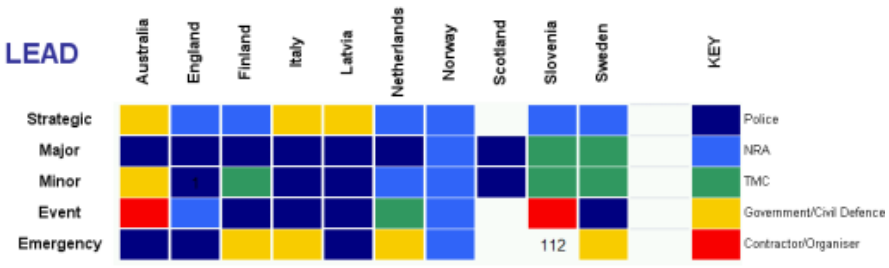

Figure 4: Responders taking lead role in Incident Management (not necessarily exclusive).

These figures show the variety of national protocols for incident management.

NRA/Country	Classification
ANAS (Italy)	Network Operator
ASFiNAG (Austria)	Network Operator +
Danish Roads Directorate	Network Operator +
English Highways Agency	Network Manager
Estonian Roads Administration	Network Maintainer +
Federal Ministry of Transport, Building and Urban Development (Germany)	Network Maintainer
Finnish Transport Agency	Network Operator +
Flemish Roads Administration (Belgium)	Network Operator
Latvian Roads Administration	Network Maintainer
National Road Authority, Republic of Ireland	Network Maintainer
Norwegian Public Roads Administration	Network Operator
Rijkswaterstaat (Netherlands)	Network Manager +
Road and Motorway Directorate (Czech Republic)	Network Operator
Slovenian Road Authority (DRD)	Network Operator
Swedish Traffic Administration	Network Operator
Swiss Federal Roads Authority (FEDRO)	Network Operator +

Figure 5: NRA Categorization (+ indicates intention to extend responsibilities).

In many countries, especially Latvia and Italy, incident management is led by the police. In Finland they also play a big role in congestion management. Indeed in Latvia the police have a sole responsibility for traffic flow management while the Netherlands, Slovenia and Sweden they have more varied tasks. Based on the leadership roles, future intentions, and level of service provision, three levels of approach to IM have been identified. Countries which indicated their intention to take more responsibility for incident management are indicated with a "+" symbol next to the categorisation (Figure 5).

- Network Maintainers: clear roads after incidents and return the infrastructure to operating standard;
- Network Operators: coordination role, detecting when incidents occur using various technology, directing responders to the scene and informing road users though variable message signs, speed limitation signs etc.;

- Network Managers: role in managing incidents, leading on scene management in a similar way to Police to minimise network disruption from incidents.

3.4 Targets in response times

Many countries have formal agreements or contracts specifying targets or maximum response times. Effective traffic Incident Management (IM) consists of reducing response and clearance times, reducing the risk of secondary incidents, ensuring the safety of incident responders and maximising the use of available responses. The incident clearance stage, which constitutes the safe and timely removal of stalled vehicles, wreckage, spilled materials and debris from the roadway or shoulders is usually the most time consuming portion of the incident management process (Pearce 2000).

Country	**Circumstance**	**Response Time (minutes)**
Belgium-Flanders	Urban	15
	Rural	20
Denmark	Contracted	30
England	Traffic Officer Service - high priority section	15
	Traffic Officer Service - heavily trafficked	80% within 20
	Traffic Officer Service - lower priority section	25
	Incident Support Unit on scene minimum	20
	Incident Support Unit on scene maximum	90
	Recovery of light vehicle	30
	Recovery of goods vehicle	45
	Clearance	80% within response+30
	Local broadcast radio traffic updates every	15
Germany	Response time legal obligation	90% within 8-12
Netherlands	Ambulance Fire TOS high priority IM TOS IM Recovery	15 min (95%) 10 min 15 min (80%) 30 min (80%) 20 min (90%)
	Goods vehicle	45 min
USA	Clearance minor incident – FHWA target	30
	Clearance major incident – FHWA target	90

Figure 6: Response time targets across Europe and other OECD countries.

In the survey most see IM as a mechanism for reducing congestion. There are several reasons underlying these differences, one major reason is the difference in density of population and congestion problems in countries. Another issue is that there is not yet a common agreement on the definition of the structure of the IM process phases as mentioned before. Figure 6 gives an overview of the difference in response times for some European countries. However, to apply successful IM

measures, it is relevant to know how these can improve the congested network. Therefore, it is important to realize that traffic incidents do not have the same effects at different locations and times on the highways. For this reason the highways are categorized. The importance of speed is strongly related to the impact that it has on congestion (Steenbruggen et al 2012b). Apart from that, it is also relevant to know where the incident occurs during the rush hours (between 06:00 – 10:00 and 15:00 – 19:00).

4 Best practice for Traffic IM

4.1 Framework guide

The main goal for a European IM framework for best practice is to facilitate the cooperation on a European level by exchanging experience and information to minimise economic cost of incidents, improve road safety and decrease mobility problems. 'On-Line' components are those needed immediately in response to an incident, while the 'Off-Line' components are those that improve overall TIM effectiveness, either before or after an incident. A third category of 'Up/Down Line' captures longer term issues that affect the overall way that TIM operates (see Table 1).

Table 1: Traffic IM components.

On-Line	Off-Line	Up/Down Line
Coordination	**C**overage	**P**olicy
Cooperation	**A**nalysis and Evaluation	**L**earning from Experience
Communication	**D**ebriefing of Responders	**A**spirations
Control	**E**xercises	**N**ew Technology and Intelligence
Command	**T**raining of Responders	**S**trategies for Improvement
Access	**P**lanning of Responses	
Personnel	**P**erformance Indicators	
Equipment	**I**nformation Services	
	Education of Road Users	

Certain procedures have been found to be successful; the following ten points are offered as forming the backbone of traffic IM practices:

1. speedy detection and response;
2. good information about location, severity and any attendant hazards;
3. protection of the scene, and ensuring safety of responders, victims and the public;
4. voordinated response with a clear structure of authority, roles and responsibility;
5. reliable communications between responders and the public;
6. provision of appropriate equipment, facilities, access paths and control centres;

7. sufficient backup services to ensure speedy clearance to minimise congestion;
8. training and debriefing systems;
9. written guidelines and formal agreements where necessary;
10. monitoring, performance assessment and feedback into practice.

4.2 Concepts for effective Incident Management

Many countries have some form of IM covering primarily motorways and main roads. Agreements are typically regional or local and occasionally national. In some countries IM includes road works and recurring congestion. In other countries only unforeseen events, which require action by different IM responders. Three substantial sources on best practice in Incident Management have been identified:

- the English Highways Agency's Traffic Incident Management Guidance Framework, developed with the UK's Association of Chief Police Officers (ACPO) and supported by a pocket-sized Aide Mémoire (UK Highways Agency 2009);
- the Netherlands 'red-blue book' available in both Dutch and English (Dutch Ministry of Transportation and Water Management 2005);
- the EasyWay Guideline for the deployment of Incident Management, which is in the form of a report but includes definitions of service levels and actions (Easyway 2010a, 2010b, 2011).

Examples of more or less local or integrated, national measures are: implementation of the traffic officer, use of incident support units, recovering contracts, maintenance contracts with performance indicators, regulation to remove abandoned cars, Traffic Management or Control Centres, guidelines on Traffic IM, use of incident screens, use of incident protection vehicles, 3D or laser location devices to survey the incident spot more quickly.

4.3 Developing capabilities as Traffic Incident Management

EasyWay is a project for Europe-wide harmonised ITS deployment on main TERN corridors, driven by NRAs and operators with associated partners including the automotive industry, telecom operators and public transport stakeholders. EasyWay's Guideline for the Deployment of Incident Management (EasyWay 2011) defines several elements or components of Incident Management at three different levels of service, as summarised in Table 2.

Table 2: Different levels of Incident Management services.

Component of Incident Management	**Level of Service**		
	Basic	**Enhanced**	**Intensive**
Coverage of IM	Critical sites and/or critical periods	Selected parts of the TERN-network during specific times of the day	The whole TERN-network, all day, every day
Communication	Phone based	Some dedicated systems	Fully dedicated systems
Cooperation and coordination	Individual systems, procedures, education & training	Partly common systems, procedures, education & training	Fully common systems, procedures, education & training
Discovery and verification	Human sources 112 calls or ERT Road and exit location signs	Camera surveillance Traffic surveillance Location signs within 500 m	Automatic incident detection and camera display Full coverage location signs
Exercises	None	Table-top and meetings	Live multi-responder exercises
Evaluation	Individual evaluation Individual criteria	Individual evaluation Common criteria	Common evaluation Common criteria
Road Authority involvement	Traffic information on traffic radio and other media Recovery service	Traffic information and regulation at the scene	Traffic Management Plans (TMPs) for rerouting Traffic Officer service
Responder coordination	Ad hoc using existing public emergency services	Police led, other responders on call	Traffic Officer service and Control Centres
Responder education and training	Ad hoc	Guidelines	Formal training and certification
Road user instruction	Instructions given to road users when making a emergency call	Pre-trip information on road user behaviour via the Web	Pre-trip advice on road user behaviour in leaflets (to put in the car)

To combine NRAs' responsibility (as network maintainer, operator or manager), coverage or penetration (that is, where and when TIM is implemented), and level of service, which in practice means the structures and organisations through which TIM is implemented and the specific capabilities they represent could be the guidelines for improving the IM capabilities of different EU countries. These depend on the NRA's policies, and can vary according to need and resources.

