At present, Chinese emergency response system (ERS) for public security is still in the developing stage. Current ERS could hardly satisfy mass citizens' requirements for assuring public security and responding to major emergencies and/or accidents. Such ERS mainly has the following defects [2]:

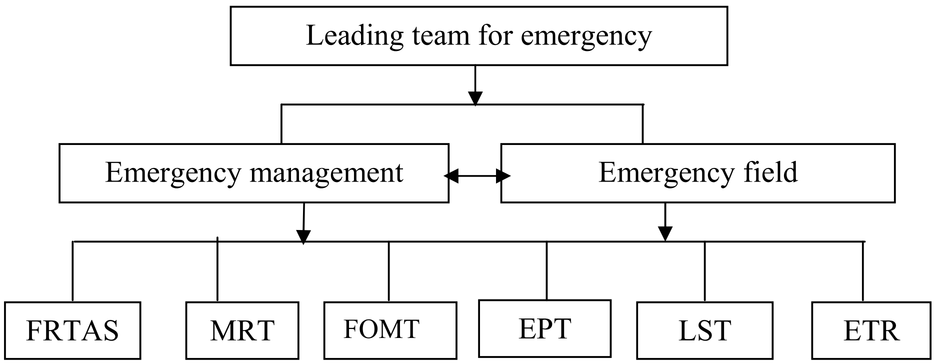
- Absence of unified urban public security management mechanism. Different functional departments have their own authorities and resources. It is often the case that a city has multiple public special service phone numbers, such as 110-public security, 119-fire alarm, 120-first aid and 122-traffic police. It is not easy for the public to keep them all in mind. And there are some other emergency phone numbers even more rarely known to common people.
- That city has no a centralized command and control system for all types of emergency sub-systems results in difficulties for different emergency command centers and departments to mutually support and coordinate timely and effectively. Their respective data resources cannot be shared so that some cities repeated construction of data resources and wasted their limited resources.
- As ERS is complicate, it is not easy for the public to remember and understand operating modes of different systems. When confronted with emergencies, urban residents cannot effectively coordinate and support mutually.

In view of the above adverse situations, the China government has integrated various limited resources to improve enterprises and departments capabilities in responding to various emergencies and facilitate citizens be involved in improving and using ERS. In 2001, Nanning, a city in the Southwest of China, took the lead in setting up China's first Urban Emergency Response Center (UERC) and issued provisional regulations on Urban Emergency Response System (UERS), realized joint operations by departments of public security, traffic police, fire-fighting and medical first-aid unified command and control and resources share throughout overall process of emergency response and greatly improving Nanning's ability and efficiency in responding to various emergencies. As shown in Table 1, great changes have been witnessed in number of police calls received by all types of policies before and after establishment of UERS.

At present, Nanning's UERS receives about 4500 police calls every day on average. During the period from April 1, 2002 to June 26, 2002, Nanning's UERC received a cumulative total of 250,000 police calls, and over 40,000 valid recourses of all kinds were handled.

In China, laws and regulations supporting ERS were also promulgated one by one. Those laws and regulations require that cities with matured conditions should establish ERS to respond to various emergencies. The current organizational structure of those built-up and under-construction ERS is shown in figure 1.

Figure 1. Organizational structure for urban emergency response



FRTAS: Field Rescue Team of All Specialties
MRT: Medical Rescue Team
FOMT: Field Order Maintaining Team
EPT: Environment Protection Team
LST: Logistics (Materials) Support Team
ETR: Expert Team for Rescue

The basic situations of work safety in China

As a developing country, China must control and reduce accidents of various types in domestic industrial enterprises while pursuing growth of the national economy. Serious industrial accidents occur constantly across the country, which cause great number of injuries and deaths and have become a noticeable problem in the Chinese economy. According to statistics from the State Administration of Work Safety (SAWS) of China, the number of accidental cases and deaths in 2002 are shown as figure 2.

Among major accidents happened in recent years, there are also many cases of casualties and economic losses due to poor emergency responses. Table 1 lists the accidents that happened during the period from January 2003 to February 2004 in China and resulted in serious casualties because of the lack of effective accident response measures. It can be seen from figure 2 that more accidents and casualties took place in coastal areas with relatively developed economy, which warns us that the establishment and development of the ERS has to be stressed as the economy develops.

The construction of emergency system for major industrial accidents

With the expansion of the general scale of national economy, industry especially the manufacturing industry aggrandizes its proportion in the national structure of economy and industry, the industrial population (high-risk group) grows up rapidly and the economic development is constantly accelerated. As a consequence, all sorts of technical hazards increase and the emergency response gradually shows its prominence. The accident rescue has become a primary means of reducing accident costs after its happening.

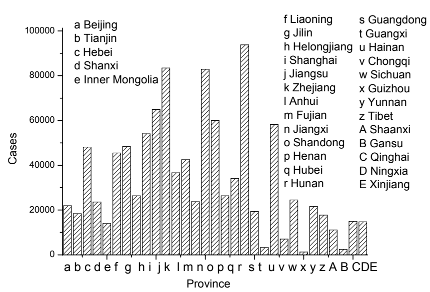
In recent years, China gradually established some emergency command systems and emergency response teams in the fields of fire control, earthquake, flood, nuclear accident, forest fire, salvage, mines and chemical sector.

Table 1. Some major accidents in China (2003.1-2004.2)

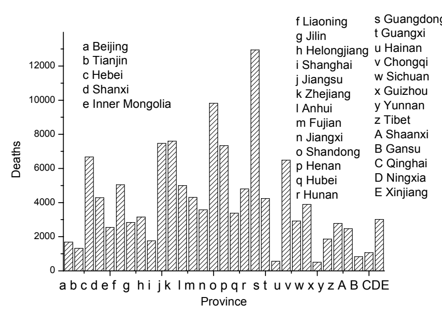
Date	Location	Reasons	Brief notes
2003.2.2	Tiantan Hotel, Harbin, Heilongjiang	Fire	33 died, 23 injured
2003.6.19	Water area of the Yangtze River at Fuling District, Chongqing	Wreck	52 died
2003.12.23	Kai County, Chongqing	Natural gas blowout, resulting in hydrogen sulfide poisoning	243 died
2003.12.30	Tieling Liaoning	Explosion of firework	38 died
2004.2.15	Zhongbai Shopping Mall,Jilin City, Jilin	Fire	54 died, 68 injured
2004.2.15	Haining, Zhejiang	Fire	40 died, 4 injured

Figure 2. China industrial accidents in 2002 (a) the cases; (b) the number of deaths

(a)



(b)



Public-safety fire-control emergency response system

On the principle of "Army establishing the system and local government holding the duties and responsibilities", China has set up a relatively complete system for public-safety fire-control emergency response. The fire-control offices of all levels of public safety sector assume the duties to command and deploy local fire brigades-control and to direct and coordinate rescue activities. It is the duty of the Ministry of Public Security to coordinate transprovincial activities in the range of the whole nation. At present, China has totally 120,000 fire brigade organization and 2600 general fire departments whose primary tasks are fire prevention and fire extinction. After the sarin accident in Japan, China has established 47 large brigades and 279 medium brigades for the treatment of special disasters in large and medium-sized cities. The fire bridges assume not only the responsibility of fire prevention and fire extinction but also that of disaster relief and emergency response. On average, the fire brigades of China handle about 250,000 cases in a year, in which over 50% of them are non-fire disasters and over 6,000 cases they treated are hazardous chemicals accidents. Since the public-safety fire-control emergency response system is characterized by its vast distribution, 24-hour service system, high specialty and flexibility, safety and public welfare, the public-safety fire-control sector has become a very important professional emergency response force in China.

Earthquake disaster response system

The earthquake disaster emergency response system is built at all levels in the sequence of the nation, provinces and major cities (counties). The State Department and relevant local governments higher than the county level has established command offices for earthquake disaster rescue, and the director of a command office is assumed by a vice premier (a vice mayor). On the principle of "Directed by government, uniformly managed by a system and respectively controlled by different levels and departments," National Earthquake Bureau takes the responsibility of directing and supervising the earthquake disaster response tasks in the nation.

Earthquake disaster is classified into three levels: ordinary destructive earthquake, serious destructive earthquake and extraordinarily serious destructive earthquake. Once an earthquake disaster occurs, it must be reported to the local and the National Command of Earthquake Salvage and both the local and the national on-spot emergency response brigade must start to rescue. For ordinary destructive earthquakes, the local command office for earthquake disaster rescue should organize forces at the place to rescue. After a serious destructive earthquake or an extraordinarily serious destructive earthquake took place, the national command office for earthquake disaster rescue would start to operate and the national emergency response brigade would hurriedly goes to the site.

In April 2001, National Earthquake Bureau, with the help of the General Staff of PLA, established a national earthquake disaster emergency response brigade with 230 members on the principle of "one bridge multipurpose and combination of army and people". At present, National Earthquake Bureau is actively boosting the establishment of regional emergency response brigades, intending to build a regional emergency response brigade in southwestern and northwestern areas respectively. The establishment of local earthquake emergency response brigades is also in process, and some provinces and cities such as Heilongjiang, Liaoning, Xiamen and Tianjin have successfully organized their own emergency response brigades.

Flood response system

The flood emergency response system is set up at four levels: nation, province, region and county and it is under a uniform command and coordination system. The National General Command of Flood and Draught Prevention is arranged at the Ministry of Water Conservancy, and the general commander is assumed by the vice premier of State Department. It leads the General Command of Flood Prevention of the Middle and Lower Reaches of the Yangtze River and the General Command of Flood Prevention of the Yellow River and it has also established flood prevention offices at the administrative authorities of five drainage areas: the Huaihe River, the Haihe River, the Zhujiang River, Songliao and the Taihu Lake. Local governments also build all levels of commands of flood and drought prevention in charge of the flood and drought prevention in the region. At present, China has appointed 19 armies as professional flood emergency fighting forces which take on the flood emergency fighting tasks of seven river basins: the Yangtze River, the Yellow River, the Huaihe River, the Haihe River, the Songhuajiang&Liohe, the Zhujiang River and the Minjiang River.

Nuclear emergency response system

China's nuclear emergency response system is a tertiary managerial system for the nation, region and nuclear power plant. The Commission of Science Technology and Industry for National Defence took the lead and a national nuclear emergency coordination commission was set up in the State Department. The provincial governments (autonomous regions or cities directly under the central government) where the nuclear power plant is located set up local nuclear emergency response commission and the operating organization of the nuclear power plant also established their own emergency response centers. The stated emergency response commissions and organizations assume the duties of nuclear emergency response management of the nation, the region and the plant. The emergency system and the response level are classified into four levels: emergency standby, workshop emergency response, on-site emergency response and off-site emergency response (general emergency response). In the emergency response, the National Commission of Nuclear Emergency Response and Coordination will duly approve the entry and termination of off-site emergency response state. At present, National Nuclear Emergency Response Center is under construction and it will operate after completion in a near future.

Forest-fire emergency response system

China's forest-fire emergency response system is set up in a hierarchy of nation, province, city and county. The fire control office of National Forestry Bureau assumes the responsibility of national forest-fire emergency response. All provinces, cities and counties have their forest-fire control command department or forest-fire control committee, regularly holding the working conference of forest-fire control to coordinate and arrange the forest-fire prevention or extinction tasks. Offices of the command departments are located at all levels of Forestry Bureaus. The major force of forest-fire control is the armed forest police. China has specially established an army of forest police with about 20000 people, and it is divided into seven troops that reside in seven important provinces of forest-fire control in the nation and take the responsibility of fire prevention and extinction of the province. Both the command of armed forest police and the National Bureau of Forestry direct the force, and in principle, the forest-fire control troops of seven provinces and normal fire brigades at the place cannot deploy each other.

In addition, all provinces and cities organized their own forest-fire control forces according to actual conditions at the expense of local government.

Marine emergency response system

The maritime salvage of China is uniformly organized and coordinated by China Marine Salvage Center that is under the direction of State Department and the military commission and performs their daily duties in the Marine Bureau of the Ministry of Communications. In the eleven coastal provinces, cities and autonomous regions (Liaoning, Hebei, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Guangxi, Hainan), province-level salvage centers are set up and the "Yangtze River" water salvage center is also established. Salvage branches are set under the provincial salvage center.

The professional forces of maritime salvage are the three salvage bureaus: the North Sea Salvage Center, the East Sea Salvage Center and the South Sea Salvage Center which take the responsibility of maritime salvage in three salvage responsibility areas: the northern sea area and the Heilongjiang River, the eastern sea area and the Yangtze River and the southern sea area and the Zhujiangkou area. The three salvage bureaus perform the 24-hour shift system. They have salvage bases and the expenses of the salvage bureaus are totally paid by the state.

Mine emergency response system

Mine ERS consists of organizations and institutions including the National Commission of Mine Emergency Response, the National Command Center of Mine Salvage, the Provincial Command Center of Mine Salvage, the mine salvage departments of cities and counties and the salvage management departments of mining enterprises. The National Commission of Mine Emergency Response is the competent department under the State Admnistration of Work Safety (the State Adminstration for Coal Mine Safety Supervision), and it is responsible for directing and coordinating mine salvage and other emergency responses.

The emergency response force of the mine ERS is divided into two parts: first-aid team and medical team. Among them, there are three levels of the first-aid team: the regional mine first-aid team, the important mine first-aid team and the mine first-aid mine. The regional mine first-aid team is the skeleton army for regional mine salvage and the center of first-aid apparatuses storage and that of training and exercising. When performing the salvage work for mine accidents, the regional first-aid team of mine salvage is directly under the direction and coordination of the National Center of Mine Salvage. At present, it is planned to set up 13 regional first-aid teams of mine salvage in the nation. The medical team primarily includes the medical centers of state-owned mining enterprises, regional and major medical centers and enterprise's aid posts.

Chemical emergency response system

After over 10 years of development, China's chemical ERS is still on its way of constant improvement, especially in the respects such as operating system, mechanism establishment and supporting and guarantee. At present, it mainly means the medical treatment of the injured. Around the year of 1994, the original Ministry of Chemical Engineering issued a series of emergency response regulations including the "Regulations on Chemical Emergency Response" and the "Regulations on Emergency Response of Chlorine Leakage Accidents and set up 8 regional salvage centers on the base of occupational disease hospitals of chemical enterprises. After the reform of the organizational structure, the command centers and the offices of chemical emergency response and the eight regional salvage centers were put under the administration of the State Admnistration of Work Safety, and the chemical ERS is basically lack of the capacity of emergency response due to the influence of expenses, equipment and the structural change of enterprises.

Although China has established some ERS to an extent, there are still a lot of problems in the capacity of salvage and the comprehensive coordination, which seriously influenced many major emergency responses in recent years in China.

Developments of laws on emergency systems against major industrial accidents in China

In China, local governments at various levels attach great importance to the improvement of laws on emergency systems against major industrial accidents and have been controlling and preventing major industrial accidents based on legal measures. Recently, a serious of relevant laws and regulations have been stipulated. Laws and legislations that have stipulated for emergency response provisions primarily include the "Work Safety Regulations of PRC", the "Law of Occupational Disease Prevention and Cure" and the "Safety Regulations on Hazardous Chemicals".

The central government of China attaches much importance to the work of emergency response, not only issuing various regulations but also establishing the administration of safety supervision and control to check the implementation conditions of grave emergency provisions in relevant enterprises. In addition, all provinces, cities and autonomous regions have also stipulate corresponding provisions for grave emergencies according to the actual situations at the place.

Research status of emergency systems in China

At present, some methods and theories about emergency systems against major industrial accidents have been developed in China, which are sponsored not only by enterprises but also by governments. Additionally, the research funds from the Ministry of Science and Technology and the Ministry of Labor and Social Security are increasing gradually year by year [3].

The National Science Foundation of China (NSFC), as one of the major sources of support for emergency systems research provided by the Chinese government, is an important link in the chain of China's emergency systems to promote basic research. The NSFC's budget has been increasing annually. During the past 18 years the NSFC has supported many projects about emergency systems, thus playing a significant role in promoting the progress and enhancing the overall quality of basic work safety research in China. The NSFC is one of the major forces to support scientific and technological innovation of safety science [4].

The National Center of Safety Science and Technology (NCSS) is a representative institution of basic work safety research on a national level in China. The foundation of this center marks the beginning of a period when emergency systems is carried out on a large scale in various complicated areas with many different departments working together for the first time in China. In the past few years, this center worked in the national or international forefront of safety science and technology. Effective and fruitful researches have been carried out in these areas.

During the past decade, different ministries of the Chinese government have also established emergency systems research institutions devoted to applied research and development of new technologies. Besides, some universities also have specialized research institutes in emergency systems.

6 Developing trends of China's emergency response system

The establishment of ERS means a lot for China to cope with various emergencies. In the coming years, the national industrial ERS will be gradually established in the principle of "complete block design, process implementation, resource integration and actual effects stressed". It will be built at three levels respectively: nationwide, professional and regional and gradually improved from bottom to top to form the frame of the national industrial ERS of China. The frame will be constructed in three steps as following [5]:

First, complete the establishment of national emergency response organization and set up the National Command Center of Industrial Emergency Response and the National Commission of Industrial Emergency Response that has an office in the command center, primarily in charge of the compilation of national policies of industrial emergency response.

Secondly, under the uniform direction and planning of the national commission of emergency response, establish several professional command centers of emergency response in the field of mines, chemicals, industry and public security. These professional command centers provide the feasibility report of the establishment of the regional emergency response brigades and compile national provisions of industrial emergency response by trade.

At last, the national command center of industrial emergency response will organize with the help of professional command centers the preliminary selection of existing emergency response organizations for local mines, chemicals, industries and public security to establish the regional command centers of industrial emergency response after training and successful qualification test. The nation will provide necessary support in the respects of staff, working site, professional equipment and expenditures.

Just like China's economic market, the emergency systems against major industrial accidents in China also have a large requirement. The government of China welcomes foreign emergency systems agencies to spread their services in China in compliance with the laws and regulations of China, and is also in favor of the communication and cooperation between safety engineers of China and their foreign colleagues.

We are aware that the basic data are not yet sufficient and some types of data are still absent due to the relatively short time of emergency systems development in China. Some industries still lack mature emergency response methods, which should be continuously modified and amended during practical application. The laws and regulations of emergency systems management should be further perfected. And the training and education on emergency response should also be strengthened.

Acknowledgements

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References

Weicheng Fan and Maohua Zhong. (2000). Present and future developments of fire science in P. R. China. China Safety Science Journal. 10(1), 11–16.

Xue Lan, Zhang Qiang, Zhong KaoBin. (2003). Crisis management in China. Tsinghua University Press, Beijing.

Han Xin, Li Jie and Shen Zuyan. (2000). Non-autonomous coloured Petri net-based methodology for the dispatching process of urban fire fighting, Fire Safety Journal, 35(2): 299- 325.

Maohua Zhong, Tiemin Liu and Weicheng Fan (2003). Safety evaluation of engineering and construction projects in China, Journal of Loss Prevention in the Process Industries. 16(3): 201-207.

Maohua Zhong, Tiemin Liu and Xing Wei. (2003). Strategy for development of work safety science and technology in China. Asian-Pacific Newsletter on Occupational Health and Safety. 10(3): 70-71.

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EARTHQUAKE RESPONSE

EQ-RESCUE: AN HLA-BASED DISTRIBUTED SIMULATION SYSTEM FOR DISASTER RESPONSE ACTIVITIES AFTER STRONG EARTHQUAKES

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Institute for Technology and Management in Construction[1]

Keywords: Disaster Response, Distributed Simulation, Earthquakes, Training, Decision Support

Abstract
Training of emergency operation center (EOC) staff typically requires the involvement of experts who estimate the consequences of the staff decisions or the additional realization of field exercises. While the dynamic of the training is usually limited in the first case combined field / EOC exercises are very expensive. Therefore computer based training is getting more and more popular. In this paper the authors introduce a distributed simulation system for disaster response activities based on the High Level Architecture (HLA) which can be used in virtual training environments. The simulation system focuses on resource management issues including the allocation of scarce response resources to operational areas. After a brief introduction to HLA-based simulations an overview of the overall system is given. The system consists of three major components: (1) simulators for the disaster environment, e.g. simulators for damages, casualties and fire spread, (2) simulators for the operations of human and technical equipment and (3) some auxiliary simulators. The simulators of the disaster environment use state-of-the-art models. While the damage simulator is based on the capacity-spectrum-method to estimate building damages, the dynamic fire spread model uses physical fire models for ignition, propagation and fire extinguishing. The resource simulators include SAR-teams, fire fighting units, heavy equipment for road clearance and SAR-support and ambulances for the transport of the injured persons. During a simulation the EOC staff receives messages and status reports from the different simulators and they can send orders to the resources. Additionally an interface to a Multi-Agent System which can be used for decision support is presented.

Introduction
Earthquakes, like the great Hanshin-Awaji earthquake which hit Kobe in 1995, and the devastating Turkey earthquake from 1999 show the high vulnerability of societies to natural disasters. One of the most challenging fields in this context is the optimization of disaster response activities following a major earthquake. Some of the main problems during this period include allocation of scarce response resources, search and rescue (SAR) of trapped persons, medical treatment of the injured, fire fighting, and repair of damaged traffic infrastructure and lifeline systems. Because such events do not happen frequently the local decision-makers are not used to properly process the large amount of incoming information and to include relevant information in their decisions. Regular training for EOC staff members helps the decision-makers to be more familiar with such unlikely situations. Typical training is based on table-top, functional or full-scale field exercises. Table top exercises are run by a facilitator and they usually have a master event list. This list comprises of more or less independent general problem statements, and the participants discuss

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possible actions without time pressure. Functional exercises are used to test one or more emergency functions in real time. Therefore the input is made via messages, and the consequences of the decisions are estimated by experts staying in separate rooms. Exercises of these two types are rather inexpensive, but the main problem is the limited dynamics to unforeseen actions and the requirement of rational and scientific sound experts. Real time field exercises are more realistic because they include field personnel as well as EOC staff. The communication flow and the participants are the same as in a real disaster. Although very realistic, these exercises are rather seldom, because they are very expensive and time consuming in preparation. Therefore, virtual training for emergency response is getting more and more popular, but its application is far from standard (Jain and McLean, 2003).

In this paper, the authors present a distributed simulation system for earthquake disaster response which can be used for training purposes. Different simulators are used to simulate the affected disaster area and the operations of the response resources in the field. The simulators are linked by a common architecture for distributed simulations which is provided by the High Level Architecture. To control the field resources elementary actions are defined. These actions can either be initiated by EOC personnel or by software agents which provide decision support for resource management topics.

