Strong Earthquakes, Rapid Damage Assessment and Rescue Planning

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

Abstract:

Effective disaster response planning covers three activities: (1) development of a realistic damage simulation model, (2) a method to rapidly assess actual damage, and (3) models to allocate limited rescue resources to damaged areas in an optimal way. Under topic (3) a model was presented in the previous conference [Fiedrich et al. 1999]. The actual paper will address the other two topics: a new damage simulation model using earthquake spectra and other input, and a method to transform information gathered from airborne laser scanning into assessment of the magnitude and types of structural damage in order to be able to quickly decide on the type of equipment and other resources to be used. Both methods are results from projects within the German Collaborative Research Center: "Strong Earthquakes, A Challenge for Geosciences and Civil Engineering" and its Romanian Partners.

Introduction

An increasing number of large cities and megacities are situated in earthquake prone areas. However in spite of extensive measures concerning strengthened building codes and retrofitting of buildings, strong earthquakes in these densely populated areas are expected to cause an increasing number of fatalities due to building collapse. Search and Rescue (SAR) activities can reduce the number of fatalities when using contemporary technologies.

First of all a damage simulation model is obligatory for appropriate response planning. The existing models are not accurate for small areas because they ignore regional seismic distinctions. Refined models would permit more exact planning in densely populated areas. Such a refined model would allow proper damage estimations when applied to real seismic data in the aftermath of an earthquake. Fast and detailed reconnaissance is the next step towards effective disaster management. As recent events proved, there is an emerging demand for further development in this field. A new attempt is airborne laser scanning for gathering height information in the affected area. If compared with height data from pre-event flyover, collapsed buildings and their according damage states can be determined very fast using expert knowledge.

In this paper the approach performed by the Collaborative Research Center 461 at the University of Karlsruhe, Germany will be presented, especially the damage simulation model, the damage assessment model and the decision support tool for onsite operations and training.

Collaborative Research Center 461 'Strong Earthquakes'

The Collaborative Research Center (CRC) 461 'Strong Earthquakes: A Challenge for Geosciences and Civil Engineering' is funded by the Deutsche Forschungsgemeinschaft (German Science Foundation) and supported by the State of Baden-Württemberg and the University of Karlsruhe. Collaborative Research Centers (SonderForschungsBereiche - SFB) aim at strategic research on issues that require intensive co-operation across various disciplines. CRCs form a framework for the development of these interactions and are expected to operate with a long-term (6 to 12 years) perspective. CRCs are peer-reviewed every 3 years. The CRC 461 has been established in July 1996. The CRC aims at strategic research in the field of strong earthquakes with regional focus on seismic events in the Vrancea region in Romania. These earthquakes have caused a high toll of casualties and extensive damage over the last centuries [Constantinescu, Enescu 1985].

The research activities are based on a strong cooperation between this CRC and the Romanian Group for strong Vrancea Earthquakes (RGVE) in a multidisciplinary attempt to earthquake mitigation [Wenzel et al. 1998].

The Damage Simulation Model

Loss estimations are developed for two different purposes:

(1) As a tool for disaster mitigation. It can be used

- to demonstrate the potential damage and loss the society has to cope with
- to assess the amount of required response resources
- to measure the efficiency of different mitigation strategies
- to measure variations of risk with time

(2) For disaster response after a strong earthquake. The input of seismic parameters permits fast post event damage and loss estimation. This enables an early beginning and coordination of response measures. The first estimation will be updated by various onsite situation reports.

For both applications the damage and loss estimation tool consists of four modules that describe hazard, vulnerability, risk to the built environment and loss of life (Figure 1). To test the model the inventory of the inner city of Bucharest with approx. 1500 buildings, additional lifelines and disaster response resources will be used. So far the data base is partly available but need to be refined before reasonable estimates emerge.