5 EU framework for information services

In this section we give the main developments related to Traffic IM in terms of standardization and information technology on a European level. The architecture and standards for Traffic IM need to achieve a delicate balance between develop-

ments in traffic management, geo-information management, and interoperability and legal issues. We now discuss these issues in more detail.

5.1 Traffic IM

Recently, eFRAME delivered the *European ITS FRAMEWORK Architecture V4.1* (eFRAME 2011a). Inititatives for the FRAME architecture were originally developed by the KAREN project (1998-2000), and first published in 2000. It was maintained by the FRAME-S and FRAME-NET projects (2001-2005), and since 2005 it has been supported by the FRAME forum. Since 2008 it has been extended by the eFRAME project. The main goal of the eFRAME project is to define EU user-needs and functionality as an architecture reference guide for implementing the ITS Action Plan (eFRAME 2011b). This is defined in the *Consolidated User Needs for Cooperative Systems* (eFRAME 2011c). It also focuses on the emergency services and Traffic IM. The architecture is in line with the four interoperability levels as defined by ISA (2009). The model is based on Data Flow Diagrams. Although the frame architecture has been available for many years, not many Member States have adopted and/or implemented it on a national scale. Furthermore, it only provides simple guidelines for technical implementation; and is just a basic need for European traffic industry.

For IM it is fundamental to create a common vocabulary to establish semantic interoperability between emergency organizations based on IDABC (see section 5.3). The involved organizations use basically the same information elements, but sometimes with different syntax or meaning. Good examples are the location definition of incidents (WGS 84, specific national identification or hectometer post) and types of incident categories. Normally, the definition of a vocabulary takes a great deal of time. However, the traffic management domain already has a solid basis in the form of the DATEX2 dictionary. This provides the definition of information elements (semantic) and the exchange platform (UML and XML) which is basically the implementation of a Service Oriented Architecture (SOA).

There are also many European initiatives to use new in-car technology and cooperative systems to increase safety for road users. An example which is directly related to IM is e-Call which stands for *Pan-European in-vehicle emergency call system*. eCall is part of the *e*Safety initiative led by the European Commission (see European Commission 2001, 2003a, 2003b, 2005, 2006a, 2006b). eSafety assists in reducing the number of fatal road accidents in Europe. eCall will have an impact on (elements of) IM. Firstly, this is because it will allow existing IM procedures (as implemented on highways) to be used in incidents on secondary roads. eCall makes no distinction between the type of road. Secondly, because an eCall includes location information. This allows the response to be directed directly to the right location. The current systems of using road number, direction and roadside distance indicators still leaves room for ambiguity. The location information of an eCall will be in geographic coordinates. eCall can be enriched with information about the involved vehicle and driver. eCalls are passed on to the emer-

gency services, giving them an early indication as to the severity of the incident and even about the vehicles involved.

5.2 Geo-spatial initiatives

For IM it is crucial to create a common vocabulary and to establish a semantic and technical interoperability for data sharing and exchange between the emergency organizations. The involved organizations use basically the same information elements, that sometimes with different syntax or meaning. As IM information is (geo-)spatial in nature, it is relevant to consider harmonization and interoperability efforts is this field in Europe (Masser 2005).

The Open Geospatial Consortium, Inc. (OGC) is an international industry consortium of several hundreds of companies, government agencies and universities participating in a consensus process to develop publicly available interface specifications. OpenGIS® Specifications support interoperable solutions that "geo-enable" the Web, wireless and location-based services, and mainstream IT. The specifications empower technology developers to make complex spatial information and services accessible and useful with all kinds of applications (www.opengeospatial.org). The OGC has a Risk and Crisis Working Group which liaises to ORCHESTRA to synchronise the work being done within ORCHESTRA and the OGC Technical Committee. ORCHESTRA is a project of the European Union, which designs and implements specifications for a service oriented spatial data infrastructure for improved interoperability among risk management authorities in Europe. The service oriented spatial data infrastructure will enable the handling of more effective disaster risk reduction strategies and emergency management operations. The ORCHESTRA Architecture is open and based on standards (www.eu-orchestra.org).

The general situation on spatial information in Europe is of fragmentation of datasets and sources, gaps in availability, lack of harmonization between datasets at different geographical scales and duplication of information collection. These problems make it difficult to identify, access and use data that are available. Fortunately, awareness is growing at both national and EU level about the need for quality geo-referenced information to support understanding of the complexity and interactions between human activities and environmental pressures and impacts. The INSPIRE directive proposal (2007/2/EC) is therefore timely and relevant, but also a major challenge, given the many IM stakeholder.

In 2002, the EU Commission began to the develop the Infrastructure for Spatial Information in the European Community (INSPIRE). The INSPIRE Directive entered into force on the 15 May 2007. INSPIRE is ambitious: this initiative is designed to trigger the creation of a European spatial information infrastructure that delivers to the users integrated spatial information services. These services should allow the users to identify and access spatial or geographical information from a wide range of sources, from the local level to the global level, in an interoperable way to assist policy making across boundaries and for a variety of application areas. The application areas that should benefit from INSPIRE are environmental and

spatial planning, traffic and transport, agriculture, nature development, energy resources, water management, incident and emergency management. Therefore, INSPIRE intend to improve the access to spatial information for public bodies, private organizations and companies and citizens in Europe. INSPIRE establishes a European network of data services (using the publish-find-bind concept of Service-Oriented Architectures) that is based on agreed data specifications for harmonized data. The INSPIRE Directive compels data providers (public authorities across Europe) to be compatible with the INSPIRE *Implementation rules and guidelines*.

INSPIRE offers opportunities for IM to adopt a harmonized framework for the application of the harmonized spatial data to create a Situation report (Sitrap) and a Common Operational Picture (COP) for IM. INSPIRE offers the ability to use a spatial data infrastructure to adopt the underlying data sharing platform for these new information-sharing concepts for IM. INSPIRE is complementary to related policy initiatives, such as the Commissions' proposal for a Directive on the re-use and commercial exploitation of Public Sector Information (European Commission 2003c).

Tracking services play an important role in allocating resources for emergency services. One of the goals of the European Commission was to make available an open, global system, fully compatible with, but independent of GPS and GLONASS global navigation systems. The Galileo program is Europe's initiative for a state-of-the-art global satellite navigation system, providing a highly accurate, guaranteed global positioning service under civilian control. The fully deployed system will consist of 30 satellites and the associated ground infrastructure. Galileo will be interoperable with GPS and GLONASS. Hence, it must be possible for Galileo receivers to also use GPS satellites. Galileo is due to be launched in 2015.

Another major geospatial European project is the Global Monitoring for Environment and Security Program (GMES), for the establishment of a European capacity for Earth Observation. Users will be provided with information through services dedicated to the systematic monitoring and forecasting of the state of the Earth's subsystems. Six thematic areas are being developed: marine, land, atmosphere, emergency, security, and climate change. A land monitoring service, a marine monitoring service, and an atmosphere monitoring service, which contribute directly to the monitoring of climate change, and to the assessment of mitigation and adaptation policies. Two additional GMES services address, respectively, emergency response (e.g. floods, fires, technological accidents, humanitarian aid) and security-related aspects (e.g. maritime surveillance, border control).

5.3 Interoperability

Interoperability is the ability of diverse systems and organizations to work together (inter-operate). The term is often used in a technical systems engineering sense, or alternatively in a broad sense, taking into account social, political, and organizational factors that impact system-to-system performance. In 2004 the European

Commission decided to create an interoperability framework to support the delivery of pan-European eGovernment services for public Administrations, Businesses and Citizens (IDABC, European Commission 2004). Interoperability, from the 'European Interoperability Framework' (EIF) perspective, is defined as "*the ability of information and communication technology systems and of the business processes they support to exchange data and to enable the sharing of information and knowledge*". The IDABC program provides guidelines to achieve interoperability with respect to three aspects:

- technical interoperability: technical issues of linking computer systems, and the definition of open interfaces, data formats and protocols including telecommunications;
- semantic interoperability: ensuring that the precise meaning of exchanged information is understandable by any other application not initially developed for this purpose;
- organizational interoperability: modelling business processes, aligning information architectures with organizational goals, and helping business processes to cooperate.

On 31 December 2009, the new ISA (Interoperability Solutions for European Public Administrations) program replaced the activities of the 2004 IDABC program and delivered a European Interoperability Framework (EIF) draft version 2.0 (ISA, 2009). The EIF 2.0 adds a legal level and a political context to the interoperability levels, as originally defined by IDABC (European Commission 2004). Legal interoperability focuses on an aligned legislation, so that exchanged data is accorded proper legal weight. In the political context it is necessary to make sure that cooperating partners have compatible visions, aligned priorities, and focused objectives.