Theory and Method

Simulation systems for disaster response training should include simulators for dynamic aspects of the disaster world (e.g. fade away times of trapped persons) and for the response operations of the resources. Additionally, it should be possible to link the simulation to computer-based decision support systems which may be used by EOS staff during the decision process. Such complex systems can hardly be run on a single personal computer. An adequate architecture for distributed simulations over computer networks is provided by the High Level Architecture (HLA). So far, HLA-based simulation has been applied mainly to the military domain. Nevertheless, some simulators for comparable fields-like logistics (Reyns *et al.*, 1998), emergency medical treatment (Pettitt *et al.*, 1998) or natural environment modeling (Gerrard *et al.*, 1999) have been developed. More recently there are increasing efforts to apply HLA to civilian domains, such as traffic and logistics (Strassburger, 2001) or emergency management (Klein, 2001).

This section is organized as follows: First the authors give a brief introduction into the HLA principles. After a description of the overall system and the information flow between the different system components, the simulators are explained in more detail. Finally a link to a Multi-Agent System which can be used for optimized resource allocation is presented.

Introduction to HLA-based simulations

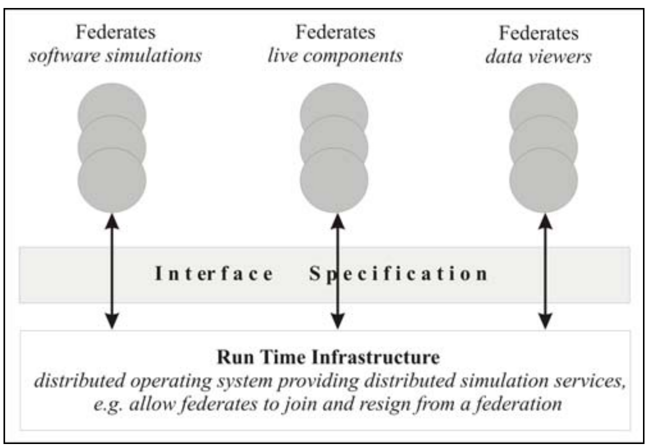
HLA was developed by the Defense Modeling and Simulation Office (DMSO) of Department of Defense (DoD) with the main goal of building a platform for war gaming and training taking into account interoperability and reuse of different simulation components. HLA has its origins in the Distributed Interactive Simulation (DIS) and Aggregate Level Simulation Protocol (ALSP). The development started in the mid-90's, and since 2000, HLA is an Institute of Electrical and Electronics Engineers (IEEE) standard for distributed simulation systems. A brief description of the HLA framework is given here. Further technical details of different aspects of HLA can, for example, be found in the IEEE standard documents (IEEE 1516-200), (IEEE 1516.1 – 2000) and (IEEE 1516.2 – 2000).

A distributed simulation using the HLA is called a federation, and each single simulator in such a federation is referred to as a federate. A federate may be a simulation, live component (e.g., physical device or human operator) or data viewer (compare Fig. 1). Federates may join or resign from a federation at any time during the life cycle of the federation. The HLA provides standardized formats for federation and federates. It consists of the following three components:

- HLA rules: The basic principles of HLA are defined in the HLA rules. Within these rules the responsibilities of federation and federates are defined. They ensure a proper interaction of all parts of an HLA compliant simulation.
- Interface specification: It defines the standard for the Run Time Infrastructure (RTI). The RTI provides software services which are essential for the interaction of single federates in a federation. These services include, for example, federation management, data distribution or time management.
- Object model template (OMT): The OMT provides a common framework for the documentation of the object models used in an HLA-based simulation. Main components of the OMT are the Federation Object Model (FOM), the Simulation Object Model (SOM) and the Management Object Model (MOM).

The RTI defined in the interface specification is the central component of an HLA-based simulation. All communication flow between the federates is transferred via this RTI. Federates follow the ambassador paradigm for the communication between the RTI and the federate. Each federate has two different ambassadors: (1) an RTI-ambassador which handles the communication from the federate to the RTI and (2) a federate ambassador for the communication flow from the RTI to the federate.

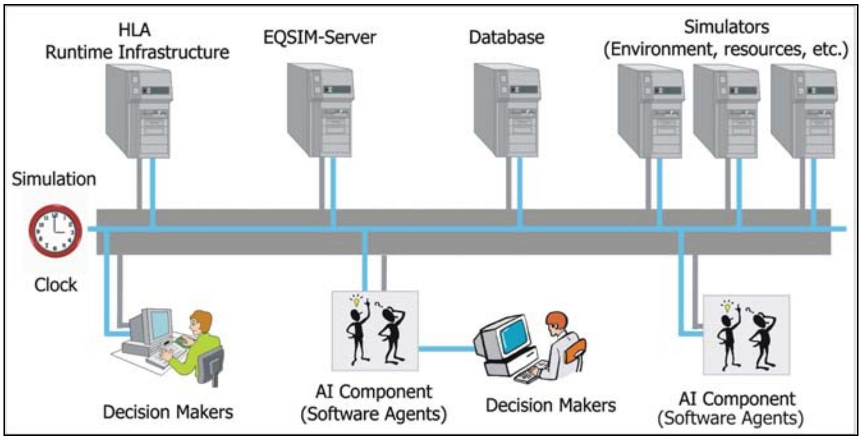
Figure 1: Possible components of an HLA-based simulation



System Overview

Typical functions of an EOC include a huge variety of different responsibilities, such as declaration of local emergency, disseminating emergency public information, tracking resource allocation, etc. The system presented here is limited to the topic of resource management with the emphasis on prioritizing the allocation of the available resources. Simulators for the disaster environment and for the resource operations are linked together in a central system where decision-makers can assign resources to the operational areas. Inventory data from the affected area is stored in a central database. This data includes information about the building stock, road network, demographic data, etc. Information about the scenario is stored in the database as well. The damage estimation tool EQSIM which is also part of the system can be used to calculate possible damage scenarios and it can be used by the EOC staff members throughout the simulated exercise to estimate the impact of the scenario earthquake. All system components implement an HLA-interface to enable the use in a common federation. Figure 2 gives an overview of the system architecture.

Figure 2: System architecture for distributed disaster simulation



Three interacting models where constructed for this system:

1. A disaster world model. This model is used for a realistic representation of the area struck by the disaster.
2. A resource model for modeling the resource movement and the operations of the response resources in the field.
3. An EOC-model which allows EOC members to send orders to and to receive reports from the resources.

Broadly speaking, the first model describes how the disaster situation would proceed if no further response activities are initiated. The simulators of the disaster world model have complete knowledge of the actual situation. This includes information about like real damage states of buildings or health states of injured and trapped persons. Therefore, the world resulting from these simulators can be specified as the *Complete Information World* (CIW).

Resources in the field only have limited access to the disaster information provided by the disaster world simulators. Each single resource has a sight radius in which it can sense the disaster world in a specific resolution. The assignment of tasks to the resources can only be initiated by external stimuli such as orders by EOC members. The subsequent operations such as movement and resource work at the assigned areas are simulated within the single resource simulators.

EOC members don't have access to the complete information of the CIW. In fact, their decisions are based on incomplete and fuzzy information. They use a second view of the disaster world – namely the *Incomplete Information World* (IIW). All the knowledge about the IIW comes from the pre-disaster-database and from on-site information of the response resources teams in the field.

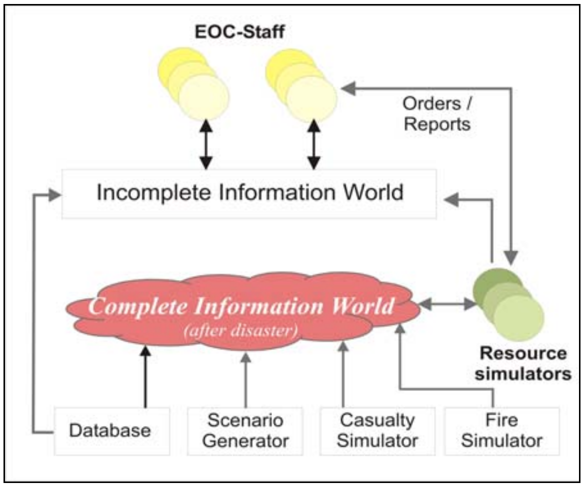
The flow of information between the different components is outlined in figure 3.

<u>Disaster World Simulators</u>

The disaster world simulators simulate the CIW, and they are influenced by the resource simulators. The CIW-federates includes three major federates:

Fire Simulator: The fire simulator uses an approach comparable to (Takai, 1999). The following three detailed physical models are used: (1) a combustion model for the fire spread within a burning building, (2) a heat release and ignition model which calculates the possible heat release from a burning building and the ignition of the neighboring buildings and (3) an extinguishing model which simulates firefighting using water. The combustion model simulates the fire spread within single storeys of a building and the flashover to above storeys.

Figure 3: Information flow during simulation



The maximum burning times of buildings are restricted by their fire load. Simulation behavior depends on building factors like height, floor area, type of construction and occupancy. The heat release to neighboring buildings is calculated under consideration of GIS-data of the buildings within the simulated area. Main Parameters for this model are the quantity of open spaces in the burning building, wind direction and velocity and distance and angle between the buildings. Within the extinguish model the heat release rate of a burning building can be reduced by the water flow from fire engines. Reduction rates are calculated according to (Torvi *et al.*, 2001). Technical details of the fire simulators can not be described within this paper, they will be published elsewhere.

Casualty Simulator: This simulator models the health state of the injured persons. Therefore, the health state is normalized to values between 0 and 100. Each injured person can be assigned to one of four injury classes. The initial injury class is dependent on the location of the person within a collapsed building. Reduction of the health states can be calculated with published survival rates for trapped victims (Coburn *et al.*, 1991). After rescue the reduction rate of an injured person is decreased as soon as they get initial treatment. As soon as an injured person arrives at a hospital it is simply assumed that the health state is stabilized and does not decrease anymore.

Scenario Simulator / Damage Estimation Tool: This component serves two purposes: (1) it is used to calculate the initial damage scenario which provides basic input data and (2) the decision makers can benefit from this module and estimate possible damages within the observed area. An HLA-compliant version of EQSIM (Baur *et al.*, 2000) serves this purpose. The underlying methodology considers the building behavior under earthquake load and it is based on the capacity-spectrum-method (ATC, 1996) which also influenced the loss estimation tool HAZUS. EQSIM permits calculating scenarios based on seismic response spectra derived from real spectra recorded by the seismic network or calculated by using earthquake specific parameters, attenuation functions and seismic design codes.

<u>Resource Simulators</u>

The main goal of the initial Search-And-Rescue (SAR) period after strong earthquakes is to minimize the number of fatalities. The system presented in this paper focuses on this objective, and therefore, only relevant resources are included. The main tasks within the first three days after an earthquake include damage assessment, clearance of critical traffic infrastructure, search and rescue of trapped persons, medical treatment and firefighting. Table 1 summarizes the resources used within the system.

Table 1: Simulated resources and their tasks

Resource	Primary operations
Plane / Helicopter	Air reconnaissance
Recon Team	Ground reconnaissance
Specialized SAR-Team	Search and Rescue of trapped persons in collapsed buildings
Search Team	Search of trapped persons in collapsed buildings
Ambulance	Transport of injured persons to hospitals
Crane	Road clearance and support of rescue work
Fire Engine	Firefighting of burning buildings
Dozer, Truck, Excavator, Roller	Road clearance

All resources are modeled as mixed time stepped and discrete event simulators. To model the real communication flow information between resources and the EOC-staff different standard protocols are used. In equal time, steps the resource simulator checks for incoming HLA-coded orders from the decision makers and if an order is received, events for the operational work of the resource are generated and stored in an internal event queue. After the initial preparation time of the resource the resource starts to move on the network to the assigned operational area. During this movement a resource senses its surrounding world and sends HLA-coded reports about the environment to the user. Therefore each resource has a predefined radius within which the world can be sensed with a specified accuracy. The resulting information helps to update the IIW and it can be used within the further decision process. The resource movement on the network is restricted by its width, height and weight. Technical specifications define estimated working times for the simulation. Each resource has a set of elementary work tasks, which can be performed by this resource (for more details see (Fiedrich *et al.*, 2000)). An incoming order is split and the associated elementary work tasks are simulated. It is also possible that one task involves more than one resource, e.g. if a crane supports SAR-work at a building. In these cases HLA mechanisms are used to coordinate a single work task over different federates. Figure 4 gives an example of the behavior within the simulation of a single fire engine.

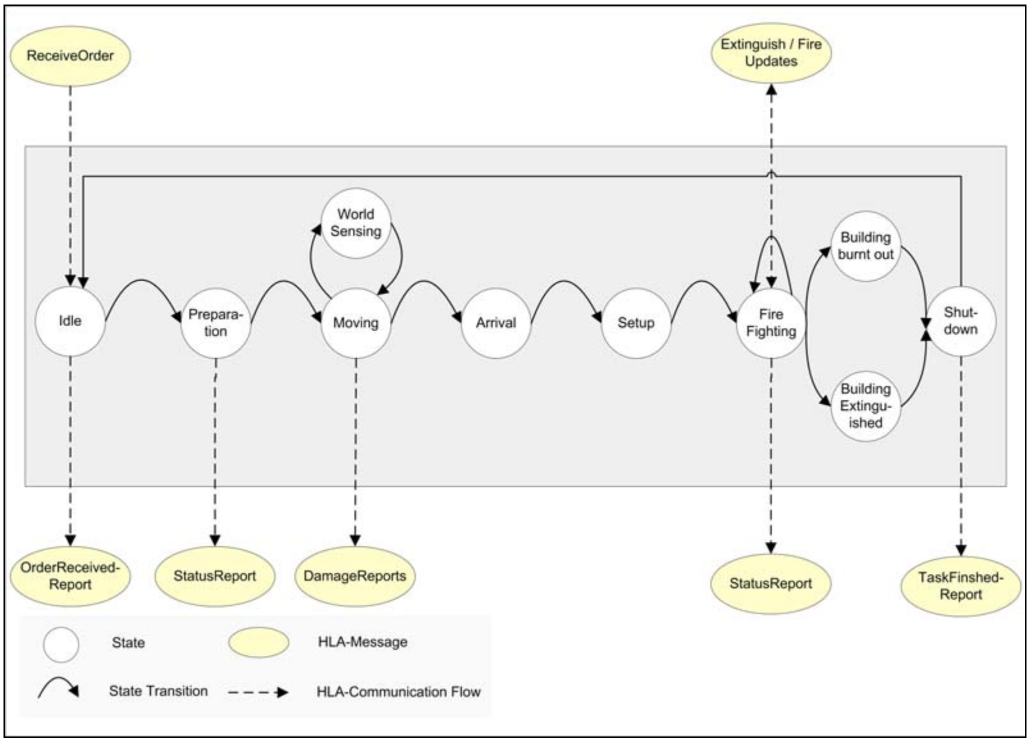
Auxiliary Simulators

There are two auxiliary federates which are used to run the disaster simulation. The first on is a manager federate which is responsible for the co-ordination of setup and shutdown process of the federation. It waits until all relevant simulators have joined the federation and it ensures that all participating federates receive relevant initialization data from other federates. The second auxiliary federate serves as a time pacer and keeps the simulation running in real-time.

Interface to Decision Makers

Interaction between the simulation of the response activities and the decision makers who define the resource allocation priorities is made via an HLA-interface. This interface allows sending orders to and receiving reports from the HLA federates simulating the resources in the field. The main actions which can be initiated by the users are the assignment of the resources to operational areas and tasks, such as transport of injured persons to hospitals. The user can select from a set of actions available for his role within the EOC. A GIS-interface enables an adequate visualization of the available IIW-information. The maps generated by the GIS show the status and location of the resources and the known information about the damages within the affected area. A messaging system allows sending messages to other users of the EOC and to persons outside the EOC.

Figure 4: Simulation behavior of a fire fighting engine



Multi-Agent System Interface

The architecture suggested in this paper includes the possibility, that software agents may be used to control the response resources autonomously or to suggest possible actions to the decision-makers (compare figure 2). These response-related software agents are based on the Belief-Desire-Intension (BDI) architecture. The BDI-approach was very much influenced by (Bratman, 1987), and software agents following this paradigm have been applied successfully to different real world problems such as fault diagnosis for the space shuttle or air-traffic management (Ingrand *et al.*, 1992). A BDI-agent pursues its given goals (*desires*), adopting appropriate plans (*intentions*) according to its current set of data (*beliefs*) about the state of the world.

Because the software agents have to act in the described simulation system an HLA-interface was defined which enables the communication flow from and to the simulated activities. Within an EOC the responsibilities are split between different EOC members. Therefore, different software agents with different roles are defined. This includes for example agents for search and rescue, medical service, fire fighting, road clearance and logistics. The plan library of each agent is based on expert knowledge about the agent's respective domain and it is derived from analysis of emergency plans and standard operation procedures as well as from expert surveys. The agent's reasoning process follows a layered approach, where – dependent on the incoming messages and the internal reasoning – events are passed to one of the following layers: (1) an elementary layer, which includes all events which can be handled directly, (2) a planning layer, which includes plans which are solely based on the agent's deliberation and (3) a co-operation layer, which requires co-ordination with other agents.

Implementation

The described system is implemented in Java and C++. HLA-related tasks, such as development of the HLA object model and the implementation of HLA-specific parts of the federates, were realized with the products Visual OMT and pRTI from Pitch, Sweden. The Multi-Agent language JACK is used for the implementation of the BDI-agents. Real world data from a defined area in Bucharest and another city in Romania with approximately 700 buildings and 40,000 inhabitants is being used for model testing. During a simulation the decisions and relevant simulation information is stored in the central database with timestamps and therefore exercise evaluation is easily possible. The implementation of the interface to the decision makers is still in progress and will be completed in near future.

Discussion

In this paper, the authors presented a distributed simulation system for disaster response activities after earthquake disasters. This system allows the consequences of the work of response resources to be simulated, including damage assessment of the affected area. It is possible to test the consequences of different priorizations of the upcoming tasks, and therefore, the system may be used in virtual disaster response exercises for emergency operation centers. By adjusting the underlying database, the simulation system can easily be adopted to different areas and scenarios.

So far the system has not been tested in a real disaster exercise, but a 2 day computer supported exercise with the Romanian Civil Protection Command is scheduled for October 2004. A detailed damage scenario for a defined test area of Bucharest will serve as training environment for the decisions of the EOC personnel. A messaging system will be included at that time and therefore it will be possible to train decision making for other tasks than those defined in the described simulation system. This may include for example preparing press reports for mass media and other natural language communication between involved agencies.

References

Applied Technology Council – ATC (1996): *Seismic Evaluation and Retrofit of Concrete Buildings*, Vol. 1 (ATC-40), Redwood City (CA), USA.

Baur, M.; Bayraktrali, Y; Fiedrich, F.; Lungu, D. and Markus, M. (2001). EQSIM - A GIS-Based Damage Estimation Tool for Bucharest. In: *Earthquake Hazard and Countermeasures for Existing Fragile Buildings: Contributions from JICA International Seminar Bucharest, Romania, 23. – 24. November 2000*, Lungu, D. and Saito, T. (Eds), 245-254, Independent Film, Bucharest, Romania.

Bratman, M.E. (1987). *Intention, Plans, and Practical Reason*. Harvard University Press, Cambridge, MA, USA.

Coburn, A.; Pomonis, A.; Sakai, S. and Spence, R. (1991). Assessing Human Casualties Caused by Building Collapse in Earthquakes. In: *Summaries of the International Conference on the Impact of Natural Disasters*, University of California, Los Angeles, USA.

Fiedrich, F.; Gehbauer, F. and Rickers, U. (2000): Optimized resource allocation for emergency response after earthquake disasters, *Safety Science*, Vol. 35, Iss. 1 - 3, 41-57.

IEEE (2001). *IEEE Std 1516-2000: IEEE Standard for Modeling and Simulation (M&S) High Level Architecture (HLA) – Framework and Rules*. Institute of Electrical and Electronics Engineers, New York. ISBN: 0-7381-2619-5.

IEEE (2001). *IEEE Std 1516.1-2000: IEEE Standard for Modeling and Simulation (M&S) High Level Architecture (HLA) – Federate Interface Specification*. Institute of Electrical and Electronics Engineers, New York. ISBN: 0-7381-2621-7.

IEEE (2001). *IEEE Std 1516.2-2000: IEEE Standard for Modeling and Simulation (M&S) High Level Architecture (HLA) – Object Model Template (OMT) Specification.*. Institute of Electrical and Electronics Engineers, New York. ISBN: 0-7381-2623-3.

Gerrard, M., Wonnacott, P., Burger, A., Gregor, J. and Williams, H. (1999). Interoperability and scalability in the Synthetic Natural Environment. In *Proceedings of the 1999 Spring Simulation Interoperability Workshop*, Orlando, FL, USA.

Ingrand, F.F.; Georgeff, M.P. and Rao, A.S. (1992). An Architecture for Real-Time Reasoning and System Control. In: *IEEE Expert*, Vol. 7, No. 9, 33-44.

Jain, S. and McLean, C.R. (2003). *Modeling and Simulation for Emergency Response: Workshop Report, Standard and Tools*. NISTIR 7071, National Institute for Standard and Technology, Gaithersburg, MD, USA.

Klein, U. (2001). *Verteilte Simulation im ausnahmetoleranten städtischen Verkehrsmanagement*. Ph.D. thesis, Otto-von-Guericke-Universität Magdeburg, Germany.

Pettitt, M.B.H., Goldiez, B.F., Petty, M.D., Rajput, S. and Tu, H.-K. (1998). The Combat Trauma Patient Simulator. In *Proceedings of the 1998 Spring Simulation Interoperability Workshop,* Orlando, FL, USA.

Reyns, R.B., Kumara, S., Satapathy, G., Smith, G. and Hummel, J.R. (1998). Distributed Intelligent Agents for Logistics (DIAL). In *Proceedings of the 1998 Spring Simulation Interoperability Workshop,* Orlando, FL, USA.

Strassburger, S. (2001). *Distributed Simulation Based on the High Level Architecture in Civlian Application Domains*. Ph.D. thesis, Otto-von-Guericke-Universität Magdeburg, Germany. SCS-Series "Advances in Simulation" AS-11, SCS-Europe BVBA, ISBN 1-56555-218-0.

Takai, Hiroyuki (1999). *Development of the Fire Spread Model for Kobe City*. Research Report No. 30, School of Engineering, Kinki University, Higashi-Osaka, Japan.

Torvi, D.; Hadjisophocleus, G.; Guenther, M.B. and Thomas, G. (2001). Estimating Water Requirements for Firefighting Operations Using FIERAsystem. *Fire Technology*, Vol. 37, 235-262.

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THE DISASTER MANAGEMENT TOOL- A MULTIDISCIPLINARY APPROACH TO EARTHQUAKE DISASTER RESPONSE

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Keywords: disaster response, damage assessment, damage simulation, earthquake, urban search and rescue

Abstract

When urban areas are stricken by earthquake disasters and experience substantial destruction, in general, the remaining operable disaster response teams are overstrained. An efficient and integrated disaster management could support their activities and help to limit human losses. For this task, the Disaster Management Tool (DMT) was developed within the German Collaborative Research Centre 461: "*Strong Earthquakes, a Challenge for Geosciences and Civil Engineering*" based on EQSIM, a damage estimation tool. The concept of the DMT is presented in this paper.