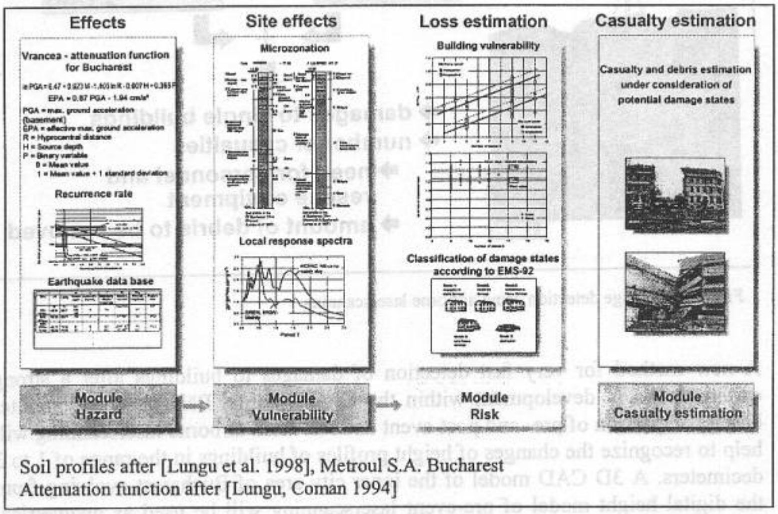

Figure 1: Scheme for modules of the damage and loss estimation tool

The essential goal for the development of the damage simulation model is a high accuracy for each single building in the surveyed inner city of Bucharest using as input:

- Peak ground acceleration (PGA) estimated for scenario earthquakes by means of attenuation relations [Lungu et al. 1998]
- Deterministic computation of the realistic strong ground motion [Radulian et al. 1999].
- Real earthquake spectra from historical earthquakes or direct measurements
- Geotechnical and seismic microzoning, compilation of available soil data, geological interpretation and extrapolation of log data, verification by seismological site effect studies

- Detailed building data for each building: building type, year of construction, condition and damages from former earthquakes, soft stories, horizontal and vertical shape type etc.

Height Information from Airborne Laserscanning

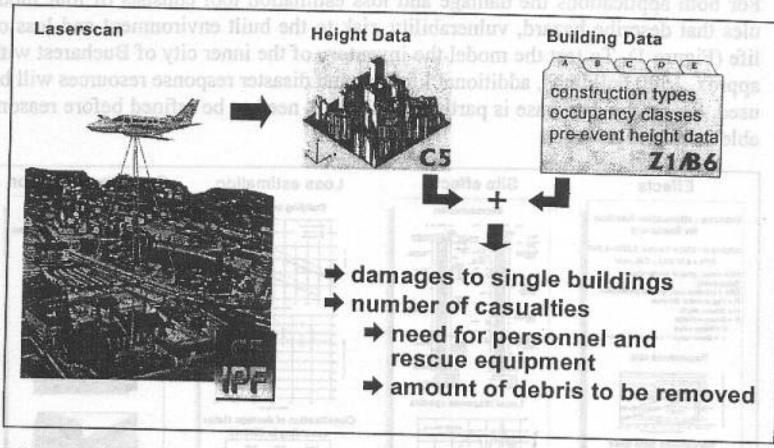

Figure 2: Damage detection using airborne laserscanning

A new method for very fast detection of damages to buildings after a strong earthquake is in development within the CRC [Steinle, Bähr 1999]: Computer based comparison of pre- and post-event datasets from airborne laserscanning will help to recognize the changes of height profiles of buildings in the range of 1 to 3 decimeters. A 3D CAD model of the inner city area of Bucharest evolving from the digital height model of pre-event laserscanning will be used as geometrical basis. The method enables very fast collection and processing of digital height data, independence of lighting conditions, even during night times, and high accuracy. Problems are caused by absorption and total reflection of the scanned area.

Figure 2 shows the further processing of the digital height model from post-event flyover. The geometric changes of the building surfaces must be analysed using building information and knowledge about typical damage states for different building types.

Detailed classification of building damages

Casualty estimation and assessment of required rescue activities for single buildings is necessary for detailed rescue planning. This is not possible if the damage state of a building is classified by a single damage grade such as used in the EMS scale [EMS 1998]. More detailed calculations are possible when the parameter 'volumetric reduction in the building form' is used [Okada et al. 1991]. This information can be gathered by using laserscanning methods.