The key for IM interoperable participants is thus sharing information. However, each IM actors its own jargon or technical terminology. The first step to sharing information is sharing a dictionary, a common set of definitions (semantic interoperability). After that we can look at the technology infrastructure that is needed to support what must be accomplished by any of the participants (technical interoperability). The driving force of this study of the possible and desirable is the set of tasks that will be needed to accomplish the tactical and strategic goals of the systems (organizational interoperability). Any requirement that is to be supported by the technology must be derived from these tasks. One of the conclusions from IDABC is that there is a shift from conventional closed systems to more interoperable systems based on SOA. In SOA information and business processes are provided in a generic way using open standards. The basic elements are a common vocabulary (semantic), using eXtenisble Mark-up Language (XML) and, web services over a telecommunication infrastructure (technical).

Interoperability within the geo-sector will be reached progressively as metadata, data and services compliant with the INSPIRE Implementing Rules are becoming available and will require the active involvement of all actors identified in INSPIRE, namely European Union Member States relevant Institutions and the Commission.

5.4 Standardization of sensors, identification and location technologies

Several organizations, such as ISO (www.iso.org), EPC global (www.-epcglobal.org), w3 consortium (www.w3.org) and OpenGeospatial Consortium (www.opengeospatial.org), operate with a broad mandate from industry and governments to ensure that technologies and services interoperate starting from the lowest level of the technology stack. The push for interoperability derives from business requirements and the possibility of developing added value services. On the other hand, interoperability eliminates one of the tradition strongholds of technology suppliers and the ability to lock-in customers to proprietary technologies that are expensive to replace. In spite of the drive towards interoperability the incentive to exploit possible open spaces, first mover advantages, or early monopolies, will remain and counterbalance the interoperability push. The benefits of standardization would be lost if in different parts of the globe, or in different sectors, or areas organizations would have to invest in different technologies for location and RFID.

For the implementation of a GDI it is necessary that it complies with certain standards. In the past there was a strong focus on data delivery, the last few years data discovery and delivery through internet, intranet and extranet is more common. Apart from national initiatives there are three main standardization organizations that play an important role in the 'opening up' from the geospatial community. These standardization organizations are the Open Geospatial Consortium, the ISO TC/211 and the W3C.

The working group TC/211 defines standards in the field of digital geographic information. This work aims to establish a structured set of standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth. These standards may specify, for geographic information, methods, tools and services for data management (including definition and description), acquiring, processing, analyzing, accessing, presenting and transferring such data in digital/electronic form between different users, systems and locations. The work shall link to appropriate standards for information technology and data where possible, and provide a framework for the development of sector-specific applications using geographic data (www.isotc211.org).

The World Wide Web Consortium (W3C) is an international consortium where member organizations, a full-time staff, and the public work together to develop Web standards. W3C's mission is: to lead the World Wide Web to its full potential by developing protocols and guidelines that ensure long-term growth for the Web. W3C primarily pursues its mission through the creation of Web standards and guidelines. Since 1994, W3C has published more than ninety such standards, called W3C Recommendations. W3C also engages in education and outreach, develops software, and serves as an open forum for discussion about the Web. For the Web to reach its full potential, the most fundamental Web technologies must be compatible with one another and allow any hardware and software used to access the Web to work together. W3C refers to this goal as “Web interoperability”. By publishing open (non-proprietary) standards for Web languages and protocols,

W3C seeks to avoid market fragmentation and thus Web fragmentation (www.w3c.org).

5.5 Legal aspects

With the introduction of IAF 2.0 (ISA 2009), legal aspects play an increasing role by accomplishing interoperability. Besides technological and market developments, the adoption and introduction of location technologies were influenced, for example by security and privacy issues. In terms of privacy, it is especially the tracking of people or goods transported which raises many privacy issues. As defined by Westin (1970) "*Privacy is the claim of individuals, groups or institutions to determine when, how, and to what extent information about them is communicated to others, and the right to control information about oneself even after divulgating it*". In this definition a person's privacy corresponds to the control of that person's information. Legislators have addressed personal information in various laws, which have implications for location and sensor services. To protect personal data from an economic perspective, extensive attention is paid in European law, in general, and more specifically for use in electronic communications. Article 7 of the *Charter of Fundamental Rights* of the European Union (European Commission 2000) focuses on some general issues on the respect for private and family life: "Everyone has the right to respect for his or her private and family life, home and communications". Directive 1995/46/EC (European Commission 1995) provides the legal framework for the protection of individuals with regard to the processing of personal data, while Directive 2002/58/EC (European Commission 2002) addresses location privacy specifically, stating that location data can be processed only after being anonymized or after having gained the consent of the user, who should be perfectly informed of the use that will be made of his/her personal data. In a broader context, information-sharing is constrained by a number of other legal aspects. For example, Smits and de Jong (2008) identified seven legal design principles for the introduction of a Common Operational Picture (COP) for Traffic IM: proportionality; explicit organizations goals; respect for fundamental human rights; interoperability; data availability; protection of personal data; and financing regulated by governments.

6 Conclusions and way forward

Despite efforts towards European harmonization of IM, there are still considerable differences in this respect between countries in Europe. Since IM is mainly an organizational problem, this is to be expected. The EU's public consultation on road safety has indicated that there is opposition to the option of the forced harmonisation of road safety and incident practices. The Member States prefer to have a final say on legislation in these matters. Since changing IM practices involves legislation, this effectively means that no European harmonization of IM procedures

can be expected in a short time period. In all countries the same services are involved in IM. Police, ambulance and fire services are called in, and all countries have automobile clubs which are involved to a varying extent in towing services. In the EU countries studied, the police have different responsibilities at the scene of the incident.

The way countries apply IM, in terms of organisation, responsibility and specific measures, varies greatly across Europe. The research and development efforts in Europe are very fragmented. A major challenge is to find an effective way in which different initiatives, like CEDR, EasyWay, ITS and FRAME, can work together to create a European framework in which countries are able to align their individual IM activities to their own national policy goals. It should be noted that not all Member States participate in the CEDR survey. However, a joint effort based on the findings of the CEDR results form a stable basis for the next steps. The main conclusion from our investigation are:

- in the last decade significant improvements have been made to reduce the impact of road transport in terms of fatalities and injuries. However, many efforts still have to be made to reach the new European 'zero-vision' goal on road safety for 2050;
- despite efforts towards European harmonization, there is still considerable variety of IM deployment across Europe, with a lack of uniform architecture, standards, data models, and definitions, and there is no general agreement on the different process phases;
- solutions for interoperable information systems for traffic IM need to balance between standards in traffic management, disaster management en the geo-information sector;
- a European IM interoperable framework should at least address four specific goals: cross-border management between countries; increase of support at the crisis management level; information-sharing between public and private road authorities, and the emergency services and, a uniform IM application on the TERN infrastructure.

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LCMS (Calamity Management System Netherlands) and IBOR (Integral Management System Public Space) deliver Added Value

Jan Cornelis den Ouden

Logica Nederland BV, PO Box 159, 1180 AD Amstelveen, The Netherlands,
e.mail: jan.cornelis.den.ouden@logica.com

Abstract

In the Netherlands the regional security organizations are using the LCMS information system for the coordination and control of calamities in the provinces and regions of the Netherlands. At the moment this information system coordinates a crises based on actor level. In this way, the LCMS platform coordinates the emergency services to go from A to B where B is the place of the crises (who should be at certain place at a certain time, with what materials and other resources.). What the LCMS system does not or barely coordinate, is the way public objects in the public space environment behave during the course of an incident. Public objects could be traffic lights, public lighting, sewers and bridges and other meaningful objects needed during the logistic movements of recourses from emergency services. For the management of objects in the public space environment IBOR is an information system that could be of enormous benefit to engage assistance on objects during the course of a crisis event.

1 Introduction

In the Netherlands the regional security organizations are using the LCMS for the coordination and control of calamities in the provinces and regions of the Netherlands. At the moment this information system coordinates a crises based on actor level. In this way, the LCMS platform coordinates the emergency services to go from A to B where B is the place of the crises (who should be at certain place at a certain time, with what materials and other resources.). What the LCMS does not or barely coordinates, is the way public objects in the public space environment

behave during the course of an incident. Public objects could be traffic lights, public lighting, sewers and bridges and other meaningful objects needed during the logistic movements of recourses from emergency services. For the management of objects in the public space environment IBOR is an information system that could be of enormous benefit to engage assistance on objects during the course of a crisis event. This paper is about the benefits between the concerted action of the IBOR system on the one hand and the LCMS on the other hand.

2 IBOR

IBOR concerns management and remote control of dynamic objects in public spaces, both integral as well as situational. Examples include the dimming or purposely brightening of public lighting for either safety or energy savings depending on circumstances. Another example is closing off a shopping area in a city for traffic or indeed opening them up for emergency services. Simply monitoring the status of the objects can already be of great value.