It includes fast and reliable damage and casualty estimation methods, up-to-date reconnaissance techniques such as damage detection based on airborne laser-scanning data and communication and information tools to support the disaster management personnel. A decision support system will help to co-ordinate the allocation of the limited number of rescue personnel and machinery to enhance their overall efficiency. Onsite rescue operations will be supported by an expert system analysing damage information acquired after the earthquake, combined with data about the buildings construction and occupancy collected prior to the earthquake.

Pre-event training and mitigation tasks, as well as post-event disaster management, are the projected applications of the DMT. For training purposes, actors of the disaster environment are simulated. A High Level Architecture (HLA) interface is used for the distributed simulation.

Development and trial of the DMT is carried out in co-operation with the Civil Protection Command of Romania and the German governmental disaster relief organization Technisches Hilfswerk (THW).

Introduction

In general earthquake disasters in urban areas can hardly be handled by the remaining operable disaster response teams of the affected region. An efficient and integrated disaster management could support their activities and help to limit human losses. The Disaster Management Tool (DMT) is a multidisciplinary approach of the German Collaborative Research Centre 461: "*Strong Earthquakes, a Challenge for Geosciences and Civil Engineering*", to perform this task.

The Disaster Management Tool is a software system supporting decision-makers, surveillance and intervention teams during disaster response. The response actors can access basic data about building stock, residents and resources as well as dynamic data like seismic measurements, damage estimations, damage observations and damage detections. It assists decision makers as well as rescue team leaders with decision support and intelligent communication tools.

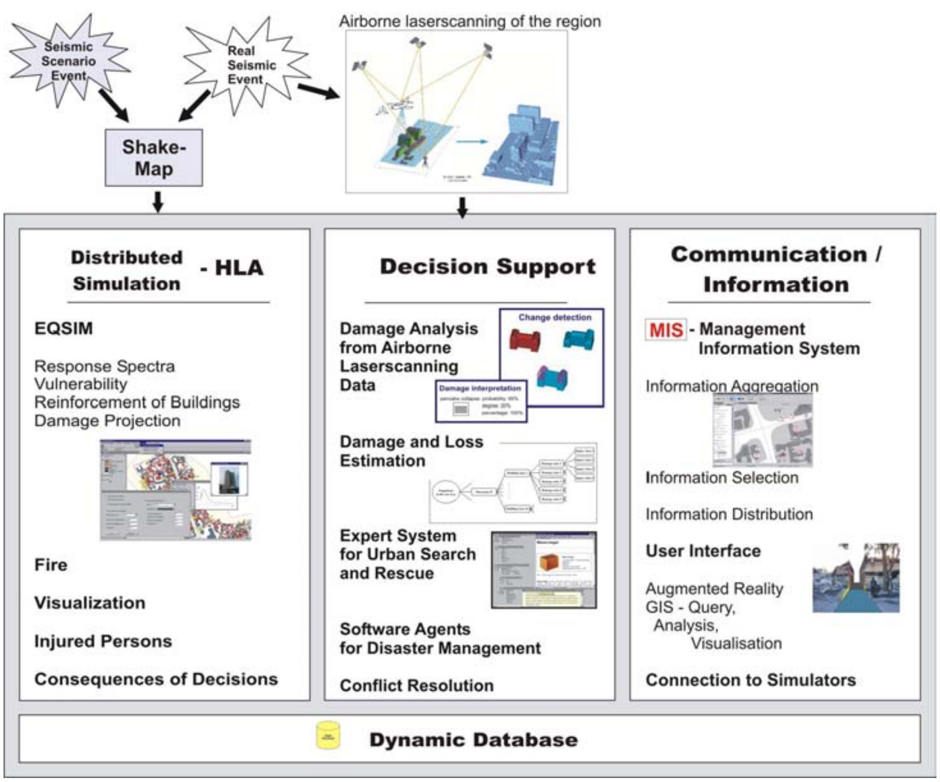
The test area for development is Bucharest, Romania, where strong earthquakes with average recurrence rates of two decades in the near Vrancea area occur periodically. DMT is designed for earthquake disasters in Bucharest as a test case, but planned to be adaptable to urban areas in industrializing countries with various disaster types.

At the present stage of development, improvement of disaster response is the main objective of the tool. Given the disaster circle leading from risk assessment, prevention and preparedness to disaster response, rehabilitation and reconstruction, the DMT can also be used for risk assessment using the damage estimation tool with expected seismic input, and for preparedness using the damage estimations for disaster response training and to define the resources needed. In this paper the different components of DMT a described in brief. The stage of development and further goals will be expressed.

Concept of the Disaster Management Tool

The Disaster Management Tool has three main functional parts. The first simulation part is responsible for fast damage and casualty estimation, simulation of future development of the disaster environment like fire propagation and consequences of decisions and simulation during exercises. The damage and casualty estimation based on seismic data is performed by the component EQSIM, which is in the most advanced stage of development within DMT.

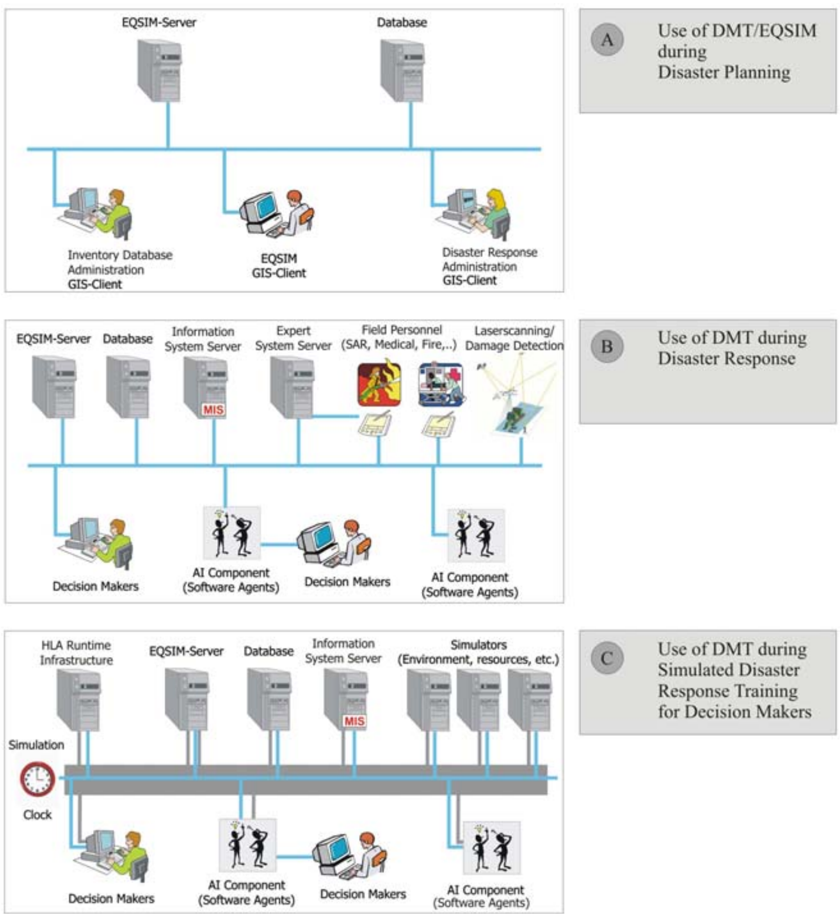
Figure 1: Concept of the Disaster Management Tool



The second part encloses elements for decision support. Main components are a system for damage analysis based on airborne laserscanning observations, damage and casualty estimation based on building stock and residential data as well as geometrical information about the collapsed buildings. An expert and information system supports rescue activities at collapsed buildings with case relevant advice and information from central database. A decision support tool for operational centre members helps to assign the response resources to maximize the effort of response activities.

To integrate the operations on the different executive levels, the third functional part of the DMT undertakes the tasks of communication and information. The management information system conducts the aggregation, selection and distribution of information relevant for the specific actors of disaster response. A graphical user interface helps to visualize the mostly geographical related information. And a special augmented reality user interface helps analyzing the situation at rescue site to accelerate response activities.

Figure 2: possible applications of DMT and EQSIM



The dynamic database is the central element of DMT. The different components use the common Oracle database to access static data like building stock data or historical earthquake data. They store and exchange dynamic data like observation results from different sources or locations of rescue resources. Backup databases are stored on the local computers depending on the components in use. Figure 1 shows the concept of the DMT.

Software Architecture

DMT uses an approach based on distributed computing over computer networks. Therefore, it consists of components (Figure 2), which will be described in detail throughout this paper. The EQSIM server program performs the calculation of the damage scenarios and implements the damage estimation methodology. Calculation requests can either come from client programs where users can define scenarios based on the historical earthquake database respectively defined earthquake parameters (such as location, magnitude and depth) or such requests arise from software agents which may be used for decision support during disaster response. During disaster response, field personnel may update the central database with observed damages that are input for a groundtruthing component of the server program to improve the scenario calculations.

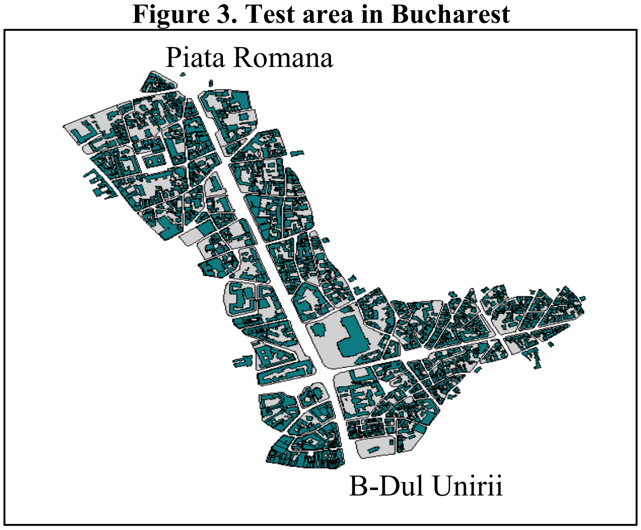
The Management Information System (MIS) server controls the communication and information flow between users and to database. It distributes new information to users with relevant demand profile.

The Expert System Servers are located at or near to operation sites. The response teams use mobile computers or PDAs connected via WLAN to the servers to obtain case relevant data and advice. Input data from field personnel is sent to central database. Additional direct access to database and use of MIS is possible for the field personnel.

During a simulated training exercise, all components are linked via a distributed simulation, which is based on the High Level Architecture (HLA). In this case, the field personnel and the response resources may be simulated by separate HLA-simulators. Figure 2 gives an overview over the possible application fields of the DMT with EQSIM.

Test Area in Bucharest

Figure 3. Test area in Bucharest



The Disaster Management Tool is designed for urban areas. Development and testing are carried out in Bucharest as a case study. An area of Bucharest was defined for high-resolution data including information for each building. The test area is located in the inner city between Piata Romana and Bodul Unirii where most of the damages of the last destructive earthquake 1977 took place (Figure 3). The data collected for this test area is compiled in the DMT-GIS and the central database, which is linked to the building layer and street layer of the GIS. The test area contains 1305 buildings with all kinds of occupancy. Supplementary 763 small garages or stores were identified in this area that consist of one storey. After visual examination, no occupancy was assigned to these buildings.

The following compilation shows the essential building information within the database for each single building:

• Street and number • Occupancy class • Number of storeys/ basements • year of construction • type of construction	• construction details (floor type, storey height, balcony..) • potential soft storey with different occupancy class • number of flats/residents

Occupancy classes and construction types base on the ATC-14 Report [1] and the HAZUS methodology [2]. Supplementary to the 36 HAZUS classes of building structures 14 European types, not common in the United States, were added. Construction data is necessary for damage estimation, damage recognition and planning of rescue operations.
The data sources were the list of expertises of highly vulnerable buildings from Romanian experts [3], building data including data of the buildings collapsed in Bucharest on March 4, 1977 from the Technical University of Civil Engineering, Bucharest, information of the used 1:500 scale map, results of the census in 1990 and the results of the inspection of the buildings in the test area. This inspection was necessary due to the different age and quality of the used data sources. Since the information is needed for each single building a questionnaire with instructions was developed for a visual inspection of single buildings. The whole building stock of the test area was inspected during three weeks with two teams consisting of 2-3 persons. At least one photo was taken of each building.

The building stock of the test area consists both of residential buildings and commercial buildings. The northern area is stamped by tall concrete frame buildings of more than seven storeys; the test area also includes many low-rise historical buildings. Other construction types in the test area are wood and steel frame buildings, precast concrete, reinforced and unreinforced masonry buildings. Altogether 20 combinations of construction type and height range specify 97% of the test area building stock.

The Database

The central Oracle 9i database stores all relevant information. The database includes tables for different aspects of the damage estimation and information to be exchanged during disaster response. The tables fall in the following groups:

Static area information: about the existing infrastructure of the test area. E.g. soil data based on microzonation or building details such as construction specifications and occupancy data.

Information about building behavior (EQSIM): capacity and fragility curves for all defined building types to calculate building damages with the capacity spectrum method.

Information for casualty estimation: these tables define the probabilities for different injury classes dependent on building type and damage class.

Earthquake related information: historical earthquake data with Vrancea earthquakes based on the ROMPLUS catalogue [4] and available response spectra from recorded time histories.

Meta knowledge (EQSIM): this group of tables includes for example parameters for the calculation of seismic response spectra or parameters for the used attenuation functions.

Scenario results (EQSIM): for scenario analysis all scenario results (e.g. damage and casualty probabilities on building level) are stored in different database tables.

Disaster response resources: personnel and material resources including fire brigades, specialized rescue teams EMS teams, civil and military trucks, excavators etc.

Plans: the disaster response plans are related to activities and disaster response resources and support decision makers

Activities: including actions and actors to notify activities exchange information about new activities, e.g. observations

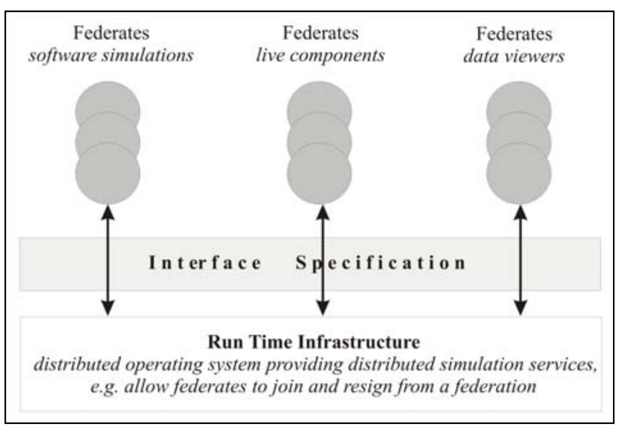
Observations: results of observations. Different observations from different actors about the same building are possible.

Because the database includes meta knowledge about the damage estimation methodology, it is flexible to be used with other areas. Additionally, the impact of different available methods on the scenario results can be examined making it a valuable tool for researchers as well.

The Simulation Component

The DMT can also be used in virtual disaster response training by the staff of Emergency Operation Centers (EOC). For this EQSIM is embedded in a distributed simulation of the response activities after strong earthquakes. This simulation uses the High Level Architecture (HLA) as a common framework.

Figure 4: Main components of an HLA-based federation (after [8], p 212)

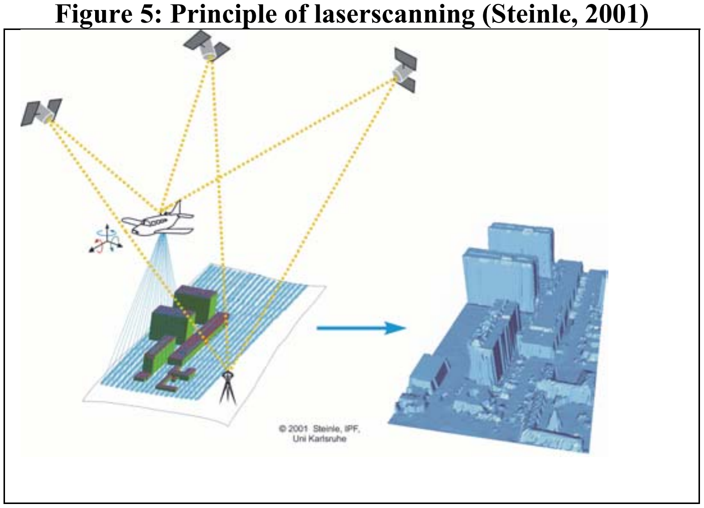


HLA was developed by the Defense Modeling and Simulation Office (DMSO) of Department of Defense (DoD) of the United States with the main goal of building a platform for war gaming and training taking into account interoperability and reuse of different simulation components. Since the year 2000, HLA is an Institute of Electrical and Electronics Engineers (IEEE) standard for distributed simulation systems. A distributed simulation using the HLA is called a federation, and each single simulator in such a federation is referred to as a federate. A federate may be a simulation, live component (e.g., physical device or human operator) or data viewer. The federates interact via a central component which is called the Run Time Infrastructure (RTI). To enable this communication each federate must implement a predefined HLA-interface (compare figure 4). Technical details about HLA can, for example, be found in the IEEE specifications [5], [6] and [7].

The EQSIM server program implements this interface as well. This allows other simulation components to send calculation requests to the server during a simulation-based exercise. In the simulation system, the disaster environment and the use of resources within the disaster environment can be simulated in real time. Simulated resources include SAR-Teams, ambulances, fire fighting units, recon units and heavy equipment resources for repair work of blocked roads and rescue operations. To interact with the simulation different elementary actions are defined. These actions can be used during a simulation by humans, such as management-level personnel, to perform either predefined or improvised plans based on the available actions. Additionally a multiagent system can be linked to the simulation environment where the software agents (software agents are computational systems with goals, sensors, and effectors, which decide autonomously which actions to take, and when) use predefined flexible plans for their reasoning process. Because both the software agents and the computer interfaces for the humans implement the HLA-interface, it is possible for them to take advantage of the damage estimation tool EQSIM for the planning of the response activities.

Concept of Rapid Damage Detection

Figure 5: Principle of laserscanning (Steinle, 2001)



One of the main deciding factors for the need of SAR resources is the knowledge about the location, the extent and the characteristic of a totally or partially collapsed buildings. Fast acquisition of such data is essential for rapid assessment of the needed rescue personnel and equipment. Within the CRC a method based on airborne laser-scanning is researched (compare e.g. Steinle & Vögtle, 2001 [9]) to obtain rapidly information about the damage situation of buildings in affected areas. This method will be briefly described in the following.

Laser-scanning and building modelling

Since the early nineties, the laser-scanning technology - an active airborne scanning technique - is operational and successfully used for dense three-dimensional point measurements (see e.g. Ackermann, 1999 [10]). This technique allows producing height data sets, e.g. digital surface models (DSM) in an efficient and rapid way (see figure5). Based on these data, three-dimensional vector models of the building can be produced. In this approach, an automatic methodology is used to model the buildings' geometry.

Change detection and damage interpretation

To be able to detect earthquake caused building damages, the buildings' geometry in their intact state must be known. Comparing the geometry of buildings before and after a destructing event (e.g. an earthquake), it is possible to detect the changes between the two states and to quantify them by using change measures like volume differences, plane orientation change, height change or size alteration. These changes must be further analyzed and interpreted.

Modifications at buildings, especially in urban areas, are not necessarily caused by damages. They can also be a result of normal modifications (e.g. by construction activities) (see Steinle & Bähr, 2002 [11] for details). The changes identified as not being caused by normal urban modifications are classified in damage types using the previously developed damage catalogue. The classification of the identified changes into damage types is done automatically by comparing the geometrical characteristics of each damage type stored in the damage catalogue with those observed at the modified building (parts) after an earthquake. As they will rarely fit exactly, the most likely damage type of the catalogue will be assigned, but the ratio of concordance will also be given.

At present, the automatic damage classification process is developed. The tests of this component are planned with laser-scanning data of an exercise area of Swiss Army. Further adjustment with the damage catalogue will be necessary.

Expert and Information system for rescue operation support and training

The technical personnel who is in charge of rescue operations after building collapse - in Germany mainly fire-brigades, the civil protection organization THW (Technisches Hilfswerk) and search groups from further organizations- rarely possess own experiences from similarly cases. However the rescue of trapped victims from collapsed buildings requires a substantial technical, personnel and organizational effort (see [12]). During rescue activities, trapped victims are moreover at risk, when building elements are relocated or extracted and when fine-grained building material trickles down on them leading to suffocation. Even rescue personnel are exposed to a substantial risk. After Tiedemann [13] more than 100 rescuers were killed during operations after a destructive earthquake in Mexico City 1985.

Standard procedures for rescue activities were designed in co-operating with the German Fire Protection federation (vfdb). For training and operation support, an expert and information system was created and tested with the THW [14]. It consists of the three components on-line manual, expert system and computation component. After integration into the DMT, communication with control personnel and data-exchange with the central database is possible. Local observations can be sent to database and construction details from database support rescue activities.

The on-line manual contains information about building types, construction components, rescue equipment and methodology. It consists of HTML and pdf documents with navigation support. It is useful for training and to easily access necessary knowledge during rescue activities. From here the user gains access to the expert system where he enters information relating to a certain case (see figure 6). Context sensitive subsequent questions are posed by the expert system. Building stock data from central database can be taken over. The diagnosis includes advice concerning the processed case and links to specific entries within the information system. Case-relevant checklists are printed and appropriate tools and methods are given. The expert system bases on the D3 Server System application [15].

Figure 6: screenshot of expert system data input

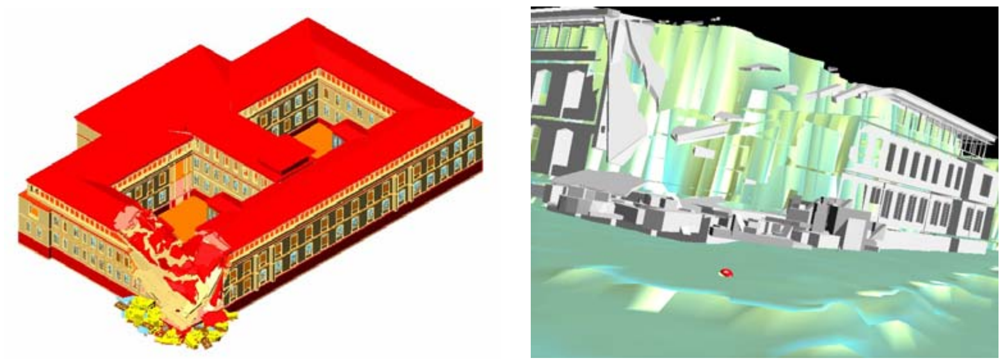
With the third computing component, calculations of debris masses and masses of building materials such as steel profiles or concrete floors can be performed easily and reliable under operational conditions. The masses then can be used for strut dimensioning, crane selection and transportation calculations with this component.