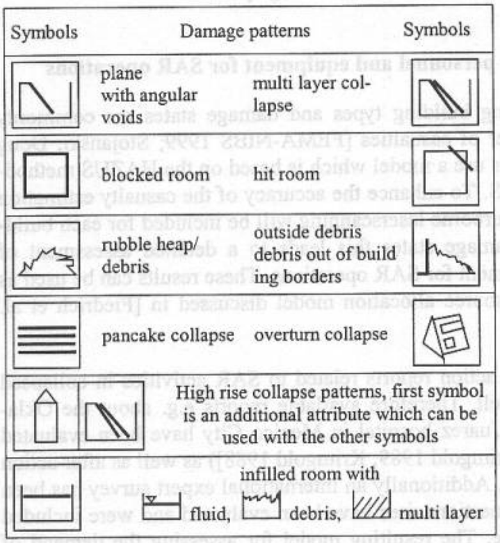

Figure 3: Damage patterns

Additionally the type of damage is important for rescue planning. After the turkey earthquake in August 17, 1999 many rescuers experienced collapsed RC-structures with damages typically observed at masonry buildings. These damages occurred due to very poor concrete floors. Figure 4 shows a damaged building in Mexico City, 1985. Different damage types can be found within one single building. The two examples show, that buildings of one type can collapse in many different ways depending on various parameters: seismic parameters, applied building code, the general vertical and horizontal shape of the building, accuracy of construction etc. Without knowledge of all these parameters, an exact prediction of the collapse mode for each building is very difficult. Consequently loss estimations are more accurate when applied to a number of buildings and less accurate when applied to a single building.

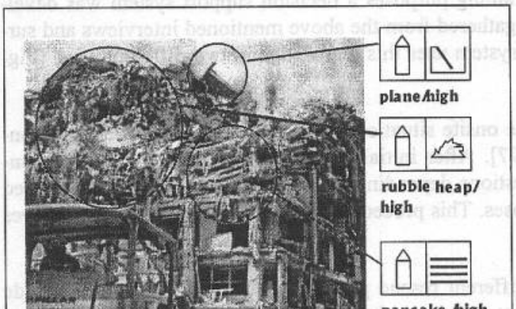

Figure 4: Damage patterns applied to damaged building in Mexico-City, 1985

For rapid damage assessment based on airborne laserscanning or direct observation a more detailed damage classification methodology is necessary to assess casualties and the demand for rescue activities, personnel and equipment. A damaged building can be divided in areas with similar damage states. These areas are characterized by damage pattern, position, extension and intensity. The damage patterns (Figure 3) were developed from the classification system used by German rescue teams. They meet the requirements to describe the related rescue work and different casualty rates. Figure 4 shows an example of a damaged building with different damage patterns.

Assessment of demand for personnel and equipment for SAR operations

Different models considering building types and damage states are commonly used to estimate the number of casualties [FEMA-NIBS 1999; Stojanski, Dong 1994]. As a basis the authors use a model which is based on the HAZUS methodology from FEMA and NIBS. To enhance the accuracy of the casualty estimation detailed observations from airborne laserscanning will be included for each building. Combined with the damage states this leads to a detailed assessment of needed personnel and equipment for SAR operations. These results can be used as input parameters for the resource allocation model discussed in [Fiedrich et al. 1999].

A detailed analysis of after action reports related to SAR activities in collapsed buildings is necessary as well. Therefore available reports e.g. about the Oklahoma City bombing or the Juarez hospital in Mexico City have been evaluated (e.g. [Wolf 1996; Shiono, Krimgold 1989; Krimgold 1988]) as well as after action reports from rescue workers. Additionally an international expert survey has been launched. So far over 200 questionnaires have been evaluated and were included in the basic knowledge base. The resulting model for assessing the demand of rescue resources will be published soon in detail.

Expert knowledge for rescue actions

Adequate training and good information are key factors for rescue personnel to do a good job. But very few rescuers are well experienced in extricating victims from collapsed buildings. For training purposes a decision support system was developed using the experience gathered from the above mentioned interviews and survey. The decision support system uses this knowledge in two different ways (Figure 5):

(1) The system inquires the onsite situation using the D3 expert system environment [Puppe et al. 1997]. After initial questions the expert system environment poses further questions depending on the situation leading to classified states and direct diagnoses. This procedure facilitates site screening with 'eyes of an expert'.