Three properties of IBOR make the concept unique: “Multi object”, “Multi vendor” and “Multi actor”.

2.1 Multi object

Multi object refers to IBORs ability to manage, control and operate a variety of objects. These include light posts, (sewage) pumps, traffic lights, road closures (boulders and barriers), bridges and water locks.

Using a Microsoft Surface table as a centrally located interface, IBOR presents all values and statuses of these objects and also offers remote control functionality.

2.2 Multi vendor

By closely collaborating with all suppliers, all systems are compatible, despite differences in protocols and management systems. This way, lighting systems, pump systems, traffic systems etc. can be managed, present and remotely controlled. This enables true improvements in management processes.

2.3 Multi actor

With IBOR, control of an object can be temporarily transferred to another organization. When it comes to sustainability, integral safety and mobility, cities are no longer on their own. When interests of police forces or safety regions are con-

cerned for example, they could be demanding control of lighting systems or other objects.

IBOR brings new possibilities within arm's reach. When emergency services need to act, it can be very useful if they can control objects in public space. IBOR will offer them this option. Transferring control to a control room for example. Bridges, boulders, and traffic lights can be operated from a control room, enabling emergency services to arrive at a site of an accident without incidents. Because IBOR collects its data from regular maintenance systems, it will even know if certain roads are closed. After arriving, emergency services can be further assisted by increasing water pressure in hydrants or illuminating the location of the calamity. Another example includes is guiding crowds to and from events in city centres. Police forces can anticipate this by illuminating certain routes and gathering places. Figure 1 below explains the IBOR system:

The heart of the system comprises of the database containing the real time object data, the connected statistic object data and several essential functions: analysis and presentation functions, dynamic functions and the connection with management systems such as ERP.

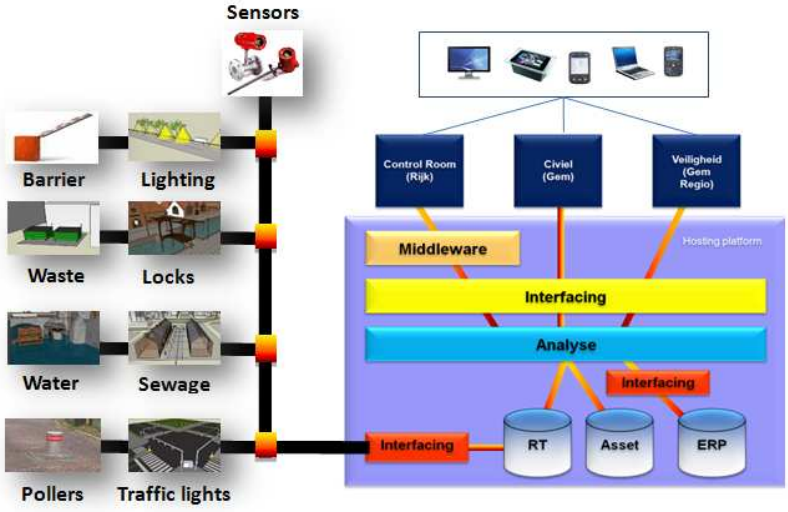

Figure 1: Explanation of the IBOR system.

Analysis and presentation can be set up for Multi actor mode and has no technical limits, ranging from smart Phone to control room. The dynamic function wirelessly connects objects and sensors to the IBOR system. This connection does not use UMTS or SMS as is done usually, but uses a protocol that is 99.998% reliable and was specially developed with Vodafone for this purpose. Using this function, object status and local circumstances can be monitored locally and allows the behaviour of the object to be controlled.

3 IBOR functionality as an aspect of the LCMS

The IBOR functionality can be integrated with the LCMS in two ways. The first one is the status quo of an object on the GEO ICT map of the LCMS. The IBOR information system reports the status, conditions or aspects of the functionality back to the GEO map of the LCMS about a certain object. In this way the emergency coordinator collects information about the status of certain objects in the field. Secondly the coordinator could manage a scenario of actions to be disseminated towards objects, which responds immediately to the scenarios that are put upon these objects. When emergency services have the opinion in certain circumstances that help is better provided, when an object is set in a certain stage, (like a poller that could go down at a specific time, or to change the lighting levels of public lighting poles). IBOR can be used as a system to provide that action needed.

SharePoint and GIS

William Vroegindewey[1], Robert Kieboom[2] and Rob Peters[3]

[1]MACAW, The Netherlands, e.mail: William.Vroegindewey@macaw.nl

[2]CityGIS, Statenplein 21, 2582 EZ, Den Haag, The Netherlands,
e.mail: Robert@CityGIS.nl

[3]VRK, Zijlweg 200, Haarlem, The Netherlands, e.mail: RPeters@vrk.nl

1 Introduction

Since July 2011 the Public Safety District organizations in the Netherlands are required to implement the Dutch "Basisregistratie Adressen en Gebouwen" (base registration of addresses and buildings, acronym "BAG") for geotagging of information generated in their main processes. This includes the use of geotagging in document management and object management solutions.

In a cooperation between the VeiligheidsRegio Kennemerland (VRK), CityGIS and MACAW, a proof of concept has been developed in which content with spatial information stored in SharePoint 2010 is geotagged with BAG data and displayed on a map using CityGIS Barracuda.

VRK is using a SharePoint Server 2010 document management solution for the registration of incoming and outgoing mail, storing of disaster management and other core process documents. Many of these documents include spatial information and will be tagged with BAG data to comply with government requirements on the one hand and to allow exposing these documents through CityGIS on the other hand.

Documents are uploaded into SharePoint through the standard SharePoint document management features and tagged with the relevant VRK metadata and with a BAG ID. The BAG data comes from a separate repository and is regularly updated with the latest information about addresses and buildings in the region.

The solution allows several ways to access and view the documents. In Barracuda users can browse the map and see objects with geotagged documents and a link to SharePoint. Clicking the link will take the user to a page in SharePoint showing all documents related to this object. From SharePoint it is possible to search for geo related BAG information (such as address, postal code etc.) and find the associated documents in SharePoint or display the related objects on a map (Figure 1).

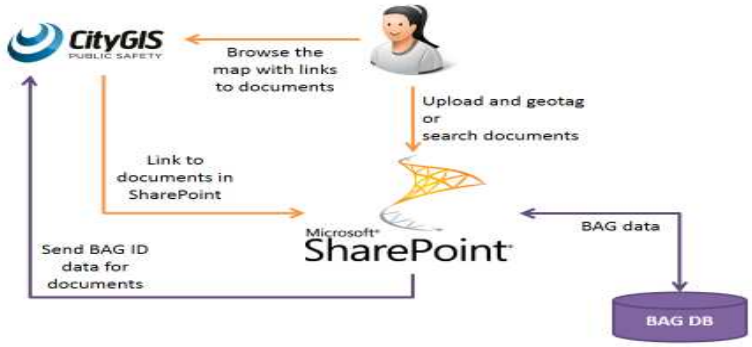

Figure 1: System architecture.

Part IV: Intelligent Systems for Crisis Response

Abstracts of papers published in 'Intelligent systems for Crisis Response', Springer, Berlin, Heidelberg

Multi-agents Evacuation Simulation Data Model with Social Considerations for Disaster Management Context

Mohamed Bakillah[1], J. Andrés Domínguez[2] and Alexander Zipf[1]

[1]Rupprecht-Karls-Universität Institute for GI-Science, Heidelberg, Germany,
e.mail: mohamed.bakillah@geog.uni-heidelberg.de

[2]Department of Sociology and Social Work, University of Huelva, Huelva, Spain

Abstract

Large scale disasters often create the need for evacuating affected regions to save lives. Disaster management authorities need evacuation simulation tools to assess the efficiency of various evacuation scenarios and the impact of a variety of environmental and social factors on the evacuation process. Therefore, sound simulation models should include the relevant factors influencing the evacuation process and allow for the representation of different levels of detail, in order to support large scale evacuation simulation while also offering the option of considering factors operating at a finer level of detail, such as at the single individual level. In particular, the impact of social factors, such as interaction between agents, should be integrated into the simulation model to reflect the reality of evacuation processes. In this paper, we present a generic data model for agent-based evacuation simulation that includes the relevant social parameters identified in the emergency literature. The model is composed of three sub-models that describe the agents, their context and behaviour, the dynamic environment in which the agents evolve and the parameters of the evacuation scenario. The objective of this model is to improve the simulation so that it can be better represent reality

An A*-based Search Approach for Navigation among Moving Obstacles

Zhiyong Wang and Sisi Zlatanova

Delft University of Technology, OTB Research Institute for the Built Environment, GIS Technology Section, Jaffalaan 9, 2628 BX Delft, The Netherlands.
e.mail: {Z.Wang-1 | S.Zlatanova}@tudelft.nl

Abstract

Summary. Finding an optimal route in a dynamic transportation network affected by disasters is a critical problem for emergency response. Although many routing algorithms have been developed, and some of them show the ability to guide first responders around the static damaged infrastructure, there are few efforts devoted to the efficient routes avoiding moving obstacles. Emergencies caused by natural or man-made disasters can result in both static and moving obstacles in a transportation network, which poses a set of serious challenges for researchers in the navigation field. In this paper, we study the shortest-path problem for one moving object to one destination in a dynamic road network populated with many moving obstacles. Existing approaches, which are developed for stationary network, are incapable of managing complex circumstances where the status of the road network changes over time. We propose a model to represent the dynamic network and an adapted A* algorithm for shortest path computations in the context of moving obstacles. Moreover, this paper presents a web-based application for route planning. It integrates an agent-based simulation tool for both analysis of the dynamic road network and simulation of first responders' movements, and web technologies for enabling the response community to easily and quickly share their emergency plans and to work collaboratively. We provide an experimental comparison of performance with the standard A* algorithm under different circumstances to illustrate the effectiveness of our approach.