The expert and information system is a server application that can be used at the rescue site with mobile computers and PDAs via wireless LAN. It was tested by professional users at model cases. Currently the connection to DMT and its database is programmed. The functionality will be enhanced.

User interfaces

The standard user interface for DMT users is a graphical user interface (GUI) with GIS functionality. The Management Information System and the EQSIM user utilize this GUI. The rescue teams use the expert and information system with an html browser. A further user interface bases on augmented reality technology. Here the user wears semitransparent spectacles. With a differential GPS and inertial sensors the position and line of vision of the user are measured. The data is corrected by comparing the view of the user, recorded with a camera, with the calculated view based on the digital surface model (DSM). Depending on the object in sight of the user, relevant data like residential use of the building or number of storeys before collapse are shown with the semitransparent display. At collapsed buildings, the three dimensional view of the building before collapse is displayed. The user can now compare directly the real view of the collapsed building with the view of the building before collapse in his spectacle. When going around the building the user can repeat this comparison from different perspectives. This helps discovering areas with possible voids in the collapse structure or areas where trapped victims are possibly located following their initial locating. This technology, which is only possible with inventory data, can help the rescuers to search selectively and thus to accelerate the rescue process.

Figure 7: model of a collapsed building and test of the augmented reality unit with this dataset



First tests of the augmented reality user interface were performed at the university campus. Figure 7 shows the result of the test using a real not collapsed building from DSM and a model of the same building in a partially collapsed state.

Conclusions and future work

In this paper, the Disaster Management Tool was described as a promising tool for disaster response in an urban environment. The client-server architecture permits to use DMT simultaneously by different users. It can be applied for disaster planning, disaster response and for disaster response training.

The data acquisition of a test area in Bucharest and the collected data was described. The central database allows the users to avail steadily actualized data of the changing disaster environment. The database is necessary for data exchange between the DMT components like Management Information System and the Expert and Information System. For simulation of response activities, the distributed simulators, EQSIM and the user interfaces communicate in case of training based on a High Level Architecture (HLA) framework.

The concept of the rapid damage detection and interpretation component, which is using airborne laserscanning technology, was given and the expert and information system supporting field personnel was described shortly. Then the augmented reality user interface and its planned application within DMT were introduced.

The first test of the whole DMT tool with local disaster management and response units in Bucharest is determined for October 2004. The exercise will be held on control center level and on onsite operation search and rescue level. At moment, the different components are adapted to DMT before the tests will be carried out under real conditions.

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References

Applied Technology Council (1987). Evaluation the Seismic Resistance of Existing Buildings, ATC 14 Report, Applied Technology Council, Redwood City, California.

National Institute of Building Sciences (1997). Earthquake Loss Estimation Methodology HAZUS. Technical Manual, Vol. I-III.

Monitorul Oficial al Romaniei, Partea I, Nr.516 bis (1999). Hotarare pentru aprobarea Normelor metodologice de aplicare a Ordonantei Guvernului nr. 20/1994 privind masuri pentru reducerea riscului seismic al constructiilor existente, 25.10.1999

Oncescu, M.C.; Marza, V.I; Rizescu, M. and Popa, M. (1999). The Romanian Earthquake Catalogue between 984-1997. In: *Vrancea Earthquakes*, Wenzel, F.; Lungu, D. and Novak, O. (Eds.), Kluwer Academic Publishers, Dordrecht, Netherlands, S. 43-47.

IEEE (2000). Standard for Modeling and Simulation (M&S) High Level Architecture (HLA) - Framework and Rules, IEEE Standard No. 1516-2000.

IEEE (2000). Standard for Modeling and Simulation (M&S) High Level Architecture (HLA) - Federate Interface Specification, IEEE Standard No. 1516.1-2000.

IEEE (2000). Standard for Modeling and Simulation (M&S) High Level Architecture (HLA) - Object Model Template (OMT) Specification, IEEE Standard No. 1516.2-2000.

Fujimoto, R.M. (2000). Parallel and Distributed Simulation Systems. *Wiley Series on Parallel and Distributed Computing 3.* John Wiley, New York

Steinle, E. and Vögtle, T. (2001). Automated extraction and reconstruction of buildings in laserscanning data for disaster management, in: Proceedings of the Workshop Monte Verita, Switzerland, 10-15 June 2001, Baltsavias, E. P., Gruen, A. and Van Gool, L. (eds.), *Automatic Extraction of Man-Made Objects from Aerial and Space Images (III)*, Balkema (Swets & Zeitlinger), Lisse, The Netherlands, p. 309 - 318

Ackermann, F. (1999). Airborne laser scanning – present status and future expectations. *ISPRS (International Society for Photogrammetry and Remote Sensing) Journal of Photogrammetry and Remote Sensing*, 54 (1999), pp. 64 - 67, 1999

Steinle, E. and Bähr, H.-P. (2002). Detectability of urban changes from airborne laserscanning data, in: Navalgund, R. R., Nayak, S. R., Sudarshana, R., Nagaraja, R., Ravindran, S. (eds.): *Resource and environmental monitoring, ISPRS commission VII symposium*, Hyderabad, India, December 2002

Coburn, A. and Spence, R., (2002). Earthquake Protection, Second Edition, Chichester, England, John Wiley & Sons Ltd.

Tiedemann H. (1992): Earthquake and Volcanic Eruptions: A Handbook on Risk Assessment, Swiss Reinsurance Company, Zürich

Markus, M., Fiedrich, F., Gehbauer, F. and Hirschberger, S. (2000). Strong Earthquakes, Rapid Damage Assessment and Rescue Planning, in: Kowalski, K.M. and Trevits, M.A. (eds.): *Proc. of the 7th Annual Conference of the International Emergency Management Society: "Contingency,* *Emergency, Crisis, and Disaster Management: Emergency Management in the Third Millennium"*, Orlando, Florida, May 1999, pp. 369-378.

Puppe, F.,Bamberger, S., Iglezakis, I., Klügel, F., Kohlert, S., Reinhardt, B., Unglert, T., Wolber, M. (1997): Wissensbasierte Diagnose- und Informationssysteme mit dem Shell- Baukasten D3 – Handbuch, Lehrstuhl für künstliche Inteligenz und angewandte Informatik, Universität Würzburg

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THE USE OF INFORMATION TECHNOLOGY IN DISASTER RESPONSE OPERATIONS OF THE TURKISH RED CRESCENT SOCIETY

H. Huseyin Guler & H. Engin Inan

Abstract

The Turkish Red Crescent Society ("KIZILAY" in Turkish) has been providing its various services since 1868 in the country and abroad. TRCS has changed its vision and mission drastically after 1999 earthquake disasters that happened in east "Marmara" region. The new strategic document of TRCS is emphasizing the importance of using the information technology and improving disaster preparedness works in the community for coping disasters.

A Geographical Information System (GIS) is able to process both the acceleration distribution data of an earthquake and the existing database in TRCS for rapid damage estimation. It is particularly aimed to predict the dimensions of a disaster in terms of damage and casualty assessment considering the prone area. Checking and investigating process starts for verifying the emergency news through TRCS communication channels with nearest branches offices and also with local governmental authorities. TRCS disaster response operation will be start as planned by taking into account the damage estimation results for appropriate action.

TRCS has powerful wireless mobile systems and satellite phones for communication and data transfer between field teams and the Disaster Operation Center (AFOM) in "Ankara". High-resolution satellite images help preliminary disaster assessment if it is available immediately. Disaster-related information and data transmission are possible for conveying the relief activities of TRCS in disaster areas. It is also due to immediate release on the interactive web page of AFOM.

Country profile

Turkey lies between two continents; Europe and Asia. It comprises an area of 778 000 square kilometers and the population is about 67 million from the census of the year 2000. The European and Asian sides are divided by two straits; "Bosphorus" at "Istanbul" city, and "Dardanelles" at "Canakkale" city. "Anatolia" is the name given to the larger Asian part, which is a plateau rising progressively towards the east, and is broken by the valleys and rivers. Because of its geographical location, the mainland of Anatolia has always found favors throughout history, and is the birthplace of many great civilizations, the remains of which have made it one of the tourist attraction centers of the world.

Administratively, the country has 81 provinces and 850 towns which headed by the appointed governors. There are 35 000 villages that is smallest settlement units and 3 200 municipalities that the population exceeds 2 000. Each municipality have a mayor who is elected by the local citizens. The representatives of the state and the elected mayors are in charge of providing all public services to the citizens in their jurisdiction.

Turkey is also one of the most natural disaster-prone countries of the world. Turkey has always been vulnerable to various kinds of natural hazards, because of its geology, topography, and climate. These hazards, coupled with high physical and social vulnerabilities, have caused unacceptable losses of life, injury, and damage to property. Earthquakes, landslides, floods, rock falls, and avalanches are the principal natural hazards. Deforestation and the attendant soil erosion exacerbate these hazards. Since the beginning of the twentieth century, approximately 96 000 people have lost their lives and another 210 000 have been injured because of natural disasters. The total number of houses damaged by natural disasters is approximately 651 000. Viewed within the context of deaths and injuries, earthquakes account for about 90% of the losses.

The Turkish economy is one of the most dynamic economies in the region. Measured in terms of direct economic losses, natural disasters have accounted for 1% loss on average GNP, of which earthquakes alone accounting for 0.8%. The 1999 earthquakes (August 17th and November 12th) that claimed almost 18 600 human lives was one of the most catastrophic disasters in the history. During the five years before 1999, GDP grew averagely more than 6.5% a year. Because of the devastating effect of two earthquakes in 1999, the GNP has decreased by 6.1%. Turkey exported goods and services in excess of $48 billions, and imported $64 billions in 2003.

Disaster management

It is a collective term encompassing all aspects of planning for and responding to disaster including both pre- and post-disaster activities. It refers to the management of both the risks and the consequences of disasters. It is not a series of events, which starts and stops with each disaster occurrence. On the contrary, it is a continuum of inter-linked activities. This set of activities - Mitigation, Preparedness, Response, Recovery, and Development - is called the Disaster Management Cycle. Relief phase is the period immediately following the occurrence of a sudden disaster when exceptional measures have to be taken to survivors as well as to meet their basic needs for shelter, water, food and medical care.

The Disaster Management Response system of Turkey is highly centralized and hierarchical. Responsibility for disaster management goes bottom-to-top, from sub-province to province and to national level depending on the scale of the event. Small-scale disasters can be handled firstly at the sub-province level. If the disaster surpasses the capacity of this level, the provincial governor, who heads the ‘Provincial Rescue and Relief Assistance Committee’ known as ‘Crisis Committee’, is involved in the response and recovery activities. If a major event that requires central government intervention occurs, then the ‘Central Coordinating Committee for Disaster’ in the capital comprised of under secretaries or high-level representatives from various ministries coordinates the response efforts for the disaster.

Introduction of the society

The Turkish Red Crescent Society (TRCS) carries out relief activities not only within, but outside the country too. It was established on 11 June 1865 by accepting "the crescent" as its emblem. The name of "KIZILAY" was given to the society in 1935 by "Ataturk" who is the founder and the first president of the republic. The TRCS is empowered and resourced by the community and carries out activities in disaster management, social relief, youth, health, blood and blood products, as well as, humanitarian relief.

Since the day it was established, KIZILAY has been providing continued in kind and cash relief services to poor citizens. The Society has been continuously enhancing its youth activities. It also helps successful students with low income by offering scholarships. Citizens, who are not protected by social security schemes, receive health services at KIZILAY medical centers. At the community centers, disaster victims are assisted to return to normal life. Traditional First Aid courses continue as one of the health services provided by the society. TRCS is one of the main organizations undertaking the establishment and development of blood services in Turkey. Extending aid to victims of all kinds of disasters impartially, it waives its flag all over the world. KIZILAY cooperates in all relief activities of the International Federation of Red Cross and Red Crescent Societies (IFRC) and its member National Societies, as well as, the International Committee of the Red Cross (ICRC).

TRCS has 672 branches and resources that give it the potential to play a lead role with other civil organizations. More branch offices of the TRCS are getting involved in local response planning because of the expectation by the local government to become part of their response system. The staff in these branches have trained in the field of Disaster Management to ensure their participation and contribution to the communities they serve is effective and valuable. Many NGOs and community self-help groups are coordinating their own public education activities and community based initiatives.

Disaster preparedness, planning and response activities

Lessons learned from previous experiences have proved that policy and activities aimed at disaster loss reduction are more efficient and effective than those of 'healing wounds'. As one of the most important organizations in this field at the national level, KIZILAY has prepared and launched training programs to inform and improve knowledge of the community as a part of its loss reduction activities within the restructuring process.

KIZILAY established a Disaster Operations Centre (AFOM) in 2000 to carry out all humanitarian relief activities more rapidly and efficiently. In parallel, KIZILAY worked out on enhancement of communication systems, creation of databases, preparation of earthquake damage early notification and stock monitoring systems to increase the level of preparedness.

Provision of emergency humanitarian relief such as shelter and food, as resources permit, activities to meet blood needs, delivery of health services within the framework defined by national legislation. KIZILAY prepares disaster preparedness and response plans. It ensures good cooperation and compliance of plans with national plans. These plans are based on results of needs assessment, physical, social and economical vulnerability and capacity assessment in terms of local human, finance, equipment, material resources etc. conducted in advance.

Strategic plan of the society

As an initial step of the planning, the mission and the vision of the society have been redefined within the organizational development plan in 2002. The mission of the Society is to provide humanitarian assistance to the vulnerable and support enhancing community capacities to fight against all types of disasters. Hence, protect human dignity in every situation, place and time, by mobilizing community resources and capacities. On the other hand, the vision determined as to be a humanitarian organization, embracing and being embraced by the entire society, continuously enhancing its reputation and service quality at national and international levels.

Goals and objectives are defined accordingly, measurable indicators are developed and performance is monitored and evaluated. Main strategic goal is to establish a disaster management system to meet needs and expectations of the community and improve its service delivery capacity at national, regional, and local levels. With its loss reduction, preparedness, response, and rehabilitation components, contemporary disaster management is a concept that should continuously be developed and updated in light of lessons learned from each disaster.

The other objective of the strategic plan is to establish a Disaster Information and Earthquake Early Damage Assessment Systems at AFOM to respond to disasters more effectively. Through an early disaster information and system, KIZILAY will be able to identify needs rapidly and transfer this information to the nearest logistics centers. The system can identify the affected area, as well as, losses and damages caused by disaster to respond as soon as possible.

Recent earthquake losses in Turkey

In seven urban earthquakes of the last decade some 20 000 people have been killed, that the vast majority of them through the collapse of residential buildings. Altogether in these earthquakes 70 000 buildings have been damaged, and some 20 000 buildings destroyed.

Event	Earthquake Magnitude	Number of Casualties	Collapsed or heavily damaged	Moderately damaged buildings	Economic loss US$ billion
Erzincan, 1992	6.8	645	1 450	8 000	0.75
Dinar, 1995	6.1	100	2 043	6 543	0.25
Adana, 1998	6.1	150	2 000	21 057	0.5
Kocaeli, 1999	7.4	>17 000	6 000	24 000	>18.
Dűzce, 1999	7.2	759	800	10 121	>1.
Sultandağ, 2002	5.8	45	2 399	737	0.2
Bingöl, 2003	6.4	174	1 600	2 900	0.1

Statistics on urban housing indicate that in the three largest cities over 50 percent of the buildings in existence today are of reinforced concrete frame construction, and over 75 percent of these are of more than three stories. Some 80 percent of urban households therefore live in these mid-rise apartments' blocks. The annual increment over recent years is even more heavily dominated by mid-rise RC frame construction - perhaps over 90 percent of new housing. Recent earthquakes have once again demonstrated that this type of construction is much more vulnerable to damage or collapse in an earthquake than the low-rise construction in which most other people live.

Earthquake early damage estimation system

Turkish Red Crescent Society has developed a joint project to have an earthquake early damage estimation system for conducting a better disaster response. As a necessity of this project, cooperation with 'Ministry of Public Works and Settlement' (MPWS) and 'Middle East Technical University' (METU) has been established. It is targeted sharing of the earthquake data coming out from the "National Strong Ground Motion" (SMA) network of the Ministry, by the related parties simultaneously. The SMA network are operating by the Earthquake Research Department (ERD) in Ankara, has more than 80 digital accelerometer stations which located along the important fault zones of our country.

The "Disaster Management Implementation and Research Center" of METU, is providing digital accelerometers through the international research projects for developing of this network. These sensors measure the acceleration records of an earthquake on the stations throughout the network, different from the normal seismology network which can measure the parameters of an earthquake. Acceleration records which define the affect of an earthquake on the ground, makes possible to calculate the estimated damage and losses. Using these estimations, the existing disaster response mechanisms of AFOM can be directed on time, rapidly, correctly and effectively for a disaster response after an earthquake to transmit the relief materials on time and to right places. Same information will be used by the related parties as they wish according to their own purposes.

The ERD has another network for disaster prevention researches. Turkish-Japanese (ERD-JICA) unique system serves only a limited service area with 10 stations which located in the central north of the country. This experimental system is still sending the results of calculated acceleration distribution data to AFOM automatically through e-mail. However on KIZILAY side, there is no system yet that will receive and process these data automatically to make early damage estimations. Besides, the system in this stage sending the earthquake information in SMS format to dedicated cellular phones to notify the experts. In the future the messages will include some early damage estimation results. This job is now being conducted with human intervention by running special software on AFOM computer system.

The new original software is under development will accept automatically the acceleration distribution data which transmitted from the ERD computer system. The software itself is flexible, credible and broader considering the necessities in the future. So, the changes and additions that can be required can easily be adapted. KIZILAY has provided the necessary hardware for the designed system, Port Multiplier, Modems and a special Server computer on which the produced original software is working on.

Also a Geographical Information System (ArcGIS) that is using the data bases in the scale of the country has been developed in AFOM. A genuine web page for AFOM has been designed for the rapid sharing of value added data, information and visual materials provided by the system in electronic format. KIZILAY is using a financial source from the American Red Cross Delegation in Ankara to realize this experimental system and to improve technical capacity of AFOM.

Damage assessment

The estimated damage of a disaster can be characterized with calculation of possible losses in case of a scenario event. If disaster happens the same calculation algorithm of calculation may applicable to the real life successfully. Damage and loss assessment are directly related with need assessment that are required for proper response to a disaster. These assessments include not only commodities of food, medicines, and shelter but also the logistical requirements of getting relief to the potential victims. From them the planner can calculate the potential extent of disaster related losses and casualties in terms of geographic area, specific populations, agricultural crops and livestock, industry and infrastructure/lifelines.

The primary sources to develop these estimates are to have some data bases such as distribution of population, type of construction, maps, space imagery and other related information of disaster area. Damage criteria and related definitions developed for Turkey has been used in the calculation procedure of the early damage estimation algorithm. Related statistical data obtained from the State Statistical Agency. In the year 2000 results of the census of population taken into account and recalculated again considering annual growth for every settlement in the country. Building stock inventory is available for the year of 2000 but only consist of municipal settlements. It was necessary to make a calculation for building stock in villages by using an empirical relation between the numbers of persons in the household, because population census and considering the building type pattern in the region.

Earthquake damaging effect can be express in terms of seismic intensity scale after field observations by experts. But the damage estimation requires calculated values that are named as instrumental intensity which are generally based on recorded strong motion data. A digital strong ground motion instrument can record and transmit waveforms to a control center. These acceleration data comes from at least in several stations if the earthquake is destructive one. It is possible to calculate the distribution of recorded acceleration by considering attenuation relationship function in the vicinity around the epicenter region. This distribution will be shown in a map that referring some degrees of intensity that decreasing from the epicenter point.

Building stock of each settlement in disaster area can be classified in 3 category of damage namely as heavy, moderate and light. Every construction type of buildings has different relative damaging ratios. On the other hand instrumental intensity is changing due to the ground condition of the site and distance of epicenter. The relative damage ratios that have been used here are extracted from the damage assessment reports of destructive earthquakes that occurred in the history of this country.
It should be noted that the accuracy of these kinds of damage estimations directly related to availability of statistical data and the appropriateness of mathematical models that assumed representing the real conditions. Naturally, many other criteria can be added to this pilot damage estimation system to obtain more precise outputs. It is expected that the system will be developed in the future while KIZILAY using and testing it in case of disasters.

Conclusion

Results of this study could contribute to the understanding of effective use of strong motion data for estimation of earthquake losses. Also the information technology tools makes possible to use these estimation of damages and resources allocation for disaster prevention and preparedness. It will be possible to make early damage estimation just after an earthquake with this new system at AFOM. Seismic information and acceleration records from ERD will be used directly and rapidly to evaluate the possible situation. It is expected that the existing disaster response mechanisms of KIZILAY can be directed properly and quickly to transmit urgent humanitarian assistance to right places.

In time of an earthquake the existing accelerometers will automatically send data to ERI center and AFOM. Acceleration distribution map will be materialized by the total evaluation of this data at AFOM computers. It is assured that this map that corresponds to the earthquake intensity zones and will give important information about the possible earthquake damage in the affected region. This information will be evaluated with related damage criterions and existing statistical data bases on the GIS at AFOM. After a series of evaluation, the wideness of the disaster area and the amount of population that may be affected by the earthquake will be determined. As a result, estimation tables will be produced by the system about the possible damage distribution, loss of life and property. KIZILAY will immediately activate a proper disaster response operation considering this early warning information from AFOM main facilities in Ankara. The system also makes necessity assessment report for KIZILAY disaster assistance in terms of tents, blankets, hygiene, food, water.

Thereby, for a destructive earthquake in Turkey, this early damage assessment system will support decision making process of KIZILAY's disaster response and humanitarian relief operations. This pilot project study will be developed with cooperation of related parties; both MPWS and KIZILAY will have ability to better response to an earthquake disaster. Earthquake damage estimation results and other related information of disaster response are now on the Internet. It is possible to access this interactive page directly with "aph.kizilay.org.tr" or through KIZILAY main page "www.kizilay.org.tr" for all interested people.