(2) The system suggests different rescue procedures. These suggestions include checklists and equipment recommendations based on experience from former events.

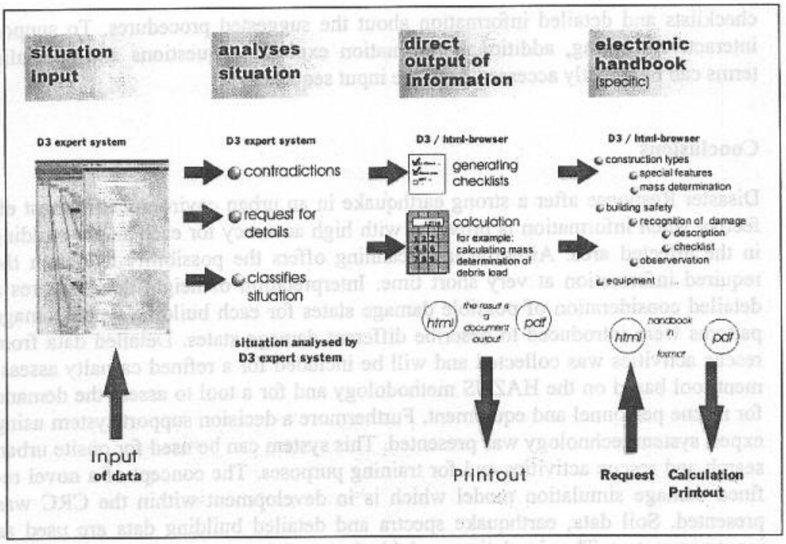

Figure 5: Decision support system for onsite SAR operations

These suggestions, calculations and information are supplied directly after diagnose. To access this information at a later point during the rescue operations, it is arranged in an individual electronic handbook depending on situation.

Figure 6 shows screenshots from the situation input sequence of the D3 expert system environment. The diagnoses lead to the information subsystem providing

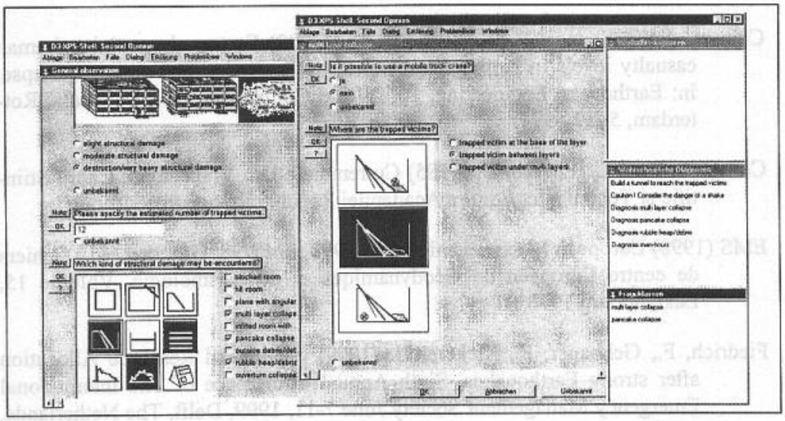

Figure 6: Situation input sequence

checklists and detailed information about the suggested procedures. To support interactive learning, additional information explaining questions and specialist terms can be directly accessed from the input sequence.

Conclusions

Disaster Response after a strong earthquake in an urban environment is most effective when information is provided with high accuracy for each single building in the affected area. Airborne laserscanning offers the possibility to obtain the required information at very short time. Interpretation of height data requires a detailed consideration of possible damage states for each building type. Damage patterns were introduced to describe different damage states. Detailed data from rescue activities was collected and will be included for a refined casualty assessment tool based on the HAZUS methodology and for a tool to assess the demand for rescue personnel and equipment. Furthermore a decision support system using expert system technology was presented. This system can be used for onsite urban search and rescue activities and for training purposes. The concept of a novel refined damage simulation model which is in development within the CRC was presented. Soil data, earthquake spectra and detailed building data are used as input parameters. The simulation model is designed for pre- and post-event use.

Acknowledgements

The work which led to this paper was supported by the German Federal Department of Civil Protection and the German Science Foundation DFG.

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