A Two-level Path-finding Strategy for Indoor Navigation

Liu Liu and Sisi Zlatanova

Delft University of Technology, OTB Research Institute for the Built Environment, GIS Technology Section, Jaffalaan 9, 2628 BX Delft, The Netherlands, e.mail: {L.liu-1 | S.Zlatanova}@tudelft.nl

Abstract

In this paper, a two-level path-finding strategy is presented. It can derive geometric indoor route according to different preferences. On the first level a room sequence is derived by means of non-metric criteria, such as the number of visited rooms or the number of obstacles in rooms. Based on the sequence, a geometric path with respect to obstacle shape and user size is computed for each traversed room. Then all of these paths compose a final path. The approach is illustrated with an example of a residential building. Compared to other related work, this strategy allows greater flexibility in providing the detailed path within changing indoor environments.

An Approach to Qualitative Emergency Management

Rami Al-Salman, Frank Dylla and Lutz Frommberger

Cognitive Systems (CoSy), FB3 – Informatics, The University of Bremen, P.O. Box 330 440, 28334 Bremen, Germany, e.mail: Rami@informatik.uni-bremen.de

Abstract

Emergency Management Systems (EMSs) are playing an important role to save people's life's and to reduce the effects of disasters such as earthquakes or floods. In this paper, we propose an approach to qualitative emergency management. This will empower emergency managers to query spatial databases using qualitative terms used in spoken language, such as 'near' or 'north of'. By providing a qualitative DBMS layer that covers the three qualitative aspects topology, distance, and direction, our system is able to handle qualitative spatial queries. Qualitative spatial queries are translated into formal Structured Query Language (SQL) database queries which are used to query and retrieve results from spatial databases.

Smoke Plume Modelling in Crisis Management

Hein Zelle[1], Edwin Wisse[2], Agnes Mika[3] and Tom van Tilburg[4]

[1]BMT ARGOSS, Voorsterweg 28, 8316 PT Marknesse, The Netherlands, e.mail: hein.zelle@bmtargoss.com

[2]Geodan, President Kennedylaan 1, 1079 MB Amsterdam, The Netherlands, e.mail: edwin@kandefang.com

[3]BMT ARGOSS, Voorsterweg 28, 8316 PT Marknesse, The Netherlands, e.mail: agnes.mika@bmtargoss.com

[4]Geodan, President Kennedylaan 1, 1079 MB Amsterdam, The Netherlands, e.mail: tom.van.tilburg@geodan.nl

Abstract

The current state of numerical modelling allows detailed, accurate weather forecasting, as well as forecasting of the transport and dispersion of smoke plumes and gas clouds. However, emergency workers do not have access to such state-of-the-art information during large incidents. BMT ARGOSS and Geodan have developed an integrated system to provide emergency workers with weather and smoke plume forecasts, in a modern crisis management system based on a geographical information system.

Simulation System of Tsunami Evacuation Behaviour during an Earthquake around JR Osaka Station Area

Ryo Ishida[1], Tomoko Izumi[2] and Yoshio Nakatani[2]

[1]Ritsumeikan University, Graduate School of Science and Engineering, Shiga, 5250058 Kusatsu City, Japan, e.mail: is003082@ed.ritsumei.ac.jp

[2]Ritsumeikan University, College of Information Science and Engineering, Shiga,5250058 Kusatsu City, Japan, e.mail: izumi-t@fc.ritsumei.ac.jp, nakatani@is.ritsumei.ac.jp

Abstract

In the case of a Tonankai earthquake or Nankai earthquake occurring, it is predicted that tsunami damage will occur at the JR Osaka Station area. The purpose of this study is to propose a computer simulation which can calculate the appropriate behavior of evacuees in order to avoid tsunami damage in that situation. There are many institutions, department stores and hotels, and an underground shopping center, around JR Osaka Station. Therefore, various situations must be considered, such as collisions between people trying to evacuate to buildings and people trying to get away from the underground shopping center and buildings to the outside, in order to plan safe evacuation. In this paper, we implement a simulation that assumes various situations, and collect data fundamental to devising a method for inducing evacuation.

Interactive Simulation and Visualisation of Realistic Flooding Scenarios

Christian Kehl[1] and Gerwin de Haan[2]

[1]Delft University of Technology, Electrical Engineering, Mathematics and Computer Science Department of Intelligent Systems, Mekelweg 4, 2628 CD Delft, The Netherlands, e.mail: {C.Kehl | G.deHaan}@tudelft.nl

Abstract

Floods are a permanent threat for urban environments and coastal regions. Due to the numerous environmental and climatological factors that cause floods, their prevention and prediction is complicated. Flood protection and prevention plans are assessed by computational models. The related risk analysis communication demands simulations of accurate inundation models and their interactive visualisation.

In our new Dutch Knowledge for Climate project we work closely together with industrial partners with whom we develop a platform that supports this communication. Our research focuses on real-time flow simulations, their interactive visualisation and steering techniques for flooding scenarios. Our goal is an interactive, realistic problem-solving environment for flooding discussions amongst decision makers, water boards, hydrologists and the general public. Most important in this research are sophisticated algorithms that promote this goal. Related work in the field is done on small-scale examples and abstract computational models. We work on large-scale, high-resolution, realistic computations while maintaining interactivity. For this we use aerial terrain LiDAR point clouds of the Netherlands and most recent, complex Computational Fluid Dynamics (CFD) models. The rendering system will apply a combination of new point cloud compression algorithms and spatial Level-of-Detail data structures. Fast CFD simulations will be achieved by subgridding and parallel processing of non-linear calculation models. Additionally, the integration of various geo-information (i.e. precipitation) is key to educated flooding decision-making.

In this paper we describe in detail our project goals, our current progress and upcoming related research tracks.

Identification of Earthquake Disaster Hot Spots with Crowd Sourced Data

Reza Hassanzadeh[1] and Zorica Nedovic-Budic[2]

[1]Geography, Planning and Environmental Policy School, University College Dublin, Blackwell room, GPEP research Unit, Richview, D4, Dublin, Ireland, e.mail: reza.hassanzadeh@ucdconnect.ie

[2]Geography, Planning and Environmental Policy School, University College Dublin, Planning building, Geography, Planning and Environmental Policy School, Richview, D4, Dublin, Ireland, e.mail: zorica.nedovic-budic@ucd.ie

Abstract

This paper explores the value of the application of Crowd Sourced (CS) data in identification of areas damaged in the aftermath of an earthquake. A survey was conducted to collect CS data based on two stage cluster sampling method from people who experienced the earthquake in Bam city, Iran in 2003. The CS data submission time was considered for data analysis, including continuous, discrete and complete data submission. The CS data reporting on the level of building destruction, the number of fatalities and the number of injuries was used to identify hot spot areas for dispatching response operation teams. To test the value of CS data in identification of hot spots, the results were compared with the Actual Earthquake (AE) data by using of Fuzzy Kappa index, Fuzzy Inference System, and cross tabulation to calculate similarity and dissimilarity, quality and allocation disagreement between them. The similarity and dissimilarity measures indicate that there is a low to moderate similarity between hot spot maps based on the application of CS and those based on the Actual Earthquake (AE) data. They suggest that CS data has a moderate potential role in identifying highly damaged areas (hot spots) and low damaged areas (cold spots). The results of this study show that the CS data is better suited for more general determination of hot and cold spot areas than to provide exact locations where the resources could be dispatched. Consequently, we conclude that CS data is useful for decision making process by dis-

aster managers if combined with the other sources of information to allocate the limited resources in affected areas.

Remote Sensing based Post-disaster Damage Mapping with Collaborative Methods

Norman Kerle

Faculty of Geo-information Science and Earth Observation, Dept. of Earth Systems Analysis, University of Twente, Hengelosestraat 99, P.O. Box 6, 7500 AA Enschede, The Netherlands, e.mail: kerle@itc.nl

Abstract

Remote sensing has become an essential tool in post-disaster response, including damage assessment, traditionally done by professional analysts. However, geodata and –tools have become ubiquitous, which has allowed other organizations and laypersons to play a more prominent role in post disaster response and assistance. This chapter addresses the prospects and challenges of collaborative damage mapping. It discusses limitations and problems of traditional damage mapping that may be overcome by modern Web 2.0-based methods. The response to the 2010 Haiti earthquake, in particular the collaborative damage mapping by the GEO-CAN initiative and a number of problems associated with this activity, are discussed in detail. These center on the analysis problem inherent in image-based damage assessment, but also the limited mutual understanding among the mapping organizers, map user and volunteer mappers. Cognitive task analysis (CTA) is recommended to address and overcome the cognitive challenges and demands in collaborative mapping.