References

Ergunay, O.(1996). Activities carried out and must be carried out for Disaster Losses Reduction in Turkey. *Ministry of Public Works and Settlement, General Directorate of Disaster Affairs, Special Report, Ankara*

Ergunay, O, and Gulkan, P.(1999). A Perspective of disaster Management in Turkey: Issues and Prospects*, Proceedings of UIA Region II Workshop on Urban Settlement and Natural disasters,Ankara, Turkey.*

Guler, H. and Ergunay, O.(2002), Country Report, *The Asia-Oceania Symposium on Information Technology/Strategy for Earthquake Disaster Reduction, Tokyo-Japan.*

Gulkan, P. (2001). Recent Structural Revisions in Turkey to Mitigate Disasters, *A Wharton-World Bank Conference on Challenges in Managing Catastrophic Risks, Washington, DC*

Ilter, N. (2000). Introduction of the Cost Benefit Analysis into Disaster Management, *State Planning Organization, Ankara, Turkey.*

Inan, E. et.al, (1998). Strong Ground Motion Records of Turkey, *General Directorate of Disaster Affairs, Ankara, Turkey.*

Moor, T. (2000), Disaster Management Notes, *Disaster Management Center of Cranfield University, United Kingdom.*

Schramm, Don. and Thompson, Paul,(1995). Disaster Preparedness Notes, *Disaster Management Center, Department of Engineering Professional Development, University of Wisconsin-Madison, USA.*

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INFRASTRUCTURE SAFETY AND SECURITY

NOVELTY DETECTION AND MANAGEMENT TO SAFEGUARD INFORMATION INTENSIVE CRITICAL INFRASTRUCTURES

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Keywords: Novelty detection, wrong signatures, critical infrastructures, case base reasoning, data mining, neural networks

Abstract
The behavior of a complex system, when anomalies or faults arise, is always different and not classifiable inside predefined rules and logical schemas. As the complexity a system manages the number of its possible faults and anomalous working conditions becomes infinite; on the contrary, the number of normal behaviors are generally low and often well determined by rules and constraints defined by the system designer.

In this paper, after a general overview of the SAFEGUARD[2] system, a more detailed description of the agents, dedicated to make early detection of faults inside the SCADA system of an electricity transmission network is given.

Particularly, the following set of novelty detection algorithms are considered inside the work:
1. The course of event recognition inside SCADA system using CBR methodology
2. Monitoring of TCP/IP data buffers using Data Mining algorithms
3. Novelty recognition inside electricity data set using neural novelty detector.

Also, in the paper are describes how it is possible to correlate the detected novelty events and decide the right recovery policies by avoiding inappropriate reactions caused by false alarms.

A test benchmark of all these novelty detectors is done inside a simulated SCADA electricity transmission system and the layout of the utilized testing environment is described in the paper.

Introduction
Nowadays emergency managers must deal with situations that are new, unusual and often different from the typologies of crisis for which they are trained. The augmented complexity of the infrastructures produces novel and emergent types of failures and anomalies.

Consider, for example, the wide range of improvised activities that will be necessary after the catastrophic collapse of the World Trade Centre following the September 11th terrorist attack (Kendra and Wachtendorf, 2002). Nobody might imagine such anomalous and unexpected scenarios.

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[2] A multi-agent system to safeguard Large Complex Critical Infrastructures developed inside EU FP5 program

Apart from this terrible scenario, in subsequent years many regions were also involved in many smaller but critical crises caused by the loss of functionality of network information systems on which every day people and industries depend.

Using the internet, we increase our connectivity with many other people around the world. Exploiting the great connectivity capability available through the Web system has definitely lowered costs in information exchange. However, hackers and malicious persons utilize the very same e-mail channels to make their attacks worldwide by executing worms that replicates themselves inside the mailboxes of e-mail users.

In all cases, the types of events and emergencies are novel and unexpected. Traditional techniques for anomaly detection are unsatisfactory because they identify individual data points that are rare due to particular combinations of features.

From the above considerations emerge the difficulty of recognizing faults or emergency situations by comparing the system behavior with predefined wrong signatures, because the incoming faults could be every time new and unpredictable.

It seems a more efficient mechanism is one where the *normal* workings statuses featuresof the system are recognized and deviations from normality are considered as new incoming anomalies. In such a way the monitoring system will be able to face also with novel and otherwise not predictable faults behaviors.

This new type of anomaly detection system seems to have great applicability in the future for information intensive infrastructures, such as telecommunication networks, SCADA[3] networks, client/server computer networks etc. where definite physical or logical models of system behavior in presence of anomalies and faults is not available.

Methodology: the Safeguard architecture

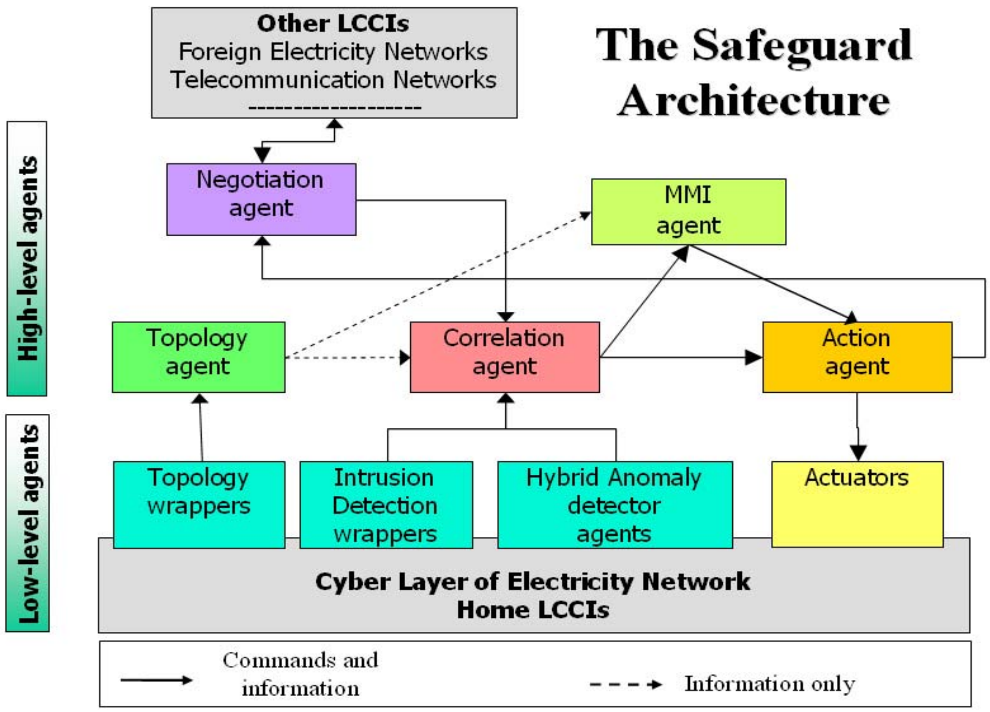
The Safeguard architecture is designed to protect the management network against attacks, failures and accidents where the novelty aspect may be frequently present. Safeguard is an agent-based system implementing the model of the *normal operation* of the network and responding to anomalies in real time.

The general layout of Safeguard architecture is outlined in fig. 1. The agent system will be integrated inside the cyber layer of an electricity network, that is a *distributed* SCADA system.

Problems in such a type of network will be diagnosed by a *correlation agent*, that bring together information from *hybrid detector agents* and more traditional diagnostic applications, such as intrusion detection systems, firewalls, virus checkers or integrity software. The correlation process is supported by a topology agent, which gathers on request local and global network topology information including connection statistics. After the evaluation of the state of the network, the action agent is triggered for an appropriate response, which may include feedback to the hybrid detectors and actuator agents. A Negotiation agent will communicate with agents in other large complex critical infrastructures to request services and pass on information about security alerts.

[3] System Control and Data Acquisition system

Fig. 1. The Safeguard system architecture



Agent operational level definition

The agency of the Safeguard system is structured in two operational levels: low and high level Agents.

The low level Agents and their roles

Here fast and effective capabilities are required, either in information processing and routing or in reaction. Inside a distributed infrastructure as a telecommunication network or a SCADA system to control an electricity network *more instances* of these agents are dedicated to monitoring and analyzing data coming from the different nodes of the network. The agents on this level are mostly simple in intelligence but optimized for their needs.

The Wrapper Agents (WA), collect data from the different nodes of the network and give the to Topology agent an interface with other traditional security applications seen such as firewall, antivirus systems or other intrusion detection systems.

The Actuator Agents (ACA) have the duty to actuate and manage the cyber infrastructure the commands and the defense policies established as necessary by the Action Agent.

The Hybrid Detector Agents (HDA) have the duty to monitor the normal operability of the infrastructure and to detect the deviations from normality. Many types of HDAs, as illustrated in the following, may be present to monitor different components located in different part of the network. Every one of them needs anyway to be *trained* to recognize the behavioral model of network.

The high level Agents and their roles

Here slower processing requisites are sufficient because all information available is filtered by lower level agents. A Correlation, Action, MMI and Negotiation Agent acting on the application level of the system are typical examples. These agents are responsible for the collection and representation of crucial information, which is not intuitively present in the network.

The Correlation Agent (CA) has the duty to make early diagnosis of the network, correlating the information coming from different low level agents. The network status obtained in such way will be communicated to the action agent.

The Action Agent (AA) receives diagnostic information from Correlation and decides, also in more stages, an adequate action policy to bring the network into a normality state. For the most critical situations or important decisions receives input from MMI agent.

The Topology Agent (TA) manages the knowledge about electricity system topology and furnishes information, on demand, to the Correlation, Action and MMI agent

The MMI Agent represents the interface between the agent system and the network operator. Its main role is to provide the operator with all the most relevant information, filtering the less relevant ones to avoid information congestion. In the most critical cases alarm is activated together with the suggested action and the relative consensus is required from operator.

The Negotiation Agent manages the interfaces with other, different or similar, critical infrastructures, with the objective to minimize the impact of a failure of a certain infrastructure on the other ones.

Anomaly detection

Inside the Safeguard system, four types of hybrid detection agents work at low level for anomaly detection:

- The *Event Courses Hybrid Agent*, utilizes Case Base Reasoning (CBR) techniques to recognize the most typical sequences of events coming from software modules working inside SCADA system. Initially it learns, offline, the time constraints of such event sequences and then, online, recognizes the sequences (Terran and Brodley, 1999) and associates an anomaly level to every one of them. The sequences of events to be recognized are defined and edited inside the agent Case Base by an expert of the SCADA system functionalities.
- The *Data Mining Hybrid Agent,* utilizes some Data Mining algorithms (Witten and Frank, 2000) to recognize anomalous deviations from normality of the values and structure of data packets flowing through a TCP port.
- The *Invariant Hybrid Agent,* utilizes the methodology of invariants (Ernst M., 2000) to associate an anomaly level to the measures coming from electrical network. This information will be utilised by the electrical state estimation tool, generally available inside the SCADA systems.
- The *Neural Network Hybrid Agent,* utilises an auto-encoder Neural Network (Timusk and Mechefske 2002) to validate the sets of data coming from electrical substations.

There are two main components that can be included inside a Safeguard hybrid agent: an anomaly detecting component specialized in defining normality and detecting deviations from normality and a signature-based component used for alert classification based on earlier knowledge. The latter is diagnostic in nature as it often attempts to pinpoint a cause. The former is for novelty detection, enabling us to detect new patterns of anomaly.

The next paragraph describes in more details the Event Course agent developed at ENEA laboratories.

The Event course hybrid detector

This agent monitors normal event sequences within the control system. Case base reasoning techniques are used to model the normal event sequences within the electricity management network and to detect anomalies inside sequences of events generated by attacks, failures or faults.

The first CBR systems were passive systems; they requires human users to activate them manually and to provide information about the incoming problem. During the recent years, new research activities have been carried out to improve the traditional passive CBR systems with the *active* property (Li and Yang, 2001). The new generation of CBR systems has real-time response and is highly flexible in knowledge management as well as autonomous in response to events that a passive CBR system cannot handle.

To apply this methodology in the real context of a more specific knowledge domain it is necessary to define more precisely the following points:

- Defining the *structure of the single case*. According to the different domains the cases structures and the working features must be specified.
- Defining the *metrics* adopted to establish the degree of vicinity between cases.
- Defining the attributes on which the *learning mechanisms* must to be applied to modify/include different cases in the Case Base.

Structure of the generic Case

The generic Case structure corresponds to a course of events where a single event (representing the activation of a certain software component) is modelled as a “fact”. An example of a course of events (ES-E6) is shown in the following table 1; the Case has a Case name identifying the course itself and contains the total time T in which the course has to be considered.

Tab. 1. Representation of a generic course of events Case

Case Name: X	E_S	E_1	E_2	E_3	E_4	E_5	E_6	Total Time
Time Label	0	t_1,d_{t1}	t_2,d_{t2}	t_3,d_{t3}	t_4,d_{t4}	t_5,d_{t5}	t_6,d_{t6}	T

E_S represents the starting event of the sequence occurring at time 0, and, inside the course, for every event following E_S a corresponding time label contains the times elapsed (t_1, t2,…t_6) from the starting event. However, in a real case the events time represents only an average time value. Depending on memory consumption and workload, time allocation could be variable. For this reason, at every time label the maximum expected time deviations (d_{t1}, d_{t2},…,d_{t6}) for the relative event are also evidenced. The events and the Case name are strings, while the time labels are numerical values.

Metrics definitions and similarity concept

During the Case Based Reasoning process, the above Case, stored inside the Case Base, must be compared with a Current Case that is acquired from software instrumentation, having the structure evidenced in the following table 2:

Tab. 2. The current Case acquired from instrumentations

Current Case	E_S	*	*	E_1	E_2	*	*	*	E_3	*	E_4	E_5	*	E_6	*	*
Time Label	0	*	*	Tc_1	tc_2	*	*	*	tc_3	*	tc_4	tc_5	*	tc_6	*	*

In the above table E_S-E_6 are the first occurrences of the events of the Case X, the "*" character represents other types of events or successive occurrences of the same types of events, tc_1-tc_6 represents the time labels of E_S-E_6 current events. Now we could evaluate the *distance* or *similarity* = S between Case X and the Current Case in such way:

$$S = \frac{\sum_{i=1}^{6} \frac{|t_i - tc_i|}{d_{ti}}}{6} \qquad (1) \qquad\qquad S = \frac{\sum_{i=1}^{n} \frac{|t_i - tc_i|}{d_{ti}}}{n} \qquad (2)$$

If we have courses composed of n different event the (1) may be written as in (2).

During Case Base reasoning the retrieved patterns of events represent the first way utilised to retrieve *similar cases*. Parameter S represents a *degree of similarity* that, in the previous formula, is normalised to 1; this means that S=0 is a situation in which two cases are completely similar, while S=1 is the case of complete lack of similarity.

<u>Case Base Training phase</u>

A *training phase* is necessary to update the Time labels of the generic cases. Generic cases could initially be defined by the experts using an appropriate Cases editor. More specific values of the case attributes will be defined through the system training phase. During the training phase, the agent does not execute any type of diagnosis; it monitors the different event sequences for a time period which must be sufficient to obtain adequate data sets to execute some statistical functions, necessary to obtain appropriate average values of the time labels.

One of the advantages of Case Base systems is the possibility of working using *incomplete sets* of Cases. In other words, it is not necessary to insert from the beginning in the Case Base the complete set of cases covering all possible situations. It is sufficient to work with an incomplete case set covering only a limited set of events that are considered the most important ones. With additional training phases it will be possible to extend the Case Base with new cases covering new situations and events.

Management of false alarms

One of the most important difficulties of novelty detection systems is the management of "false alarm". In fact, some deviations from a normal working condition could sometime emerge not for a real attack or fault condition but from some temporary congestions or unexpected modification of the network.

In Safeguard system, while low level agents have the duty to detect novelties as symptoms of possible incoming failures, the high level agents, mainly the Correlator and Action agent, have to filter the set of candidate failures reducing the possibility of false reactions.

This is similar to the behavior of a complex organization in which a high level manager works together with many low level managers to improve the efficiency of a large goods-transportation and delivering system composted by many delivering nodes connected together (hubs). The low level managers are in charge of monitoring the normal working status and activities inside single hubs of the transportation network, while the high level manager must to coordinate the works avoiding that problems arising inside a hub will propagate to the other hubs. When a low level manager detects an anomaly, like some congestion or inefficiency inside the hub he is controlling, he communicates such anomalies to the high level manager. The high level manager considers the anomaly, but before taking some drastic decision, he must:

- Analyze if the congestion inside the hub, may be considered as a local anomaly that could be solved in the next future, taking into account the status of the neighboring hubs. This is a *correlation* process that in Safeguard system is performed by CA agent.
- Gain some time, with the objective to study the situation during a temporal phase in which he could verify if the anomalous condition is increasing or decreasing, is persistent or not. Only with such additional data, collected during a certain period of time, he could decide if a global emergency strategy is needed, or if the situation could be solved easily at local level. This is *recovery policy* process that in Safeguard is performed by the AA agent.

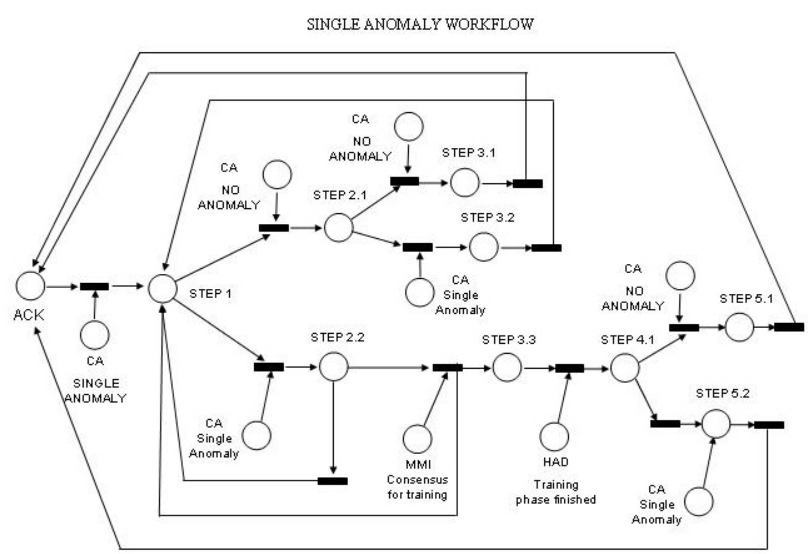
Correlation and Action agents use the Workflow methodology to formalize and execute the above described process.

A very modular system of correlation and recovery policy has been designed. Threads of reasoning and action are bound together in an augmented work flow model. All correlation reasoning is defined *within* the context of a particular work flow.

The expressive power of the workflow process model is an extended Petri Net that allows all forms of dependency, including concurrency, required to model business processes. Activities are triggered by timers, manual intervention and events.

Fig. 2 shows the workflow utilized by the AA in presence of a single anomaly notified to the CA by a low level anomaly detector. In the workflow, the circles in the main paths, named as "step X", represent the different states of the workflow in which some decision have to be taken, while the black rectangles are the waiting states in which an input is waited by other agents.

Figure 2. Workflow for processing a single anomaly



The workflow of fig. 2 starts when the CA agent notifies an anomaly coming from some anomaly detector. In step 1 AA takes the decision to *decrease the sensitivity* of such detector. In fact many anomalies could be caused only by a too high sensitivity level. After the actuation of this command AA waits for further notifications from CA. If the no anomaly condition is notified the path on the top part of the workflow is undertaken. Otherwise the bottom path is undertaken where further actions are executed, like a new training phase for the detector, aimed to confirm the validity of the signaled anomaly.

Besides this single anomaly workflow, many other workflows are implemented in Safeguard system, to manage *composite anomalies* (e.g. coming from more anomaly detectors), invalid sequences of events, corruptions of data etc. A workflow engine is implemented inside CA and AA agents that execute a concurrent processing of them.

Results: test of Safeguard agents

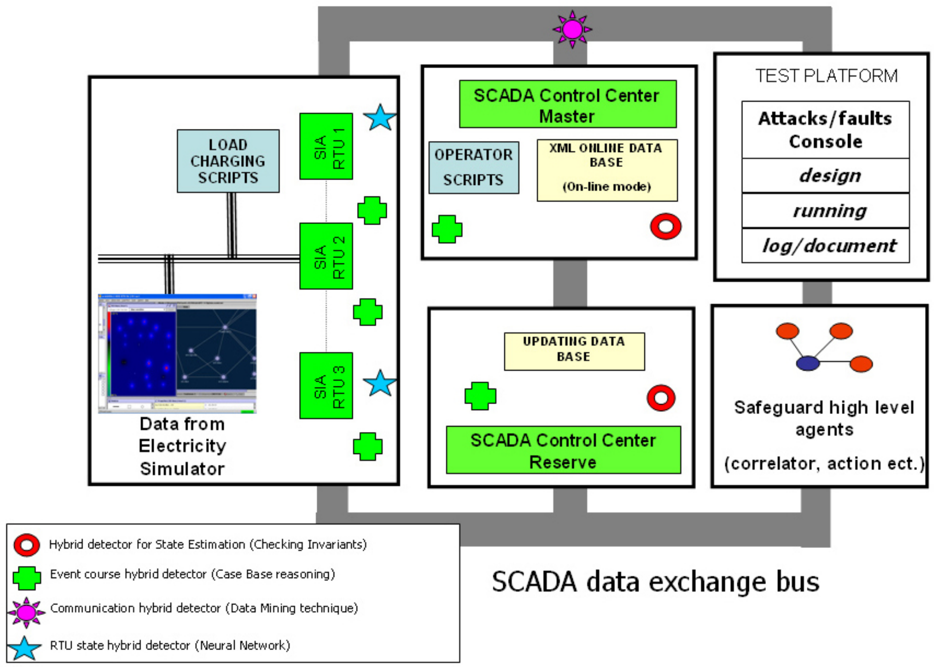
A SCADA emulation environment of an electricity network control and supervisory system was developed at ENEA laboratories to investigate if Safeguard agent system reacts efficiently against novel types of intrusions and faults. The testing activity will be undertaken during the course of 2004.

The anomaly detection agents control different nodes of such emulation environment. In figure 3 the SCADA bus is visualised on which are installed four different machines. On the left machine an electricity network simulator is installed and generates power flow data acquired through a set of RTUs (Remote Terminal Units) devices. The values of the electrical charging loads are variable every day, weekly and during the different season depending on the population needs. Two machines emulate the Control Centre functionalities, one of them working as master and one ready in steady state as reserve. In the master Control Centre, a script emulates the normal operators' behaviour, activating the sequences of actions that normally the operator cyclically executes every day.

A special machine on the right is contains the Safeguard agent platform, while another one is used as console to design and run the malicious tasks taking part of the attack scenario (Balducelli, 2003).

In the figure are visualised the locations in which different instances the various types of anomaly detection agents are installed.

Fig 3:. Safeguard testing environment



Conclusions

Using novelty detection algorithms to be advised early of possible imminent failure seem to be a promising methodology to discover new types of incoming crisis that cannot be foreseen with different approaches.

It seem anyway very important, to increase the efficiency of such systems and to avoid an intolerable number of false alarms, provide them with a collection of anomaly detectors based on different types of algorithms giving the possibility to correlate different candidate symptoms.

In addition it seem also important to establish the recovery policies not in a deterministic way, but analysing, during a certain time window, the trend and the persistence of the detected anomaly.

We hope that the exhaustive testing of Safeguard agents, in presence of complete sets of attack/fault scenarios, will give more definitive indications about the possibility to utilise novelty detection inside real emergency scenarios.