Automatic Determination of Optimal Regularization Parameter in Rational Polynomial Coefficients Derivation

Junhee Youn, Tae-Hoon Kim, Changhee Hong and Jung-Rae Hwang

Korea Institute of Construction Technology, 283 Goyangdae-ro, Ilsanseo-gu, Goyang-si, Gyeonggi-do, KOREA, e.mail: younj@kict.re.kr

Abstract

Recently, massive archives of ground information are provided by imagery from new sensors. To establish the functional relationship between image and ground space, sensor models are required. The rational functional model (RFM), which is used as an alternative to rigorous sensor model, becomes attractive due to its generality and simplicity. To get a rational polynomial coefficients (RPC) in RFM, we encounter the problem for obtaining a stable solution, because design matrix for solutions usually ill-conditioned in the experiments. To solve such an unstable problem, regularization techniques are generally used. In this paper, we describe the determination of optimal regularization parameter in the regularization technique during RPC derivation. A brief mathematical background of RFM is presented, followed by numerical approaches for automatic determination of optimal regularization parameter with the Euler Method. Experiments are carried out; assuming tilted aerial image is taken with known rigorous sensor model.

Granular Computing and Dempster-shafer Integration in Seismic Vulnerability Assessment

Fateme Khamespanah[1], Mahmoud Reza Delavar[2], Hadis Smadi Samadi Alinia[3] and Mahdi Zare[4]

[1]Department of Surveying and Geomatics Engineering, College of Engineering, Tehran University, Iran, e.mail: Fa_khamespanah@ut.ac.ir

[2]Center of Excellence in Geomatics Engineering in Disaster Management, Department. of Surveying and Geomatics Engineering, College of Engineering, Tehran University, Iran, e.mail: mdelavar@ut.ac.ir

[3]GIS Division, Department of Surveying and Geomatics Engineering, College of Engineering, University of Tehran, Tehran, Iran, e.mail:, alinia@ut.ac.ir

[4]Seismology Research Center, International Institute of Earthquake Engineering and Seismology (IIEES), Tehran, Iran, e.mail: mzare@iiees.ac.ir

Abstract

Iran is one of the seismically active areas of the world due to its position in the Alpine-Himalayan mountain system. Tehran has several faults hence huge earthquakes will permeates human settlement there. Production of seismic vulnerability map could help disaster management organizations to develop and implement a plan to promote awareness of earthquake vulnerability and implementation of seismic vulnerability reduction measures in Tehran. The process of seismic vulnerability assessment is a supervised classification problem which undertaken by implementation of classification rules obtained from relationships between classes defined by a set of attributes and a unified decision of a group of experts.

Therefore, seismic vulnerability assessment is a multidisciplinary problem which needs a multi criteria decision making. The influencing factors make the problem and the process of decision making a complicated disaster management problem. To overcome this problem, this paper proposes an integrated model based upon the granular computing and Dempster-Shafer to extract classification rules for classification of urban areas regarding seismic vulnerability. One of the significant properties of granular computing is induction of more compatible rules having no inconsistency. In this paper, Dempster-Shafer theory is used to integrate and model the conflict among different experts' viewpoints to get an informed decision regarding the measure of seismic vulnerability in each statistical unit in the study area.

Managing Satellite Precipitation Data (PERSIANN) through Web GeoServices: a Case Study in North Vietnam

Maria A Brovelli[1], Truong Xuan Quang[1] and Gérald Fenoy[2]

[1]DIIAR, Politecnico di Milano – Como Campus (Como), Italy, e.mail: {maria.brovelli, xuan.truong}@polimi.it

[2]GeoLabs SARL, Futur Building 1, 1280, Avenue des Platanes 34970 Lattes, France, e.mail: gerald.fenoy@geolabs.fr

Abstract

Rainfall is one of the most important factors affecting various types of hazards such as: landslides, floods, sea level rise and so on. With the availability of satellite rainfall estimates at fine time and space resolution, it has also become possible to mitigate such problems over the world. But satellite rainfall needs to be monitored before use, because the satellite data does not reflect the strong influences on precipitation of topography in some cases. Relief of study area is very complex including mountain and plain areas. In this paper we present a Decision System and an intelligent geoportal for North Vietnam based on Web Service allowing users to investigate satellite rainfall by means of a direct comparison and of the Revised Universal Soil Loss Equation (RUSLE) model. The comparison method uses data from Precipitation Estimation from Remote Sensing Information using Artificial Neural Network (PERSIANN) and rain gauges (RG) to investigate the interpolation of RG data. Furthermore, we also estimate a correlation and examined a percentage of simultaneous rain or no-rain between them. We realize that correlation between PERSIANN and gauge data meets expectation value when we investigate monthly data. The RUSLE model for computing the soil loss, which requires a huge amount of information and data, was handled for both PERSIANN product and rain gauges data to estimate the difference due to the usage of the two data sources.

Applying GIS in Seismic Hazard Assessment and Data Integration for Disaster Management

Rumiana Vatseva, Dimcho Solakov, Emilia Tcherkezova, Stela Simeonova and Petya Trifonova

National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, Acad. G. Bonchev Str., Bl. 3, Sofia, Bulgaria, e.mail: rvatseva@gmail.com, {dimos, et, stelas}@geophys.bas.bg, petyageo@mail.bg

Abstract

Among the many kinds of natural and man-made disasters, earthquakes dominate with regard to their socially and economically impact on the urban environment. Seismic hazard assessment for industrial objects is of a substantial importance, because it provides valuable information for seismic safety and disaster mitigation. The main objective of the study is to integrate basic geo-datasets in thematic mapping products and to assess the seismic hazard using GIS techniques to provide a basis for disaster management of the case study of Ada Tepe in Bulgaria. GIS is applied as a valuable tool to support an effective decision-making by managing, structuring and utilizing comprehensive data for disaster prevention. Web GIS is of interest to us in the future work, because it is provided the ease for real-time access and simultaneous informed decision-making process for all stakeholders involved.

Methodology for Landslide Susceptibility and Hazard Mapping using GIS and SDI

Tomás Fernández[1], Jorge Jiménez[2], Jorge Delgado[1], Javier Cardenal[1], José Luis Pérez[1], Rachid El Hamdouni[2], Clemente Irigaray[2] and José Chacón[2]

[1]Department of Cartographic, Geodetic and Photogrammetric Engineering, Campus de las Lagunillas, University of Jaén, 23071 Jaén, e.mail: {tfernan, jdelgado, jcardena}@ujaen.es

[2]Department of Civil Engineering, Campus de Fuentenueva s/n, University of Granada, 18071 Granada, e.mail: {jorgejp, clemente, rachidej, jchacon}@ugr.es

Abstract

In this work a methodology for preparing landslides susceptibility and hazard maps is presented, based in a bivariate analysis between past movements and determinant factors. The methodology for determining the susceptibility is an adaptation of the matrix method to a GIS, and it has been tested and validated in different zones and environments of Andalusia (southern Spain). The text also discusses the availability of information layers in Spanish SDI to developing these susceptibility maps. For the hazard evaluation, we propose a methodology of determining the susceptibility in different return periods from inventories of landslides that show activity in these considered periods. The activity was estimated from stereoscopic and monoscopic analysis of aerial photographs from different dates, using geological and geomorphic criteria, and the study of rainfall time series. Since all, four periods were considered in logarithmic scale of 10 years (approximate return period of rainfall generating instability in the area), 100, 1000 and 10000 years. After determining the susceptibility, it was transformed into annual hazard dividing by the number of years of the return period. Finally, a total hazard map was obtained by determining at each point the maximum value of hazard of the different periods and it is expressed in several intervals.

Transport Network Vulnerability Assessment Methodology, based on the Cost-distance Method and GIS Integration

Toma-Danila Dragos

National Institute for Earth Physics, 12 Calugareni St., Ilfov, Romania, e.mail: toma@infp.ro

Abstract

Considering the various effects of natural disasters, and the need for a fast intervention and recovery time, before facing the associated problems it is needed to mitigate the risks. A basic and initial step is to assess the vulnerability in high risk areas. The importance of a transport network is major, whether it is a road, railway (for access) or pipe (for resources) network. Various methods were described for analyzing their behavior to disastrous events (like earthquakes, landslides, flooding). The methodology proposed in this study integrates all related input data within a GIS software, adding by so the spatial dimension, and adapt the cost-distance method to obtain fictive costs that translate into vulnerability states for each point of a network. Also, the hot-points that can determine detour costs are taken into consideration, by means of random "What if?" scenarios that are generated by an automation model. The fact that the cost-distance method requires origins to which the costs will refer it is important, because the vulnerability values will also be related to how hard it is for an emergency intervention team to reach a certain segment of the network. Because of the various degrees of freedom in the methodology, different methods can be also added to the actual core, in order to serve the purpose, whether it is emergency route analysis, road planning or loss estimation assessment. In order to test and exemplify the methodology and the results, a road network seismic vulnerability assessment example is presented, for a Romanian County right on top of the Vrancea Seismic Area. Specific details are given about the possibilities to implement the methodology.

Effectiveness of Net-centric Support Tools for Traffic Incident Management Results of a field experiment

John Steenbruggen[1], Maarten Krieckaert[1], Piet Rietveld[1], Henk Scholten[1] and Maarten van der Vlist[2]

[1]VU University, Department of Spatial Economics, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands. e.mail: (john.steenbruggen, m.n.m.krieckaert, p.rietveld, hscholten)@vu.nl

[2]Ministry of Infrastructure and Environment. Zuiderwagenplein 2, 8224 AD Lelystad, The Netherlands. e.mail: maarten.vander.vlist@rws.nl

Abstract

In the last two decades traffic Incident Management (IM) has become an important tool to reduce and prevent congestion on the road network, especially in urban areas. IM involves the coordinated interactions of many public and private actors. To support their tasks in an effective way, information systems are increasingly important. Especially information and system quality and situational awareness has been identified as major hurdles for effective emergency response. This paper reports the results of an empirical analysis of the effectiveness of net-centric information systems to improve the cooperation between public and private IM organization. A set of controlled experiments were conducted with 16 participants. Data on the responses of the participants were collected through questionnaires and observer notes. The analysis focused on the comparison between the tools tested in terms of the appreciation of information and system quality, the comparison between communication and coordination of emergency workers; the value of Situational Awareness in the performance of the decision making process, and, how scenario complexity can effect design principles of a net-centric systems.

A Customizable Maturity Model for Assessing Collaboration in Disaster Management

Jaana Mäkelä and Kirsi Virrantaus

Department of Real Estate, Planning, and Geoinformatics, Aalto University School of Engineering, P.O. Box 15800 FI-00076 Aalto, Finland, e.mail: {jaana.makela, kirsi.virrantaus }@aalto.fi

Abstract

A maturity model can be used as a tool to assess the current state of competence, to set a roadmap for improvement and to assess the effects of development of collaboration in disaster management. Customized maturity models were developed for two disaster management exercises: a search and rescue exercise and an ICT exercise. The contents of the models were based on a literature review on maturity models, on the goals of the exercises, and on the interviews of the participating organizations. In the exercises, human agents performed a quick maturity assessment where they assessed the maturity level of the key capabilities of collaboration such as the sharing of critical information. Critical information such as geographic information is a prerequisite for shared situational awareness. The results of the maturity assessments were visualized on radar charts which facilitate the display and comparison of multivariate data from different exercises. They highlighted the strengths of collaboration and capabilities that need further development. The process itself: the development of the maturity model, the quick maturity assessment, and the presentation of the results is the main result of the research.

Geographic Information for Command and Control Systems
Demonstration of Emergency Support System

Tomáš Řezník[1], Bronislava Horáková[2] and Roman Szturc[2]

[1]Faculty of Science, Department of Geography, Masaryk University, Kotlářská 2, 611 37 Brno, Czech Republic, e.mail: tom@mail.muni.cz

[2]INTERGRAPH CS, Prosek Point – budova A, Prosecká 851/64, 190 00 Praha, Czech Republic, e.mail: bronislava.horakova@intergraph.com

Abstract

This paper deals with the issue of integration of geographic information (GI) into (existing) command and control systems. The main motivations and benefits of such integration are described at the beginning. Open as well as proprietary solutions are discussed. The core of the paper lies in the definition of the Emergency Support System, including the user requirements, architecture, field tests and assessment. Beside others, conclusions depict issues of a system based on the Service Oriented Architecture that is integrated into a command and control system. Such issues consist of existing procedures and processes in crisis and emergency management, connection to other components of Spatial Data Infrastructures and future development

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On the Roles of Geospatial Information for Risk Assessment of Land Subsidence in Urban Areas of Indonesia

Hasanuddin Z. Abidin[1], Heri Andreas[1], Irwan Gumilar[1], Teguh.P. Sidiq[1] and Yoichi. Fukuda[2]

[1]Geodesy Research Group, Faculty of Earth Science and Technology, Institute of Technology Bandung, Jl. Ganesha 10, Bandung, Indonesia, e.mail : hzabidin@gd.itb.ac.id

[2]Graduate School of Science, Kyoto University, Japan

Abstract

Land subsidence is a silent hazard that may occurs in large urban areas, and usually caused by combination of excessive groundwater extraction, natural consolidation of alluvium soil, load of constructions and tectonic activities. Geospatial information is useful for studying the characteristics, causes, impacts and cost of land subsidence. This paper concentrates on the roles of geospatial information for risk assessment of land subsidence in three large cities in Indonesia, namely Jakarta, Bandung and Semarang. Geodetic based results show that land subsidence rates in all three cities generally have spatial and temporal variations, and their magnitude is in average about 5-10 cm/year and can reach up to about 20 cm/year at certain locations and times. The impact of land subsidence can be seen already in the field in forms of the buildings and infrastructure cracking, the wider expansion of (coastal) flooding areas, and increased inland sea water intrusion. Land subsidence has a strong linkage with urban development process. Urban development increases the built-up areas, population, economic and industrial activities, and also groundwater extraction, which can then lead to land subsidence.

The STIG: Framework for the Stress-Test for Infrastructures of Geographic Information

Bujar Nushi and Bastiaan van Loenen

Geo-information and Land Development, Research Institute for the Built Environment, Delft University of Technology, The Netherlands, e.mail: {b.nushi, B.vanLoenen}@tudelft.nl

Abstract

Spatial data infrastructure (SDI) facilitates the collection, maintenance, dissemination and use of spatial information. To stimulate SDI development effectively and efficiently, it is key to assess the progress and benefits of the SDI. SDI is difficult to assess because of its complex, dynamic, multi-faceted and constantly evolving nature. Several SDI assessment methods exist. However, these are still in an infancy stage and none of these appear to meet the requirements of practitioners. As a result, SDI decision makers are still without any guidance on the success of their SDI. In this paper we propose a new method for SDI assessment: The STIG, a Stress-Test for Infrastructures of Geographical information. The development and application of the Stress-test methodology will provide new valuable information for decision-makers about the aspects of SDIs that need to be improved in order to take full advantage of the potential benefit of the SDIs, especially in the instance of disaster management.

Towards an Integrated Crowd Management Platform

Nico Van de Weghe[1], Rik Bellens[2], Tom De Jaeger[3], Sidharta Gautama[2], Roel Huybrechts[1], Beat Meier[4] and Mathias Versichele[1]

[1]Department of Geography, Ghent University, Krijgslaan 281, S8 9000 Ghent, Belgium,
e.mail: {nico.vandeweghe, roel.huybrechts, mathias.versichele}@ugent.be

[2]IOF Innovation Centre i-KNOW-UGent, Gent, Belgium, e.mail: {rik.bellens, sidarta.gautama}@ugent.be

[3]TERSEC, Gent, Belgium, e.mail: tdj@tersec.be

[4]FAST Protect, Gent, e.mail: beat.meier@fastprotect.net

Abstract

To date, numerous tracking technologies are being used in order to get insight in various situations where movements of objects are of major importance. Moving objects might be cars moving along the road network, animals running in the forest, people visiting mass events. Our research focuses on this last specific domain. Our aim is to build an integrated centralized system capable of acquiring, analysing, and modelling the complex movement interactions occurring at mass-events in order to fully support the organizers in crowd management, security and possible evacuation. The integrated system will focus on two systems developed over the past years and successfully deployed at several mass events. The first system

(BlueMAP) focuses on visitors, the second system (Terra 3D Incident Management Platform) focuses on the emergency services.

Evaluation of a Support System for Large Area Tourist Evacuation Guidance: Kyoto Simulation Results

Seiki Kinugasa[1], Tomoko Izumi[2] and Yoshio Nakatani[3]

[1]The Graduate School of Science and Engineering, Ritsumeikan University, Kusatsu city, Shiga, 525-8577, Japan, e.mail: cc006064@ed.ritsumei.ac.jp

[2]The Graduate School of Science and Engineering, Ritsumeikan University, Kusatsu city, Shiga, 525-8577, Japan, e.mail: izumi-t@is.ritsumei.ac.jp

[3]The Graduate School of Science and Engineering, Ritsumeikan University, Kusatsu city, Shiga, 525-8577, Japan, e.mail: nakatani@is.ritsumei.ac.jp

Abstract

Most studies on providing evacuation guidance have targeted residents, with little consideration for evacuation guidance for visitors to the area, such as tourists and businesspeople. Accordingly, this study targets the development of a system that supports the safe and efficient evacuation of tourists from disaster areas to specific safe destinations. The system models the evacuation behavior of tourists and then simulates an evacuation process in which a specific evacuation guidance method is utilized. A major characteristic of tourists in disasters is that they tend to converge on the limited number of railway stations, which may result in severe crowding and panic. The system therefore makes it possible to compare and evaluate the effectiveness of various evacuation guidance methods. The effectiveness of the system was tested by simulation of evacuation processes that utilize a phased evacuation guidance method that is to be introduced in Kyoto, the most popular tourist destination city in Japan.