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Authors biographies

Dr. Claudio Balducelli is a senior scientist working at ENEA as project manager since 1983 in the field of AI technologies applied to operator decision support systems for emergency industrial accidents. His interests include operator models, knowledge formalization, planning, computerized procedures, plant diagnosis, case based reasoning, learning and fuzzy algorithms. In the last years he was also involved in the coordination of research projects in the field of distributed AI applications. He co-ordinated also the prototypical implementation of various site applications like a cooperative training system for the Genoa Oil Port managers (MUSTER project) and an emergency operator support system for major Oil Deposits and Pipelines in Italy. Actually he is team leader inside SAFEGUARD FP5 project (Safeguarding Critical Infrastructures).

Dr. Giordano Vicoli from 1988 to 1992 took part in research projects in the field of design and development of expert systems for diagnosis and control of industrial plants. From 1993 he has been working in the field of design and development of decision support systems and training applied in emergency management of high risk industrial plants. His interests include the development of distributed application with J2EE and CORBA technologies. He is actually working inside SAFEGUARD project where he developed the simulated SCADA system environment.

Dr. Luisa Lavalle worked as software analyst and designer at Nortel-Networks S.P.A. from 2001 until 2003. From July 2003 she is a researcher at ENEA working with a post-doctoral position inside SAFEGUARD project team. Her duty mainly refers to design and development of novelty detection agents.

References

Balducelli C. (2003), Modelling Attack Scenarios against Software Intensive Critical Infrastructures, *10th Annual Conference of the International Emergency Management Society*, Sophia-Antipolis, Provence, France, June 3-6, 2003.

Kendra J., Wachtendorf T. (2002), Creativity in Emergency Response after the World Trade Center Attack, *9th Annual Conference of The International Emergency Management Society*, Waterloo, Canada, May 14-17, 2002.

Terran L., Brodley C. E. (1999), Temporal sequence learning and data reduction for anomaly detection, *ACM Transactions on Information and System Security (TISSEC)*, v.2 n.3, p.295-331, Aug. 1999

Witten H., Frank E. (2000), Data Mining, *Morgan Kaufmann Publisher*, 2000, S. Francisco, CA, USA

Ernst M. (2000), Dynamically Discovering Likely Program Invariants, PhD Thesis, *University of Washington* 2000

Timusk M.A., Mechefske C.K. (2002), Applying Neural Network based Novelty Detection to Industrial Machinery, *KES 2002 Knowledge-Based Intelligent Information Engineering Systems & Allied Technologies*, IOS Press Ohmsha

Sheng Li, Quiang Yang (2001), An Agent System that Integrate Case-Base Reasoning and Active Databases, *International Journal of Knowledge and Information System* (2001) 3:225:251, Spriger-Verlag

EVALUATING TRADE-OFFS BETWEEN INFRASTRUCTURE PROTECTION AND CRITICAL MAINTENANCE IN A BUDGET-CONSTRAINED ENVIRONMENT

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Keywords: Trade-offs, infrastructure protection, critical maintenance, reservoirs, lock

Abstract

The U.S. Army Corps of Engineers operates and maintains several hundred critical navigation locks and multipurpose reservoirs that are subject to varying levels of risk from both natural and malevolent-act hazards. Additionally, like all other civil works infrastructure, these structures require periodic maintenance to insure appropriate levels of service. Currently, funding for both civil works infrastructure protection and continuing operations and maintenance (O&M) are drawn from the Operations and Maintenance General account.

Recommendations for investments in infrastructure protection are developed for critical Corps projects using an approach based around the RAM-D (Risk Assessment Methodology – DAMS) methodology. Continuing operations and maintenance investments have historically been developed and prioritized subjectively at district levels, although investments in major rehabilitation of infrastructure are developed using a risk-based analytical approach. Increased O&M needs, some stemming from increased requirements as structures age, have resulted in a significant backlog of unfunded O&M. The current budget approach requires infrastructure protection investments to compete with continuing O&M for funding within the constrained O&M General account. However, no tools exist that can evaluate trade-offs between investments in infrastructure protection and continuing O&M.

This paper explores research currently underway to develop an approach to prioritize investments in infrastructure protection versus continuing O&M within the framework of the O&M General budget. The research will use expert elicitation techniques combined in an Analytical Hierarchy Process (AHP) to develop a systematic method of considering all elements of the issue. The resulting prioritization process will be tested on lock and reservoir infrastructure on the Columbia River system in the Pacific Northwest.

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Introduction

The U.S. Army Corps of Engineers involvement in works "of a civil nature" goes back almost to the origins of the U.S. Over the years, as the Nation's needs have changed, so have the Civil Works missions of the Corps of Engineers. Those missions today fall in four broad areas: water infrastructure, environmental management and restoration, response to natural and manmade disasters, and engineering and technical services to the Army, Department of Defense and other Federal agencies.

The Corps currently manages 383 major lakes and reservoirs, 276 locks on the inland navigation system, 4,340 recreation areas and performs maintenance dredging on 299 deep draft and 627 shallow draft harbors. The Corps of Engineers is responsible for operations, maintenance and security of all its major lakes and reservoirs, inland navigation locks and dams, and recreation areas. Many of these critical facilities were constructed following World War II, in fact by 2010, 55% of our inland navigation lock and dams will be over 50 years old. Unfunded critical maintenance backlogs have developed in many divisions of the Corps due to the increased maintenance needs at aging structures and generally insufficient funding levels.

Following the tragic events of September 11, 2001, emphasis was placed on securing the nation's infrastructure from potential terrorist attack. The Corps of Engineers immediately initiated a program to protect its critical infrastructure from terrorist attack where necessary. All Corps projects were screened to identify those deemed critical based on subjective assessments of economic consequences and loss of life from a potential terrorist event. Vulnerability assessments were preformed on critical projects using the RISK Assessment Method – Dams (RAM-D) tool. RAM-D was developed and validated by the Interagency Forum for Infrastructure Protection (IFIP), an interagency group chartered to exchange security and protection systems information among the owners and operators of Federal dams and other infrastructures. As stated in the RAM-D Field Manual, RAM-D provides a risk assessment process to analyze the current security risks at dams and provide information to support risk-reduction decisions by dam managers.

The results of the RAM-D assessment were used to develop security upgrades packages for over 300 Corps structures. Generally, most of the protective measures were relatively low costs upgrades such as fencing, locks and gates to prevent access. However, there were some more elaborate measures, such as sensors and monitors, recommended for certain facilities. Using the vulnerability assessments developed from RAM-D, the critical project list was re-prioritized to insure the most vulnerably structures were protected first. The Corps of Engineers received supplemental Congressional appropriations specifically to upgrade security at its critical infrastructure and work was initiated based on the reprioritized list of security upgrades.

The Corps received supplemental funding in both 2002 and 2003 for critical infrastructure security and a large number of infrastructure protection were completed. However, no funding was received in 2004 and a number of projects were left unfinished. The critical infrastructure security projects must now compete with other continuing operations and maintenance (O&M) in a constrained O&M General account.

Research Problem

The research problem them becomes how to evaluate investments in infrastructure protection upgrades against investment in operations and maintenance in a constrained budgetary environment. Ultimately we must assess on some level the likelihood of unsatisfactory performance (or failure) and the consequences of that unsatisfactory. On a very basis level, assessments of this type require knowledge and information. We have an extensive knowledge of consequences of different types of unsatisfactory performance associated with Corps multi-purpose dams and inland navigation locks and dams through our major rehabilitation program. That program requires a probabilistic assessment of unsatisfactory performance along with a determination of associated consequences. Similarly, the Corps dam safety program provides us knowledge of consequences from catastrophic dam failure events. Relatively speaking we have an adequate understanding of potential consequences gained from those programs that can be applied for decision-making purposes in this problem.

However, our understanding of the likelihood of unsatisfactory performance from a terrorist event is extremely limited at best. Malevolent acts, like terrorism, are not predictable. No likelihood of a terrorist strike can be developed using historic occurrence, as is the case for floods or to a lesser extent earthquakes. Terrorists strike at their own convenience. They may wait until a target has relaxed its' security posture. They shift to a target that is less well protected. They make little distinction between types of target, as long as they inflect casualties and economic disruptions, and gain stature through the notoriety the attack generates. The number of potential targets seems endless and so may be the terrorists' patience.

Our understanding of the likelihood of unsatisfactory performance due to lack of maintenance, while not extremely limited, cannot be viewed as extensive by any means. Historically, budgets for O&M have been relatively healthy. The Corps simply hasn't needed to analyze the effects of lack of maintenance on project performance because there has historically been plenty of money to maintain or in some cases over-maintain infrastructure. Certainly, sound engineering analysis can fill in many of the unanswered questions about degradation due to deferred maintenance. An infrastructure work group has been formed to analysis this issue, and will eventually develop needed tools, decision-making methodologies and risk communications strategies. However, the trade-off issue with infrastructure protection investments cannot be addressed by engineering analysis alone

Proposed Methodology

Given the high degree of uncertainty in evaluating trade-offs between infrastructure protection and operation and maintenance, an investment decision-making tool based on expert-opinion elicitation will be used. Expert-opinion elicitation is a formal, heuristic process of obtaining information or answers to specific questions. In this application, expert-opinion elicitation will be combined in an analytic hierarchy process (AHP) to develop recommendations for decision-making. AHP is a decision-making process that provides a systematic method of considering all elements of a problem.

Key to the use of expert-elicitation in any application is the selection of experts. In this application a diverse group of experts will be selected based on their knowledge of both terrorist threat and engineering knowledge of O&M practices, equipment and components at Corps facilities. Because the backgrounds of these experts may very substantively from each other, the panel of experts will be constructed to have balance and a broad spectrum of viewpoints. Additionally, because infrastructure protection and O&M are managed from different organizations within the Corps, organizational representation will also be balanced.

In order to develop common expectation of the process, each expert will be sent material prior to the meeting including:

- An objective statement of the process and the desired outcome.
- A list of experts, the facilitators and their biographical statements
- Consequences associated with unsatisfactory performance from terrorist attack or maintenance-related incidents.

- A description of the potential investment actions

The process proposed for use, AHP, was developed by Dr. Thomas Saaty in the early 1970's at the Wharton Business School. AHP is a decision-making process that provides a systematic method of considering all aspects of a problem. It essentially organizes the problem into smaller parts and then calls for simple pairwise judgements to develop a hierarchy. This hierarchy is then manipulated analytically to produce a final matrix representing the overall priorities of the alternatives relative to each other. One can then make a logical decision based on the pairwise comparisons made between alternatives and the criteria being used in the decision.

The experts will develop prioritization using the AHP Based tool *Expert Choice*. Potential decision criteria used in the tool could include:

- Likelihood of Unsatisfactory Performance
- Return on Investment
- Public Health and Safety
- Reliability
- Environmental Sustainability
- Impact on System Performance

Case Study

We have selected a small subsection of our portfolio of critical infrastructure to test the prioritization process. The Columbia and Snake River system is located in the Pacific Northwest portion of the U.S. in the states of Oregon and Idaho. The Corps of Engineers operates 9 dams some with navigation locks on the system, which also serve multiple other purposes including water supply, hydropower, flood control, recreation, fisheries and water quality. Some number of these dams have already been protected by infrastructure protection upgrades before budget constraints slowed funding. One of the dams, John Day, on the Lower Columbia, has been plagued by lock and dam maintenance problems described as the worst case amongst northern dams. Problems have occurred, not just with the navigation locks; but also additionally with leakage, causing sinkholes that may eventually result in loss of hydropower. The Corps is currently operating the lock at 50 per cent capacity reducing upstream navigation by a similar amount. These types of issues make this system ideal for making comparisons of infrastructure protection versus maintenance investments. The selection of the case study also allows the Corps to introduce systems considerations into the investment decisions. Both from a maintenance and infrastructure protection point-of-view the prioritization process must consider how performance will be improved within the context of the system of dams and reservoirs serving multiple inter-dependent needs.

Other Considerations

As can be readily seen, the Corps is developing this analysis in some level of isolation without consideration of the infrastructures of others. Currently, multiple Federal, and state agencies appear to be using multiple approaches to justify funding for infrastructure protection projects. After developing a list of critical infrastructure, the Corps, for example, used the RAM-D process to identify infrastructure protection investments as a function of likelihood of attack, consequence and effectiveness of the infrastructures' security system. RAM-D allows a systemic evaluation of risk at a particular structure, but those results are not necessarily comparable across even a portfolio of Corps critical infrastructure much less any other potential target. The U.S. Department of Homeland Security has an active critical infrastructure protection program and undoubtedly will eventually develop a standardized, systemic approach for infrastructure protection risk management and investment decision-making for all potential targets.

Additionally, we must note that this paper should in no way be construed to suggest infrastructure in the Corps or in the United States, in general, is unprotected due to budget considerations. The Corps, like most other agencies, also emphasizes random antiterrorism measures to reduce vulnerabilities for all projects including those not viewed as critical. Significant upgrades in security and response capabilities have made the nation more prepared for both natural and man-made disaster events than at any point in its history.

Conclusion

Constrained budgets force difficult investment decisions for any agency and developing a process to make choices between infrastructure protection and maintenance investments is particularly disturbing for the Corps. This paper describes ongoing research that attempts to overcome the unknowns and uncertainties associated with these choices and develop a defensive approach to decision-making. This research represents a crucial first step in addressing the infrastructure challenges of the 21st Century.

References

Ayyub, B.A. (2000), Methods for Expert-Opinion Elicitation of Probabilities and Consequences for Corps Facilities.

Interagency Form for Infrastructure Protection (2001), IFIP Risk Assessment Methodology for Dams (RAM-D) Field Manual.

Author Biographies

Ronald R. Conner

Mr. Ronald R. Conner has served as a lead economist at the Institute for Water Resources of the U.S. Army Corps since June 2002. In this capacity he serves as the Institutes' subject matter expert for policy and research studies in the emergency management, homeland security and flood damage reduction business programs.

Mr. Conner began his government career in the Corps Los Angeles District office as a project economist in 1984. As a project economist, he developed unique benefit-cost methodology for relocations and alluvial fans analyses. Mr. Conner was subsequently promoted to Chief, Economic and Social Analysis Section in the Los Angeles District in 1990. In that capacity he was responsible for all District economic and social analysis conducted for Civil Works projects, base closures studies and environmental and regulatory assessments. He additionally served as Emergency Operations shift leader during emergency response operations for the Northridge earthquake and California floods of 1995.

In June 1995, Mr. Conner was transferred to the Headquarters of the U.S. Army Corps of Engineers to serve as an economist in the Planning Division. Mr. Conner was responsible for a significant rewrite of Corps planning guidance, which incorporated environmental restoration considerations in decision-making on Civil Works projects. In 2000, Mr. Conner transferred to the Emergency Operations Branch as an Emergency Response Program Manager, responsible for program research and development and strategic planning.

Mr. Conner has a B.S. in Economics and Business Administration from the University of LaVerne in LaVerne, California. He has earned numerous awards and citations for his performance including the Clifton, Arizona Relocation Study in 1986, the Las Vegas Wash Flood Control Study in 1990, the Northridge Earthquake response in 1993, the Planning Guidance Notebook Team of 1999, and the Civil Works Project Management Business Team of 2002.

Edward J. Hecker

Mr. Edward J. Hecker, appointed to the position of Chief, Homeland Security Office, Directorate of Civil Works, Headquarters, U. S. Army Corps of Engineers, as of 23 February 2003.

Mr. Hecker is responsible for providing leadership in the coordination and facilitation of USACE Homeland Security missions in support of the Department of Homeland Security (DHS), the Department of the Army (DA), and the Department of Defense (DOD). Program manager for all USACE efforts to assist Federal, state and local emergency management and emergency response organizations with mitigation, planning, training, and exercises necessary to build and sustain capabilities to provide protection from and respond to any emergency or disaster, including a terrorist incident involving weapons of mass destruction (WMD) as well as other natural or manmade hazards.

Mr. Hecker began his governmental career in the Corps Baltimore District office (Civil Project Management), and transferred to the Headquarters, U. S. Army Corps of Engineers in Washington, DC, before moving to San Francisco, California. In San Francisco he was the Chief, Emergency Management for the South Pacific Division, which encompassed California, Nevada, Arizona, Utah, and portions of Idaho, Colorado, and Wyoming. He was the program manager for the Corps response to the Loma Prieta earthquake in 1989.

In October 1991, Mr. Hecker returned to Washington, DC to assume the position of the Chief, Readiness Branch of the Operations, Construction and Readiness Division, having responsibility for overall management of the Corps disaster preparedness and response missions.

Ed, his wife Sylvia, and their three children reside in Severn, Maryland. He has a B.S.C.E. from the John Hopkins University, and has earned numerous awards for his performance in response to major disasters, from Tropical Storm Agnes in 1972 to Hurricane Hugo/Loma Prieta Earthquake in 1989, Hurricane Andrew in 1992, and the Midwest Floods of 1993.

MANAGEMENT DECISION SUPPORT FOR CRITICAL INFRASTRUCTURES

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Keywords: Decision Support, Critical Infrastructures, Interoperability, System Architectures

Abstract

This paper describes a new approach to management decision support for critical infrastructures (MEDSI). The MEDSI approach is developed on the basis of a European Research & Development Project "MEDSI" by a consortium of 11 partners of 8 European countries. The objective of the project is to develop the web-based integrated set of software services as a tool to enhance the capabilities of crisis planners and crisis managers in both private and governmental organizations.

MEDSI will enable them to utilize various information sources for better monitoring and reduction of potential and actual risks and for more effective response in case of threats imposed especially to the subjects of the critical infrastructure. MEDSI will also be capable to create, maintain and optimise the typical scenarios and procedures how to solve the situations.

Software, utilizing the data fusion of geospace, organizational and other territorial and operational area will be created and integrated in a standardized IT environment. The standardization and openness will bring the possibility to further grow this seed in national and international levels and to assure the interoperability with other systems. The system will be used by users from general security area, as well as, environmental protection, utilities management, airports and seaports, healthcare, transports, roads, energy plants, borders control etc.

The system MEDSI has the potential to be installed in the organization or agency information environment and interoperate with other systems via standardized messaging. A part of MEDSI will be also the simulation subsystem allowing designing, optimising and interpreting various scenarios and contributing to the training of crisis management staff and support of exercises.

1. Introduction

In the current years we have been recognizing a new term of Asymmetric threats, which represents a new situation in the world politics, where a "classical" war threats are losing importance against a new ones, caused mainly by terrorist activities. The possibility to use for example chemical plants or other elements of infrastructure as "civil weapons" and the increasing frequency of bomb attacks calls for solutions in the area of emergency and crisis planning and response.

There are many local data sources available, describing geospace of specified territory, but the tools, which would bring relevant integrated information to the fingertips of the crisis managers, are missing.

2. The MEDSI Framework

Access to information and administration of it in the European environment is a key piece for the development of services to the citizen and a ¨knowledge need¨ for our companies and administrations.

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The huge quantity of information around the correct knowledge of the European Critical Infrastructure is not only a problem of information administration, but also a serious problem when trying to look for wide enough generalist frameworks to be able to manage information flows. Therefore it is necessary to provide a new open and innovative European reference framework for data sources fusion and interpretation.

Once established the above-mentioned European reference framework, the overall aim of the MEDSI Project is the development of an innovative system which, based on the utilization of various data sources, provides an integrated set of services to crisis managers and planners, especially to protect the critical infrastructure against a “classical” threats as flooding or other natural disasters, industrial catastrophes and also against the terrorist attacks.

The key objectives for MEDSI project are as follows:

- Provide Integrated software support for
    - Reduction of risks and protection for critical infrastructure
    - Effective and fast response support
- Show the functionality of the system as a tool on a real application.
    - Will be applied on the territory of one of the consortium partners.

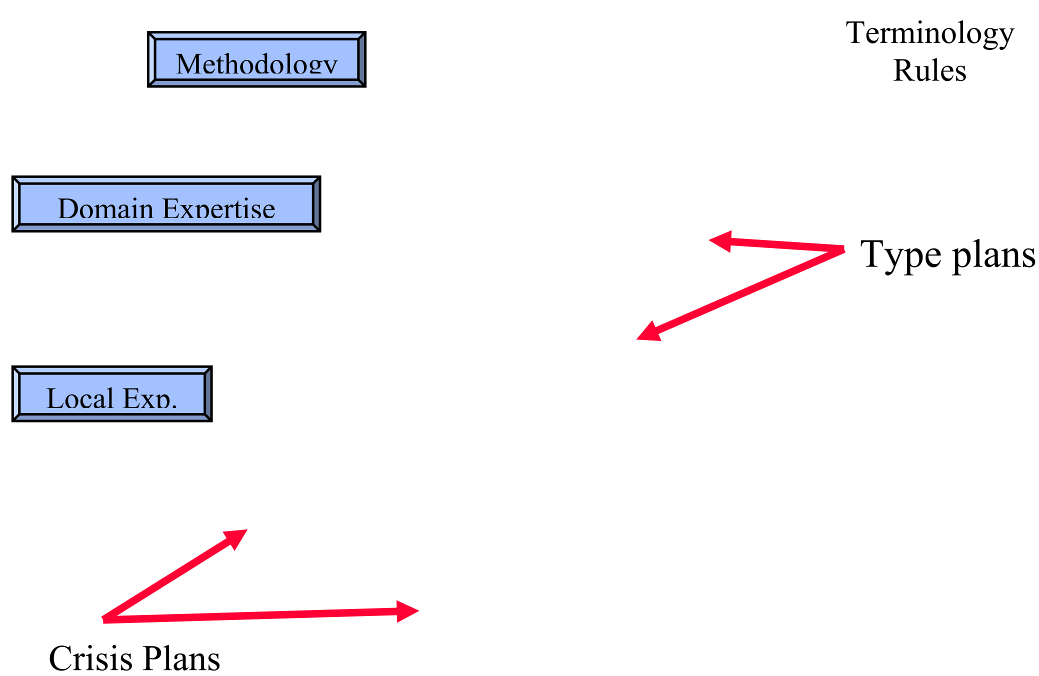
The software support will be realized as the integrated set of web-based services, possible to operate both in standalone and distributed network environment, assuring the support of multiagency operations and providing support both for fixed and mobile workplaces.

MEDSI will allow to impose the standardised methodology to the domain knowledge in various areas and to build type plans according to the needs of the specific organisation.

2.1. MEDSI Users

MEDSI will support the activities at various level of management or command – from the city or company level up to the national and international. It will allow creating, maintaining, optimizing and executing various scenarios corresponding to the specific threat and specific territory.

Figure 1: Structure of Crisis Planning



Among MEDSI users will be for example:

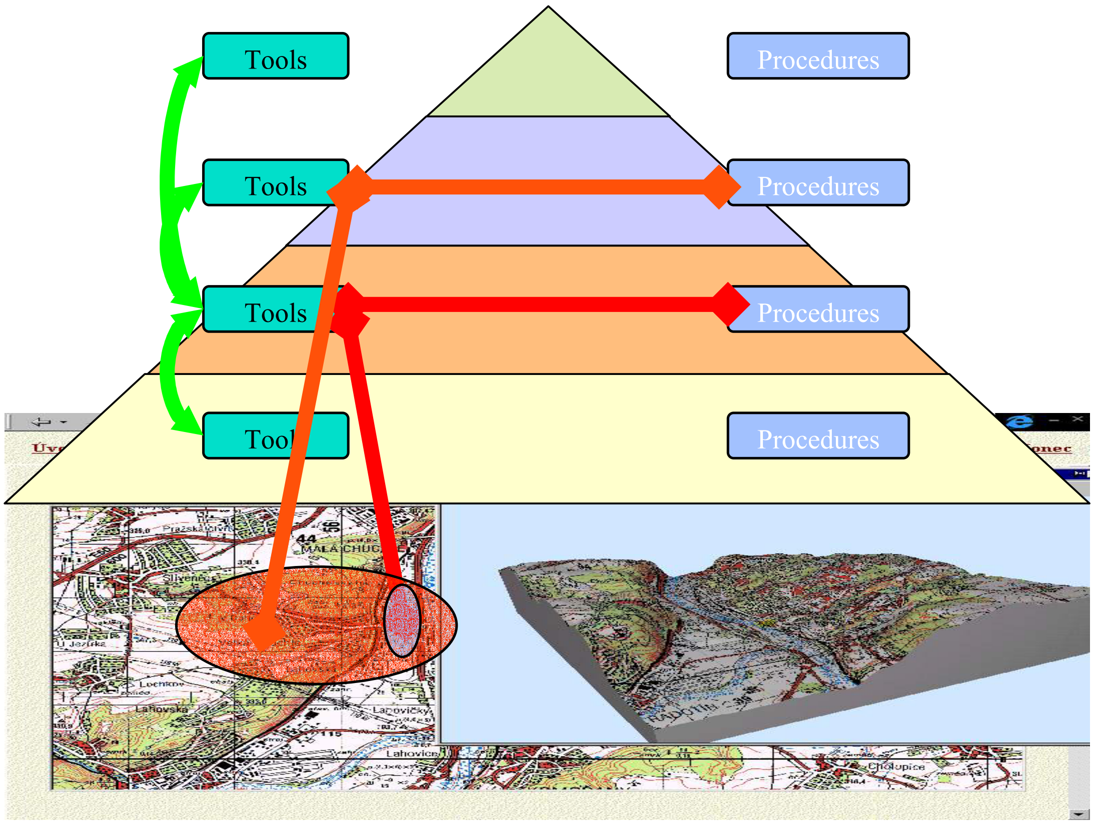
- City managements
- Regional managements
- Central institutions and agencies
- International crisis-management organizations
- Special forces as police, firemen, ambulances, intelligence services etc.

In order to achieve it, it is necessary to reach the following:

- To characterise and categorise various crisis scenarios.
- To develop a MEDSI-specific database schema, which will map the needs of the users and possibilities of existing information sources.
- To advance in the standardisation of information exchange between crisis management systems and heterogeneous data bases.

Based on these system objectives, MEDSI will be covering the main activities and information sources needed for the crisis planning and decision support. These activities fall in the areas of Risk analysis, Planning and production of plans, measures and Standard operation procedures (SOP), Resources management and the decision support in the crisis situations.

Figure 2: Levels and scopes of crisis management

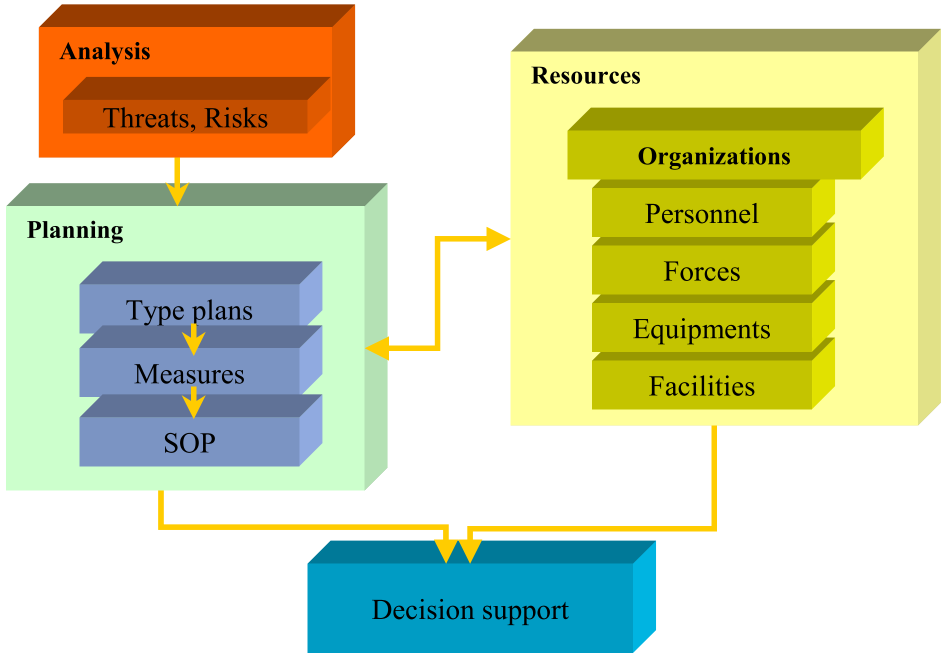


2.2. MEDSI Features

MEDSI basic features will be as follows:

- The system will be distributed and operate on Wide Area Network.
- The system performs high availability features.
- The area of coverage will be seamless and could be approached from different scales enabling the system to manage crisis over areas of any size and to be able to utilize or suggest emergency resources within these or outside of the areas.
- The system will incorporate optimization and artificial intelligence procedures to help in optimal decisions using the available emergency resource information.
- Commonly encountered crisis scenarios will be embedded in the MEDSI system before it is released.
- The system will be platform independent. Interoperability between components of the distributed architecture will be defined and handled seamlessly, using web-based services.
- The system will have an efficient and effective infrastructure that provides; prompt and precise reporting of disasters and fast communication between all concerned parties like crisis management centres, hospitals, fire brigades, police department, transportation units, and shelters
- The system will also serve as a planning tool for the visualization of parameters effecting natural disasters such as floods, earthquakes, and avalanches. Therefore it can be used in the urban and rural planning for better land use development.

Figure 3: Main activities covered by MEDSI



The interoperability between MEDSI system databases and emergency resource databases will be handled using web services using for communication a standardized set of messages developed specifically for emergency management domain.

MEDSI will work with several specific databases, using operating thru the general MEDSI database schema and using data standardisation and fusion to make information available for various MEDSI modules (including models as floods, terrorist attacks, NBC, earthquakes, etc., procedures maintenance, logistic planning, common operation environment services and so on).

The typical information areas the location of roads, railroads, residential areas, industrial and commercial zones, etc.

3. Approach

The current situation shows a lot of more or less consolidated data sets stored in various systems or databases using various data schemas. There is lot of redundancy and inconsistency, the methods and procedures to keep the data actual vary. There is an urgent need to integrate all of these data by methods of data fusion to be able to use them for an effective decision support.

The data fusion requires at the beginning to identify the information consumers and their needs and then to map all the available data sources and set up the ways and tools how to put them into one integrated picture.

At the present time we can describe the general composition of the centres of crisis administration with the rising configuration:

- Communications
- Databases
- Presentation and analytic tools
- Use of scanned maps and satellite pictures (non geo-reference)
- Use of GIS systems

All the above-mentioned is more or less developed but its interactions continue being carried out in independent way of a common system.

The great step forward that will bring MEDSI consists on making work in a completely integrated way, i.e. integrating, filtering and interpreting all the data resources needed to help the crisis managers to react in a real time and to interoperate effectively with others.

To cut down reaction time and improve coordination efforts are the key of a crisis management system, because that put the difference in between more or less casualties and this is the most important advance that MEDSI does in the state of the art.

The consortium will proceed from several base facts, which characterize the current situation

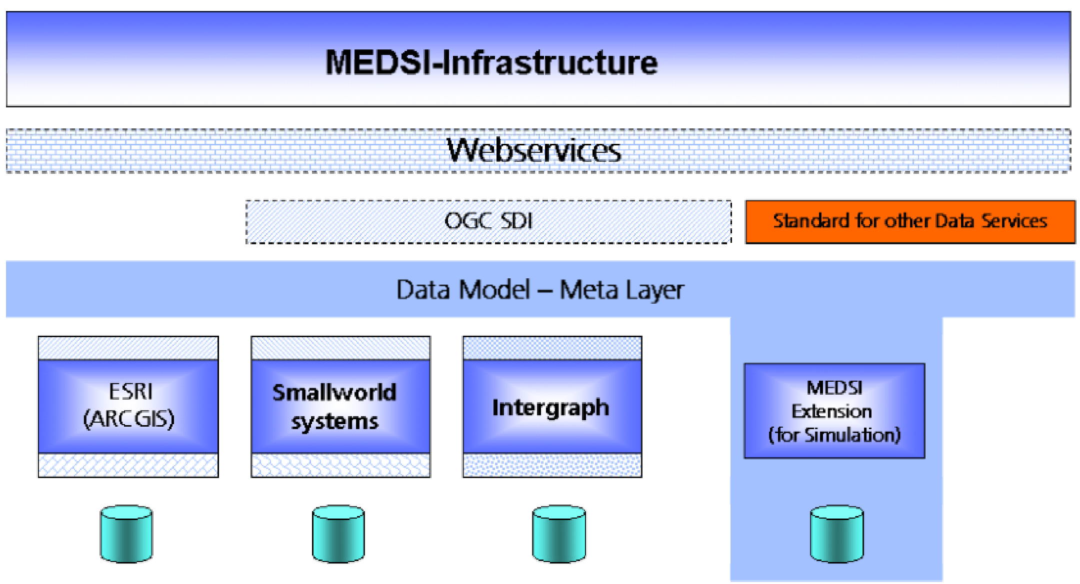
- Existing databases, not integrated, not interoperable
- Existing software tools
- Existing technologies and know-how

4. MEDSI Infrastructure

The information processing will be assured by using the layered architecture, with the standardized interfaces.

- System architecture design – as open, web-services-based system framework, which may instantiate at a specific place and situation and which enables further extensions by adding other services.

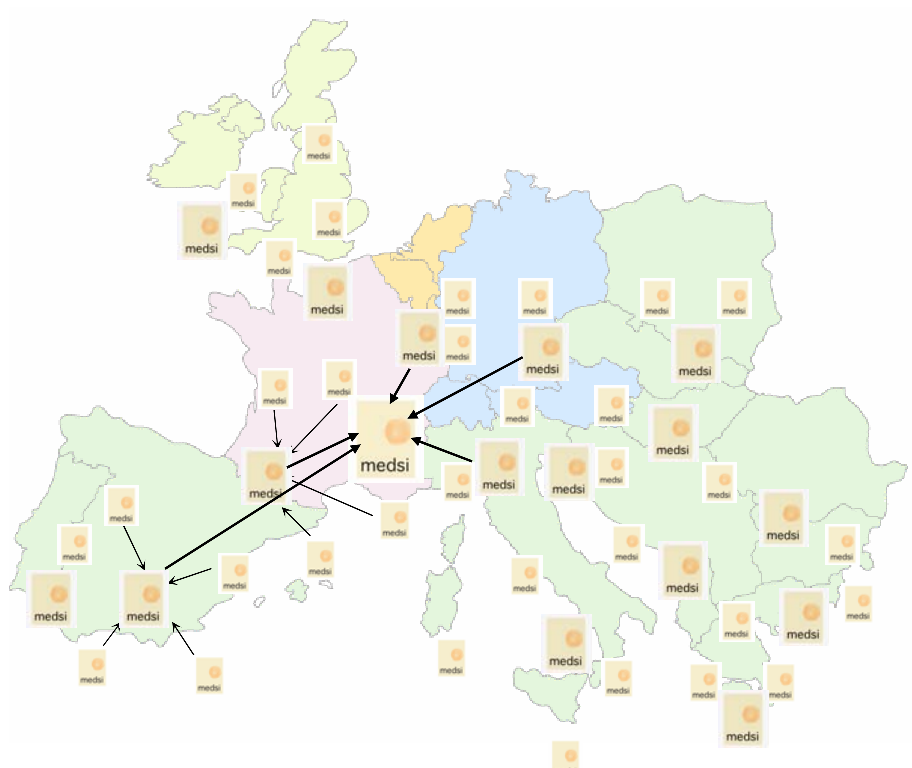
Figure 4: MEDSI architecture



The MEDSI infrastructure will consist of specific web services, built mainly upon the standardized OpenGIS standard and also upon the standard specific to the project. The meta-layer of the MEDSI data model will cover both commercial data formats and MEDSI-specific ones.

- Definition of interoperability standards – selection of common standards set to be used in MEDSI environment plus definition of additional standards for the specific purpose of crisis management information support.
- Prototype implementation, testing at the real situation.
- Assessment of the functionality and performance of the system.
- Dissemination of the standards, know-how and enabling of the base set of tools for further customisation and enhancement.

Figure 5: MEDSI Service Infrastructure



Among the innovative aspects of the MEDSI approach are:

- Generic data schema to support crisis management in general, making use of the synchronized simulation and geospatial information. In this sense, MEDSI can be considered as a tool to define and manage crisis scenarios to support trans-national scenarios for critical infrastructure protection.
- The layered MEDSI architecture based on services will allow to provide a scalable system interoperating with other systems currently in usage or in development and make the huge quantities of information accessible.
- The smart symbology, coming out of the users perception of the crisis situation and helping the effective overview of the situation and international understanding in a cross-border crisis.
- The integration of simulation features to MEDSI will allow the effective support of planning and training, utilizing the real scenarios.
- The new concept of GIS and simulation integration, which is not present within current OpenGIS standards and which will be based on a new generation of simulation standards. The project will include the prototype implementation.

- Provide a basis for interoperability among European data sources for crisis management, bringing the standardization of messages for emergency management domain.
- Bringing up the reference solution for the critical infrastructure protection with a potential to extend the services to provide a fundamental support to European Union candidate countries, facilitating in this way the adaptation to the procedures and coordination of initiatives in the European common space.
- Standards in Emergency Management: The MEDSI project will focus on existing and emerging standards related to the largest extent possible regarding the application area of Emergency Management and the technology areas involved.
  Among the standards being considered are, just to name a few: OASIS EM-related XML-standards (http://www.oasis-open.org/committees/tc_home.php?wg_abbrev=emergency), NFPA 1600 (http://www.nfpa.org), HLA (http://www.dmso.mil), Open GIS Consortium Specifications (http://www.opengis.org), etc.

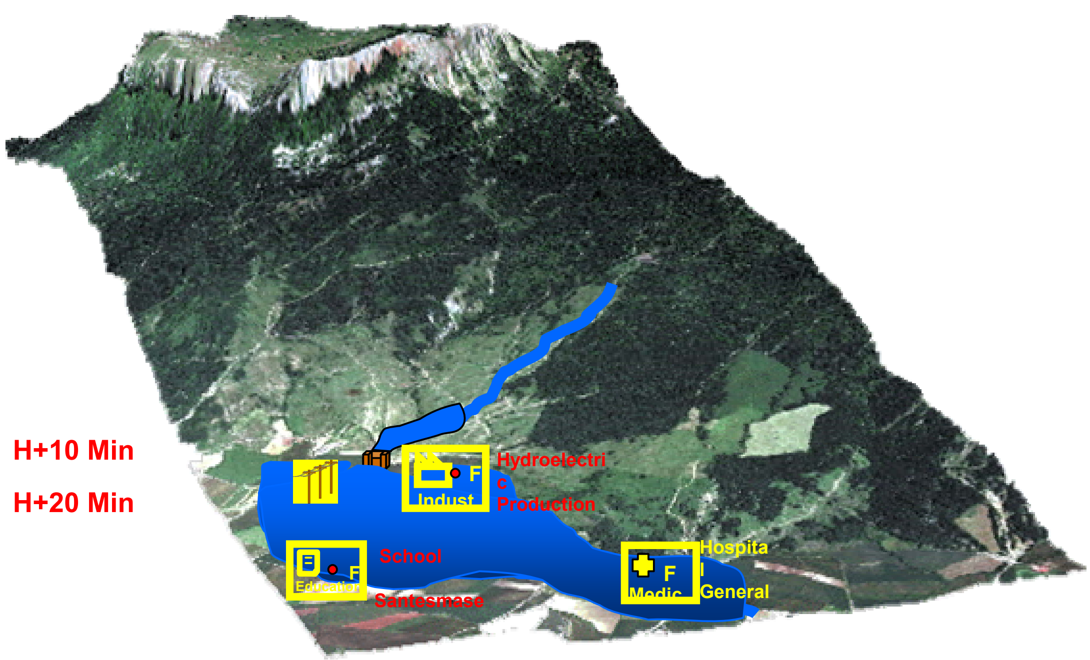
5. Planned Scenarios

The MEDSI prototype is planned to be tested and evaluated using several scenarios throughout Europe. While the preparation of and decision on the scenarios is still underway, it will result in at least three scenarios focusing on

- Natural disaster (expected scenario: Flooding, Region: Magdeburg, Germany)
- Technological disaster (expected scenario: combined traffic / chemical accident)
- Assymetric threads / terrorist attack.

Other scenarios, disaster types and regions might be defined.

Figure 6: Example Flooding Scenario



6. Conclusion

In this paper we have described a new approach for management decision support for critical infrastructures. This approach is currently being realized based on a EU-funded R&D project. It focuses on interoperability and standardization of systems and services and makes use of an infrastructure based system architecture. As the paper describes the current status of an ongoing project we will be able to report on the scenarios and results of the MEDSI project in the near future. The current status of the project is available at the MEDSI website http://www.medsi.org.

References

Bernard, L., Krüger, T. (2000). *Integration of GIS and Spatio-Temporal Simulation Models.* Transactions in GIS 4(3): 197-215.

Buehler, K., McKee, L. (eds) (1998). *The OpenGIS Guide*. Wayland, MA, OpenGIS Consortium Technical Committee.

Klein, Ulrich (1999). *Simulation-based Distributed Systems: Serving Multiple Purposes through Composition of Components*. In: Beroggi, Giampiero E. G. (Hrsg.): Proceedings of the International Emergency Management Society Conference 1999 (TIEMS 99), 8.-11. Juni 1999, Delft, Niederlande. Delft: Delft University of Technology, 1999, pp. 79 - 86.

Klein, Ulrich. (2000). *Simulation-based Distributed Systems: Serving Multiple Purposes through Composition of Components*. In: Safety Science 35 (2000), pp. 1 - 11.

de Silva, F. Nishakamura; Eglese, R. W. (2000). *Integrating Simulation Modelling and GIS: Spatial Decision Support Systems for Evacuation Planning*. Journal of the Operational Research Society (JORS), Special Issue Simulation. Journal of the Operational Research Society, Volume 51, Issue 4, April 2000.

Nyerges, T. (1992). *Coupling GIS and Spatial Analytic Models*. In: Breshanan, P., Corwin, E., Cowen, D. (eds.), 5th International Symposium on Spatial Data Handling. Charleston, USA, International Geographic Union: 524-533.

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This work is based on the joint effort of the partners of the MEDSI Consortium.

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The MEDSI Consortium is described at http://www.medsi.org.

Academic and Professional Practice

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RISK IDENTIFICATION AND MANAGEMENT

A SMART BROWSER-BASED DECISION SUPPORT TOOL FOR COMMUNICABLE DISEASE CONTROL IN THE UNITED KINGDOM

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Keywords: Communicable Disease Control, Risk Management, Decision Support, inical Governance; Evidence-based Practice.

Abstract

This paper describes the design, development and implementation of an object-oriented Decision Support Tool for Communicable Disease Control (CDC). The system developed includes a risk assessment model based on five orthogonal risk attributes, which are assessed dynamically. The browser-based tool includes an automated log of data input, assessments, decisions and actions carried out by many health professionals for a given incident(s). The tool is based on timely risk assessments at a particular time, making it useful for looking back at an event and recapturing how it was dealt with at the time. The tool has a range of operational functionality including emails, tasks, reminders, prompts, forum, notice board, and can be linked to internal and external data sources including standard operating procedures and codes of practice. The tool is designed to help rather than replace the user. It is based upon the real needs of the Consultants in CDC and other professionals who will be using the system on a day-to-day basis. Immediate gains from such an integrated tool include using a consistent risk assessment model, developing "institutional wisdom", promoting benchmarking and sharing accurate and timely data. The tool has applications in wider health protection systems.

Introduction

Communicable Disease Control (CDC) is a complex, multi-disciplinary, high profile public health function. Current systems used by Consultants in Communicable Disease Control (CsCDC) work well enough, but are variable. There is therefore an urgent need, or an implied duty, for improving the quality of decisions that affect public health, for facilitating the collection, benchmarking and

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sharing of good practice so that lessons can be learned and the same mistakes never made again. Securing a sequential record of risk assessments and subsequent decisions carried out in a consistent manner is arguably an aspect that needs the greatest attention. The drive for evidence-based practice necessitates the development of a consistent, risk-informed, integrated, and multidisciplinary decision support system, which promotes the sharing of information and knowledge in real-time. The need for clinical governance necessitates the development of a more integrated, software-based approach to health protection and the development of standards for the storage and retrieval of data, which would support the dissemination and sharing of data, information and knowledge.

Work on this project began with the development of a risk assessment model based on the quasi-probabilistic estimation of five orthogonal attributes namely Severity, Confidence, Spread, Intervention and Context. The model has been validated locally, regionally and nationally using simulated time-bound scenarios.

This paper describes the development of a web-browser based decision support tool called HPZone for use in communicable disease control. Great emphasis has been placed on the use of open standards. HPZone uses XML throughout as the means of describing objects, processes and interfaces. The software development strategy used is very much a bottom-up and democratic one, based upon the real needs of CsCDC and other professionals who will be using the system on a day-to-day basis.

Theory and Methods

The starting point of this research began with two key publications [Advisory Committee on Dangerous Pathogens 1996, and Lammerding and Paoli 1997] on microbiological risks and environmental toxicology respectively and later by a strategic communication by the Department of Health [2002]. Several reviews have been carried out on the application of risk assessment in generalised health studies and a significant volume of literature can be found about communicable diseases in terms of description, symptoms and necessary remedial actions [Lynn 1995].

Risk Assessment

The research began with the development and validation of a comprehensive risk management model for communicable disease control [Kara-Zaitri et al. 2000 and 2002]. The model developed was not confined to the use of Severity and Likelihood attributes only but included other factors such as Spread, Intervention and Context. The definition of each attribute was developed using Delphi methods and the model was validated in several workshops involving health professionals from many disciplines. Each attribute is quantified quasi-probabilistically in line with other models in a wide spectrum of disciplines and is shown in Table 1.

Table 1: Risk attribute definitions and ratings.