A Virtual Police Force as Part of an Integrated Community Security Network
The Case of the Dutch VPK Programme

Wim Broer

Innovatieplatform Politie Nederland, Papendorpseweg 68, 3528 BJ Utrecht, The Netherlands, e.mail: Wim.broer@vpkteam.nl

Abstract

The internet revolution, with all of its accompanying positive and negative consequences, has increasingly come to impact on society at large. It also has significant consequences and opportunities for the police. The task is to respond to these challenges with intelligent solutions, and using these solutions to empower police professionals in the field. The desire to meet these challenges has led to a programme called 'the Virtual Police Korps (Corps or Service)'. Its ambition is to build a new way of delivering professional policing services, by making optimal use of information cloud technology. This will maximise the rich source of information and communication potentially available on the internet.

Integration of Real-time UAV Video into the Fire Brigades Crisis Management System

Mark van Persie[1], Menso C. van Sijl[1], Edwin Wisse[2], Janio B. Tjoe-Awie[3], Arnout J. de Jong[4] and Wim Bakker[5]

[1]National Aerospace Laboratory NLR, A. Fokkerweg 2, 1059 CM Amsterdam, The Netherlands, e.mail: Mark.van.Persie@nlr.nl

[2]Geodan, President Kennedylaan 1, 1079 MB Amsterdam, The Netherlands, e.mail: info@geodan.nl

[3]Nieuwland Geo-Informatie, H. van Suchtelenweg 4, 6703 CT Wageningen, The Netherlands, e.mail: janio.tjoe-awie@nieuwland.nl

[4]Delft Dynamics B.V., Molengraaffsingel 12, 2629 JD Delft, The Netherlands, e.mail: info@delftdynamics.nl

[5]Veiligheidsregio Noord- en Oost-Gelderland VNOG, Europaweg 79, 7336 AK Apeldoorn, The Netherlands, e.mail: w.bakker@vnog.nl

Abstract

During a fire incident live airborne video offers the fire brigade an additional means of information. Essential for the effective usage of the daylight and infra-red video data from the UAS is that the information is fully integrated into the crisis management system of the fire brigade. This is a GIS based system in which all

relevant geospatial information is brought together and automatically distributed to all levels of the organization. In the Dutch Fire-Fly project it was investigated in what way and under which conditions the information obtained with small unmanned aerial systems (UAS) can be integrated into the fire brigades crisis management system in support of their operations. In cooperation with the Dutch fire brigade of the VNOG requirements and a concept of operation were defined, based on which a technical system was developed and demonstrated in practice. An existing robot helicopter was equipped with the proper sensors, a geospatial video server was integrated in the local command center and the fire brigades crisis management system was adapted for the display and distribution of real-time geospatial airborne video and derived product to the involved operational levels during a fire incident. This article describes the technical and operational approach and results.

Agent-enabled Information Provisioning while Retaining Control: a Demonstration

Peter de Bruijn[1] and Niek Wijngaards[2]

[1]Stichting Studio Veiligheid, Caballero Fabriek, Saturnusstraat 60,
2516 AH Den Haag, The Netherlands, e.mail: peter.debruijn@studioveiligheid.net

[2] Research & Technology, Thales Nederland BV, Delft; D-CIS Lab, Delft,
The Netherlands, e.mail: niek.wijngaards@d-cis.nl

Abstract

The project 'SlimVerbinden' addresses the challenge of retaining autonomy while sharing information among multiple parties. Based on a web of trust, information providers can grant and deny access to information, while information consumers can delegate access to specific members within their 'organization' (which can be defined within and/or across existing organizations). The policy- and PKI-based realization enables an agent-based secure shared distributed dataspace where no single party knows 'everything' and the barriers to information sharing are lowered. The use-case involves public-private cooperation during the mitigation of an incident and drives the development of an operational pilot.

Agent-based Information Infrastructure for Disaster Management

Zulkuf Genc[1], Farideh Heidari[2], Michel A. Oey[2], Sander van Splunter[2] and Frances M.T. Brazier[2]

[1]Delft University of Technology, EEMCS, WMC Group, P.O. Box 5031, 2600 GA Delft, The Netherlands, e.mail: Z.Genc@tudelft.nl

[2]SDelft University of Technology, Facult of Tecnology, Policy and Management, Section Systems Engineering, Faculty of Technology, Policy and Management, Delft University of Technology, P.O. Box 5015, 2600 GA, Delft, The Netherlands, e.mail: F.Heidari@tudelft.nl, M.A.Oey@tudelft.nl, S.vanSplunter@tudelft.nl, F.M.Brazier@tudelft.nl

Abstract

The success of a disaster management process depends on effective, se-cure and efficient information flow. This paper proposes an agent-based distributed information infrastructure to enable the realization of such secure information flows in disasters. The proposed infrastructure uses software agents in the exchange and processing of information, secure and dynamic information sharing and automated information flow generation and configuration.

Using a Base Registry Key in Disaster Information Management: a Dutch Case Study on Linked Data

Jan-Willem van Aalst[1], Bart van Leeuwen[2] and Rob Peters[3]

[1]Imergis, Wilhelminalaan 19, 3701 BD Zeist, The Netherlands, e.mail: jw@imergis.nl

[2]Netage, Enschedepad 76, 1324 GJ Almere, The Netherlands, e.mail: bart_van_leeuwen@netage.nl

[3]VRK, Zijlweg 200, 2015 CK Haarlem, The Netherlands, e.mail: RPeters@vrk.nl

Abstract

This paper describes the process of using the Dutch Base Registration Identification number (BAG) as a primary key to link various sorts of information about a particular built-up object. This greatly increases the quality and effectiveness of the common operational picture. Consequently, the paper investigates the usefulness and affordability of Linked Data (a method of publishing structured data so that it can be interlinked). Several practical applications are considered and evaluated. The primary conclusion is that the BAG Base address registration greatly enhances the possibilities for safety workers to gain a common insight about particular built-up objects. This pertains to the "cold" risk-analyses and preparatory work phases, as well as in the "warm" incident and disaster management phases. It is in the combination of these two phases where the profit is maximized: when attempting to assess the consequences of the disaster management processes during and after the incident, relevant data about the particular object is now much easier than before, and with much better quality. This is already turning out to be very

profitable for the fire brigade workers, the police officers, the ambulance drivers, as well as the municipal officers.

Using Icons as a Means for Semantic Interoperability in Emergency Management: the Case of Cross-border Moor Fires and Schiphol Airport

Rob Peters[1], Jan-Willem van Aalst[2], Frank Wilson[3] and Til Hofmann[4]

[1]Public Safety Authority Kennemerland, Ultrecht, The Netherlands, e.mail: rpeters@vrk.nl

[2]Imergis, Ultrecht, The Netherlands, e.mail: jw@imergis.nl

[3]Interaction Design Ltd., London, UK, e.mail: frankwilson@btconnect.com

[4]Cologne University of Applied Sciences (CUAS), Köln, Germany

Abstract

The understanding of terms and maps is considered a vital part of emergency management by its practitioners. This paper describes a solution chosen by the emergency management information officers of the Twente and Kennemerland Dutch regional authorities to bridge the gap of understanding between first responder officers of different agencies. After having implemented a National emergency management system with a strong tendency to standardize protocols and tooling the designers involved realized that one cannot superimpose a single symbology for everyone involved. A need for a more flexible harmonization with partners like colleagues from cross the border and the IATA governed Schiphol Airport was necessary. To achieve flexibility and understanding at the same time a method for on-the-fly translation of icons was developed. The technology that

powers the translation is the application of SKOS semantic web trippels. The paper describes some of the challenges that occurred when different icon sets based on different standardization regimes were analysed.

Network Information Management for Collaboration in Disaster Management: Concepts and Case Study

Fons Panneman[1], Erik de Vries[2] and Peter de Bruijn[3]

[1]Stichting Studio Veiligheid, Caballero Fabriek, Saturnusstraat 60, 2516 AH Den Haag, The Netherlands, e.mail: fons.panneman@studioveiligheid.net, erik@ienm.nl, peter.debruijn@studioveiligheid.net

Abstract

Interorganizational information exchange has become crucial to increase resilience and agility in disaster management. New collaborations between organizations to exchange information through innovative technologies create challenges for information management. It implies different stakeholders, diversified policies, multiple interpretations of innovative technologies, restricted knowledge of each other's organizations and shared governance of processes of innovation, cooperation, design and decision making. We offer an approach for Network Information Management that allows for and takes advantage of these differences between stakeholders and their organizations. An approach in which innovation, cooperation, design and decision-making is shared among stakeholders. The approach is based on three basic components: process management, scenario based development and organizing vision. These components reinforce each other resulting in convergence of stakeholder's positions throughout the process. The approach has been applied and tested in an innovation project for disaster management in the Netherlands, which serves as a case study in this paper.