Risk Attribute	**Attribute definition**	***Attribute rating***
Severity	The seriousness of the incident in terms of the intrinsic propensity *in the specific circumstances* to cause harm to individuals or to the population.	*0*: Very Low, *1*: Low, *2*: Moderate, *3*: High and *4*: Very High.
Confidence	The level of confidence, epidemiologically, clinically, statistically and from laboratory evidence, that the diagnosis is correct *in the set of circumstances.*	*0*: Very Low, *1*: Low, *2*: Moderate, *3*: High and *4*: Very High.
Spread	The intrinsic temporal and spatial potential for spread including the infective dose, the virulence of the organism, the availability of the route(s) of spread, the observed spread and the susceptibility of the population (e.g. lack of immunity) *in the set of circumstances*.	*0*: Very Low, *1*: Low, *2*: Moderate, *3*: High and *4*: Very High.
Intervention	The feasibility to intervene to alter the course and influence the outcome of the event in terms of containing, reducing or eliminating the transmission of the organism, or assuaging public anxiety. The feasibility of delivering what is needed, to whom it is needed and when and where it is needed, considering the extent to which interventions are intrinsically simple, effective, available, affordable, cost-effective, acceptable, accessible, timely and well targeted.	*0*: Very Easy, *1*: Easy, *2*: Passable, *3*: Difficult and *4*: Very Difficult.
Context	The broad environment, including public concern and attitudes, expectations, pressures, strength of professional knowledge and the overall setting of external factors including politics, in which events are occurring and decisions on responses are being made.	*0*: Very Calm, *1*: Calm, *2*: Passable, *3*: Difficult and *4*: Very Difficult.

Object-Oriented Design and XML

During the past decade, a number of approaches to clinical decision-making using advanced information technologies have emerged. These include evidence-based medicine [Cowling et al., 1999 and Øvretveit 1999], outcome-based medicine [Sanderson 2000, and Fairfield and Long 1997], and evidence-based clinical guidelines [Hall and Eccles 2000] to name a few. The research described in this paper aims to develop and implement similar methods for improved health protection management at operational, tactical and strategic levels. It is designed to handle the five phases of a given incident – a disease outbreak in this context. The five phases are “well before” i.e. training and awareness, “before” i.e. surveillance, “during” i.e. handling the outbreak, “just after” i.e. limitation and “well after” i.e. organisational learning.

Clinical governance necessitates the development of a more integrated, software-based approach to health protection and the development of standards for the storage and retrieval of data, which would support the dissemination and sharing of data, information and knowledge. In order to achieve this, great emphasis has been placed on the use of open standards in this research. The application developed is object-oriented and uses XML throughout as the means for describing objects, processes and interfaces.

Object oriented programming techniques have the aim of creating and defining reusable objects from which applications can easily be built. This is possible since complex behaviours of these objects are readily incorporated in the objects. For the application to be maximally useful, every object must draw its information content from a generic class model. This includes clear definitions of attributes for each of the classes, inheritance structures and instance connections or relationships between the classes as well as the associated state transition data.

eXtensible Markup Language (XML) is a language for documents containing structured information [Holzner 1998, Leventhal and Lewis 1998, Khare and Rifkin 1997, Megginson 1998, Harold 1998]. Structured information contains both content and description. XML provides a standard and elegant way for sharing and exchanging clinical data in an efficient way. The number of XML-based health-oriented applications currently being developed is expected to drastically increase in the near future. Example applications include the standardisation of medical texts [Malet 1999], healthcare information exchange standards [Alschuler 1998] and applications for the transition from non-structured to structured data [Fierz W. and Grótter, and Ceusters 1997].

Many applications combining the benefits of object-oriented programming (OOP) and XML already exist in the health sector. They include the European Healthcare Information Systems Architecture (HISA) [Scherrer and Spahni 1999] and the well-known Health Level 7 (HL7) suite. HISA uses the combined approach to develop a standard capable of handling many different platforms, even sometimes heterogeneous to each other. HL7 is an object-oriented methodology for the development and specification of collaborative information exchange of healthcare information in clinical settings. The core concept behind the HL7 [Lyman et al. 2003] is the notion that an external event, a trigger event, occurs and is recognized by a healthcare computer application. After recognizing the event, HL7 sends a specific message based on that trigger event. HL7 includes aspects of patient administration, financial management, medical orders, inter-enterprise referrals and scheduling, clinical results reporting, information and medical record management, vocabularies and medical terminology, patient care goals and guidelines, decision support, and home health services.

Software development strategy

In order to achieve maximal flexibility in the design and development of the application, classes have been grouped by common organisational, logical, and technical properties. The software development strategy was to involve end-users as much as possible throughout the development and validation phase to ensure that an application, which is functional, relevant and useful is developed.

A toolset using object-oriented techniques including unified modelling language (UML) and XML has been developed with a significant input from health professionals via steering group meetings, targeted one-to-one presentations, and regional and national workshops. Brainstorm sessions and workshops with potential users have been used continuously to inform the software architecture and functions of the system. The class library constructed is completely generic and takes into account different levels of abstraction and granularity thus enhancing software openness and flexibility.

Results: The development of the web browser-based decision support

The software application developed is called HPZone and consists of a server-side suite of components written in C# running under .NET and a client-side suite of interface objects written in JavaScript, using Microsoft's Internet Explorer Browser for delivery. The software adheres fully to W3C standards for HTML and the DOM (Document Object Model). The software is configured and driven using XML to describe not just the data objects (their attributes, relationships, behaviours and states), but also the interface, in terms of what actions can (and should) be carried out by the user. The specific software features developed are built upon this robust foundation, providing for a much faster development cycle than would otherwise be possible.

HPZone uses a number of core objects to record and display information within the application. Central to the Communicable Disease workflow management are the Case and Situation objects. A Case is used to record any report of a Person who may be affected by a disease. A Case can be recorded even if there is only a suspicion that a Person may be suffering from a disease. It should be recorded even if the person has recovered. A Situation is used to record any set of circumstances that may present a risk to public health now, or at some time in the future. A Situation may be created with or without cases attached.

These objects form the focal point, allowing additional information and objects to be recorded in the system. It is the linking of Cases and Situations to other objects that provides the data richness making HPZone a valuable searchable tool for data mining and discovery.

HPZone is designed to provide a central team-working resource for Case and Situation Management. To this end, Actions and Events form key functionality within the application. At key points (e.g. the creation of Cases or Situations), users are prompted with "Essential", "Recommended" or "To Be Considered" Actions that should be created and assigned to users within the system. By ensuring that relevant tasks are highlighted, considered and assigned at the initiation of any set of circumstances, HPZone provides the user with an overview of best practice, directing the novice user and prompting the experienced.

Where relevant, object creation is carried out in a managed sequence, guiding the user through the essential data entry components in a logical order. For example, in the creation of a Case, a user is first asked to enter the details of the Person who is affected by a communicable disease. The user will then enter the Case information, detailing the key facts about the Case. Finally, a series of Actions (dependent on the disease and the confidence in the diagnosis) are generated and assigned by the user to the relevant parties. The dynamic risk assessment is reserved for Situations depending on the set of circumstances including Case and Situation Events and associated Actions. The application interface has three views, each corresponds to a tabbed window within the application with two panes, the left pane holding a hierarchical tree menu, and the right pane being the display area for what is selected on the left.

- *Class View*: The Class View enables the user to explore objects via their class. It is possible for each class to apply specific filters to rapidly navigate to the objects that are currently in working scope. Such filters might provide access by time-based criteria, today's journal entries, this week's new cases, or this month's situations. Alternatively, they might provide access by status, such as all open actions, all overdue actions etc. Filters can be added within the application itself, and the class view tree will dynamically rebuild itself. Also, within this tree are options to lookup objects based on their name, or run a query by form to find objects based upon very precise criteria. The Class View also provides access to other system functions such as mail, reports and administration functions.
- *Item View*: When any object is selected for view from the Class View it is normally displayed in the Item View where the left-pane is used to decompose the object in terms of its own intrinsic views, data components, and linked objects. In this way, all items that are linked to the item in focus can be explored and viewed in place. This promotes the concept of automated data discovery.
- *Set View*: When any set of objects is selected for view from either the Class View or the Item View they are displayed in the Set View where the left-pane is used to list all the objects in the set, allowing the user to browse through and view each member object without leaving the focus of the set. It is possible to save sets of objects as private, for personal access, or as public, for open access.

An example display of the Class view and Item View are shown in Figures 1 and 2 respectively.

Figure 1: "Explore HPZone" Function

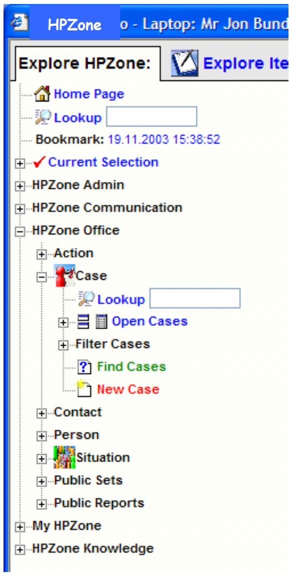
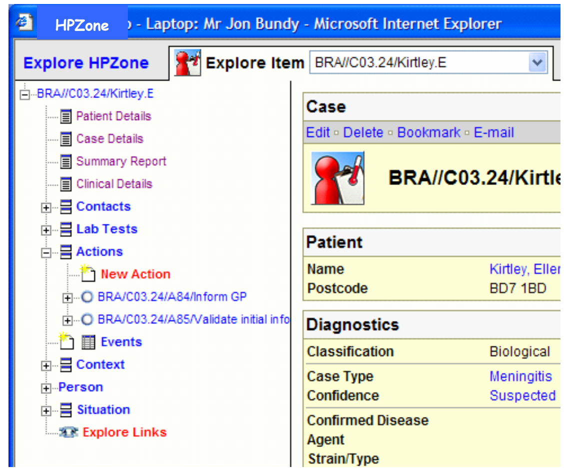


Figure 2: "Explore Item" Function

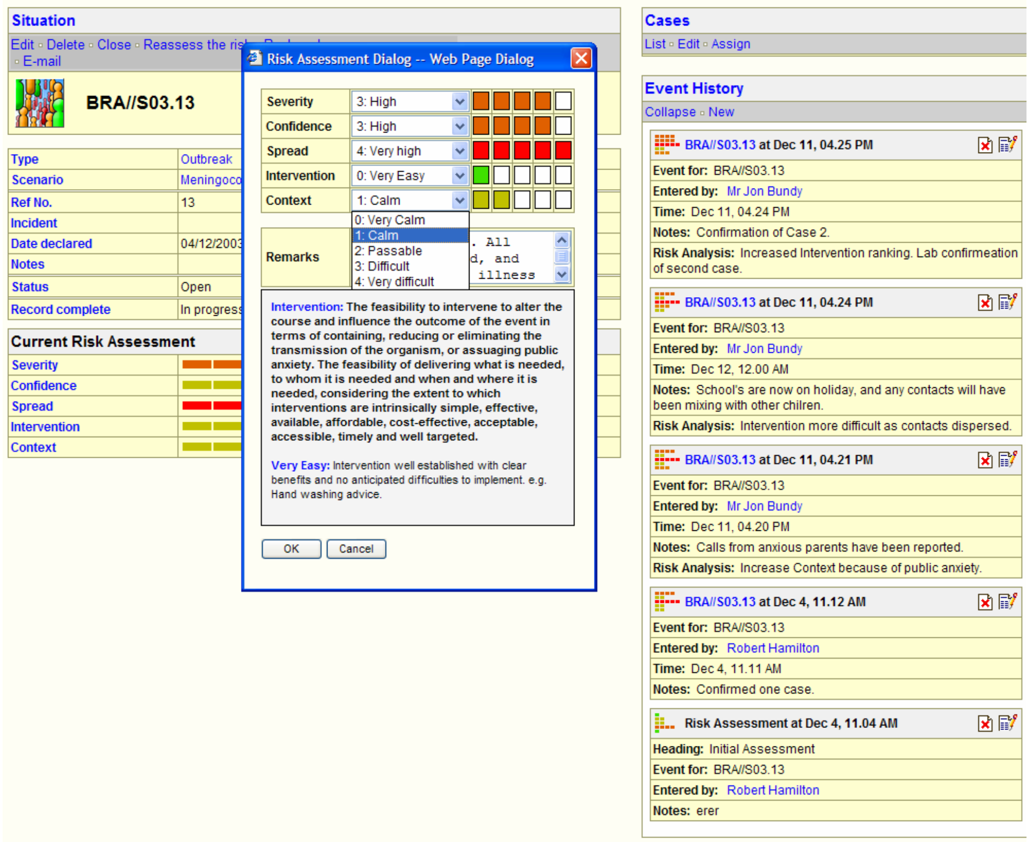


The Class view offers the User a number of options as follows:

- HPZone Office: This contains the main engine room of HPZone and includes all information related to Journal Entries, People, Cases, Contacts, Situations, Events, Laboratory results and Actions.
- HPZone Communication: This contains access to email, forum, message, and SMS communications.
- My HPZone: This provides a virtual 'desk' within the application and includes personal Notes, Memos, Private Sets, Reports and Knowledge.
- HPZone Knowledge: This contains a library of information and documents relevant to Health Protection.
- HPZone Admin: This contains a variety of administration aspects with appropriate security, permission and access rights.

An example of the risk assessment for a given Situation and the Event History of linked cases is shown in Figure 3.

Figure 3: Example Risk Assessment display for a given Situation



The methodology adopted is to instantiate each object in the 'Case' and 'Situation' classes by a 'Type of' class, each instance of which corresponds to a combination of Scenario and Probability. The scenario could be the disease in the case of Communicable Disease Control, or another health protection incident such as a Chemical or Radiation Incident. The linguistic variables describing Case and Situations probabilities are {Confirmed, Suspected, Possible} and {Outbreak, Potential Outbreak, Threat} respectively.
The Type of classes for Case and Situation are associated with the Task Class, the objects of which represent all the possible tasks associated with the function of a Communicable Disease Control Unit. It is possible for the system administrator to link specific task objects to each scenario. This means that when a new instance of a Case or a Situation is created, an instance of each linked Task will be created, effectively producing a list of Actions, which can be assigned to specific individuals or roles within the Health Protection Team under consideration.

When linking a Task to a Scenario the link must be ranked as either "Essential", "Recommended" or "To be considered". This reflects how the Actions appear to the user in the interface. There is also an association between the Task class and the Scenario class so that it is possible to associate specific tasks directly to the Scenario, independent of the probability. This is true where the same action is required for some diseases independent of whether a Case is confirmed or just possible.

In this way, the object model allows the Consultant in Communicable Disease Control to enshrine best practice for a particular disease simply by linking actions with Scenarios and probabilities. The system offers the user essential and recommended Actions for a given Situation. It also offers those Actions that need to be considered based upon the precise context. The system records all those actions undertaken, and provides support for the management of the situation, both locally and remotely. It is expected that "best practice" encapsulated by the system in this way could be exported to XML and then adopted by other teams using the system. The model will allow individual users to develop their own practice, and this facilitate benchmarking and knowledge sharing.

In the development of link-rich objects, there is obviously ample opportunity to start at a specific object and browse links to related items. In particular, the Explore Item view on HPZone allows the user to view all items related to a particular object. This provides Health professionals with the opportunity to research, investigate and probe the data in HPZone in a non-structured way. HPZone provides easy to use functionality to facilitate Data Discovery. Furthermore, HPZone also incorporates a Sniffer engine, which provides surveillance data every time a given rule is fired such as same virus at same location and at same time. Complex rules can be stored in an XML format outside the HPZone engine.
HPZone includes an automated log of data input, assessments, decisions and actions carried out by many health professionals for a given incident(s). The tool is based on structured risk assessment at a particular time, making it useful for looking back at an event and recapturing how it was dealt with at the time. The tool has a range of operational functionality including emails, tasks, reminders, prompts, forum, notice board, and can be linked to internal and external data sources including standard operating procedures and codes of practice.

Discussions

During the development of HPZone, a number of regional and national Workshops were carried out in the United Kingdom to showcase and explore the strengths and weaknesses of HPZone. The feedback received so far from a wide spectrum of health professionals has been overwhelmingly positive. The detailed feedback captured at every workshop has been very constructive and has helped address the concerns of users and ensure that the application is useful. The One-to-one sessions have also been very successful in engendering a sense of involvement in the development process amongst end-users.

Using HPZone on a daily basis has many advantages. Since the data are stored electronically, they can be comprehensively searched, viewed, analysed and shared. More importantly, the data can be readily packaged and used to automatically create customised reports including those required for surveillance, notification and incident reporting purposes. The tool complies fully with the e-Government Information Framework (e-GIF) and provides a flexible yet robust facility for managing cases and sharing key data on a team, local, regional and national basis, without the installation or maintenance of additional software. Such data include control of cases and clusters, incident management and event logging, task management, communication between the various organisations, support for a forum and notice board, training, organisational learning, plus extensive reporting and analysis tools.

The ultimate outcome of this project is a tool that could be readily integrated into a national information system network, supporting the development and dissemination of best-practice, providing a valid incident management review and audit system as part of an evidence-based Quality Assurance programme. Immediate gains from such an integrated tool include improving data communication systems, developing "institutional wisdom", promoting benchmarking and sharing accurate data and good practice. Although developed primarily for communicable disease control the tool can be extended to cover the wider challenges of health protection.

The real benefits of HPZone would be in facilitating the realisation of data standards covering all aspects of data definitions, coding structures, schemas identifying the order and structure of data fields in electronic messages and the mechanism for encoding these schemas. Standards will greatly facilitate the exchange of high quality, comparable data throughout the Health Protection community. HPZone will embrace these emerging standards as they evolve and, from the outset, help promote their wider use by example. HPZone offers the opportunity for collaboration; for discourse on national and regional differences and similarities; and for specialization of the model to meet local needs. Thus, it can serve as a vehicle for harmonizing disparate standards in the future.

To this end, the authors are actively seeking further collaboration with other research groups including standards development organisations, creators and maintainers of health vocabularies, government agencies and regulatory bodies, and clinical professional specialty groups.

Conclusions

Immediate gains from HPZone as an integrated tool include using a systematic and consistent approach to dynamic risk management – an effective solution for capturing “institutional wisdom” and providing a bank of useful risk scenarios for training purposes. The object-oriented structure of the software tool can be readily applied in a wider spectrum of other applications in the chemical, nuclear and transport industries.

The browser-based tool includes an automated log of data input, assessments, decisions and actions carried out by many health professionals for a given incident(s). The tool also has a range of operational functionality including emails, tasks, reminders, prompts, forum, notice board, and can be linked to internal and external data sources including standard operating procedures and codes of practice. The use of a web browser system enables all those involved in managing the outbreak to both input data and to follow the situation in “real time” even while working from diverse locations, while allowing control of the outbreak to be clearly invested in one individual.

As many consultants in communicable disease control are haunted by the prospect of being asked at an inquest what they thought of a situation several years previously, the explicitness of HPZone, particularly when used sequentially through an evolving scenario would be invaluable. Decisions are made on the information available at the time, and in the given context. HPZone is highly functional, inter-linked and practical. The gains from such an integrated system in terms of improving individual skills, developing “corporate wisdom”, unified risk management and clinical governance are significant.
The strengths mentioned above make HPZone a worthy candidate as a methodology to use for generating collaboration and consensus between different systems in an international setting.

References

Advisory Committee on Dangerous Pathogens. 1996. *Microbiological risk assessment: An interim repor*. London HMSO.

Alschuler L., Brennan S., Rossi A., Sokolowski R., Dudeck J., "SGML/XML in healthcare information exchange standards", Proc SGML Europe `98. Graphic Communications Association, 1998: 425-33.

Ceusters W., Steurs F., Zanstra P., Haring E.V.D. and Rogers J. From a time standard for medical informatics to a controlled language for health, IMIA Working Conference on Standardization in Medical Informatics, Bermuda, September 1997.

Cowling A., Newman K. and Leigh S. Developing a competency framework to support training in evidence-based healthcare. *Int. J. Health Care Qual. Assur.* **12** 4 (1999), pp. 149–159.

Department of Health. 2002. Getting ahead of the curve. A strategy for combating infectious diseases (including other aspects of health protection) A report by the Chief Medical Officer.

Fairfield G. and Long A.F. Measuring the outcomes of disease management. *Int. J. Health Care Qual. Assur.* **10** 4 (1997), pp. 161–165.

Fierz W. and Grótter R., "The use of a structured XML document to integrate distributed heterogeneous computer systems in a multi-centered clinical study", In E. Greiser & M. Wischnewsky (Eds.), Methoden der Medizinischen Informatik, Biometrie und Epidemiologie in der modernen Informationsgesellschaft (pp. 324-326).

Hall L. and Eccles M., Case study of an inter-professional and inter-organisational programme to adapt, implement and evaluate clinical guidelines in secondary care. *Br. J. Clin. Governance* **5** 2 (2000), pp. 72–82.

Harold E.R. *XML: Extensible Markup Language*, IDG Books, Foster City, CA (1998).
Holzner S. *XML Complete*, McGraw Hill (1998).

Kara-Zaitri, Gelletlie, Barnes, Black, Walker, Hatton, Schweiger and Wilson. The development of a Risk Management Model for Communicable Disease Control in the UK. PSAM5. Universal Academy Press. 2000. 4, 2247-2253.

Kara-Zaitri, Gelletlie, Black, Barnes and Schweiger. The design, development and implementation of a dynamic risk management priority index for communicable disease control in the United Kingdom. PSAM6. 2002, Vol. 1. Elesevier Science. ISBN: 0-0804-4120-3

Khare R. and Rifkin A., XML: a door to automated web applications. *IEEE Internet Comput.* **1** 4 (1997), pp. 78–87.
Lammerding A. M. Paoli G. M. 1997. Q*uantitative risk assessment: an emerging tool for emerging foodborne pathogens. Emerging Infectious Disease.* 3:4.
Leventhal M., Lewis D. and Fuchs M. *Designing XML Internet Applications*, Prentice Hall (1998) ISBN: 0-13-616822-1.

Lyman JA, Scully K, Tropello S, Boyd J, Dalton J, Pelletier S, Egyhazy C. Mapping From a Clinical Data Warehouse to the HL7 Reference Information Model. Proc. American Medical Informatics Association Symposium. 2003;920.

Lynn F. M. 1995. Public Participation in Risk Management Decisions: The Right to Define, the Right to Know, and the Right to Ac. *Risk Analysis*, 1:11.

Malet G., Munoz F., Appleyard R. and Hersh W., A model for enhancing internet medical document retrieval with medical core metadata. *JAMIA* **6** 2 (1999), pp. 163–172.
Megginson D. *Structuring XML Documents*, Prentice Hall, Upper Saddle River, NJ (1998).

Øvretveit J., Evaluation informed management and clinical governance. *Br. J. Clin. Governance* **4** 3 (1999), pp. 103–108.

Sanderson H., Information requirements for clinical governance. *Br. J. Clin. Governance* **5** 1 (2000), pp. 52–57.

Scherrer J.R, Spahni S. Healthcare information system architecture (HISA) and its middleware models. Proc. American Medical Informatics Association Symposium. 1999. pp:935-939

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