KNOWLEDGE REPRESENTATION IN TECHNICAL INFORMATION SYSTEMS FOR EARTHQUAKE LOSS MITIGATION

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ABSTRACT: The available commercial technical information systems for disaster management show significant deficits with regard to disasters in general, and earthquake loss mitigation in particular. This is as a result of the fact that disasters occur seldom, and therefore the financial barrier for precautionary provision is high. This is even more critical, because in these situations the local rescue organisations have to be supported by foreign ones, which do not know much about the local infrastructure. A further problem is also the fact that the actual extent of the disaster is often unknown. The major difficulty is the lack of operational data with regard to the victims involved, the available resources, the damages and so on. In this study, two main tasks are identified. Firstly, the need to overcome the lack of information by systematically collecting information and representing this appropriately in a state of the art information system. Secondly, the collected information has to be made available using well adapted data mining methods.

1 Introduction

One of the objectives of the German Collaborative Research Center 461 (CRC 461): "Strong Earthquakes, A Challenge for Geosciences and Civil Engineering" is the development of tools for effective disaster response planning. Within this context, a major question is how commercial computer aided dispatch systems may be extended to a technical information system (TIS) for disaster management. Up to now, there exists hardly any TIS solutions for disaster management that are able to reflect the workflow of the disaster response management. In addition to this, there is the need to integrate new developments into the TIS including, airborne reconnaissance, damage simulations, data analysis. In this paper, some analysis methods for a TIS to support disaster management are studied.

The interest in new analysis methods is a result of the needs of the new reconnaissance strategy of the CRC 461. The CRC 461 has designated an iterative reconnaissance strategy. First of all, a damage simulation model is generated. In the next step of refinement, one uses airborne data acquisition, e.g. laser-scanning, for verifying the simulated data. These initial assessment and reconnaissance operations are extended by reconnaissance on the ground. This all together establishes a new reconnaissance strategy. It may provide another standard of knowledge for the disaster response management. The new aspect is that, one has not only partially distributed information, but a quick general survey is also available. However, this

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results in a large amount of data. The huge amount of information can only be handled if there are adequate data analysis methods.

This paper is divided into two parts. The first part deals with image analysis, while the second addresses the evaluation of the results using spatial data mining methods.

2 Image Analysis

In image analysis, two objectives are often identified. The first task is the determination of building damages. On the other hand, the second objective is the determination of channels through which affected areas may be accessed. The approach used to determine the events of damage is described in detail in (Vögtle & Steinle, 2000). Along similar lines is presented in this paper an attempt to determine ways for the transport of rescue resources. This is based on fusion of data acquired by different sensors, because this combination simplifies the recognition task.

2.1 Test Area and Data Sources

The selected test area for this study encompasses a typical urban scene in the city of Karlsruhe. The city lies in the south-western part of the Federal Republic of Germany, near the boundary with France. The image includes part of the main campus of the University of Karlsruhe. The principal data used is airborne Daedalus scanner imagery. This is basically an opto-mechanical line scanner with 11 different multi-spectral channels and 8 bit data quantisation. The system specifications for this sensor are described in (Kramer, 1996). A normalised digital surface model (DSM) derived from airborne laser scanning (ALS) data is also employed. Details on the operating principle of ALS are articulated in (Wehr and Lohr, 1999).

2.2 Fusion of Multi-Source Data

Data fusion is defined as a formal framework in which are expressed means and tools for the alliance of data originating from different sources. This aims at obtaining information of greater quality (Wald, 1998). In principle, the fusion of multi-source data may be performed at different levels for instance, at measurement, attribute, rule or even decision levels. Furthermore, different approaches to the fusion of geo-spatial data may theoretically be employed including, RGB colour composites, IHS transformation, Principal Component Substitution, multi-resolution analysis, among other methods (Pohl, 1999). The particular method adopted is influenced by several factors including, the type of application under study, the structure of the data to be fused, as well as the image characteristics that need to be enhanced or preserved.

The fundamental ideas behind the combination of multi-source data for scene labelling are outlined in (Hahn and Stätter, 1998). Similarly, the combination of image and range data in the reconstruction of buildings is discussed in (Haala, 1996). In the application considered in this study, the geometric information of the ALS data is fused with the multi-spectral information of the Daedalus imagery. In this regard, several different approaches to data fusion may be adopted. For instance, it is possible to make use of the hierarchical classification approach, the additional channel concept or even, a knowledge-based strategy. Because of its simplicity, as well as the enhanced flexibility in the data processing, the additional channel concept is adopted for the data fusion in this study. Hence, the normalised

ALS data is introduced as an additional channel alongside the multi-spectral channels of the Daedalus imagery.

2.3 Integrated Classification Approach

The spectral signature is conventionally employed in the classification of multi-spectral imagery. However, results obtained from such methods are usually unsatisfactory, particularly for applications involving the mapping of man-made structures and natural features in complex urban scenes. These are often characterised by limited accuracy and low reliability (Haala and Brenner, 1999). In applications where high accuracy is required or high resolution remotely sensed data is employed, it is imperative to enhance the object feature base. As shown in Table 1, this needs to be expanded to include spectral, spatial as well as context features. In general, the feature characteristics adopted for a particular segmentation case are influenced by several factors including, the geometric and spectral resolution of the remotely sensed data, the particular object feature(s) of interest, the level of segmentation aspired, among other factors.

Feature domain	Feature characteristic
spectral	spectral signature
spatial	Texture structure/form size shape/contour topology
context	Distance Orientation Area

Table 1: Expanded object feature base (modified after (Schilling, 1996))

Different classifiers may be employed in the supervised classification of remotely sensed data, namely: maximum likelihood, minimum distance and parallelepiped classifiers (Lillesand and Kiefer, 1994). For the study presented here, a maximum likelihood classification approach, as opposed to contextual segmentation methods, is adopted after an initial clustering procedure. The selection of the training data is basically done using manual digitising. Five basic urban object classes are identified: *Buildings, Pavements, Trees, Grass-covered areas* and *Special*. The class *Special* is introduced in order to take care of the many miscellaneous urban objects of limited dimension (e.g., vehicles, water fountains, sculptures etc.) that otherwise exhibit a disturbing influence on the segmentation of other object classes. The final classification results obtained in the presence of both the multi-spectral and geometric data are shown in Fig. 1.

In order to smoothen the extracted segments and minimise the level of noise in the segmentation results, use is made of mathematical morphology and connected components. A more comprehensive discussion of these is given in (Serra, 1986) and (Haralick and Shapiro 1992) respectively. As an example, segments are extracted for the object class *Buildings*. A Delaunay tessellation is then applied. Valid building segments are then fused and the vector output from this is used in further analysis as described in the following chapter.

Figure 1. Classification results for fused multi-spectral and ALS data

3 Spatial Data Mining

The disaster mitigation process has a strong spatial reference. In this regard, terms like distance, velocity and nearness play a relevant role. The reconnaissance strategy described in chapter 1 presents a fairly good overview of the whole damage or thread situation with their spatial interrelations. As shown in chapter 2, the results of the image analysis do not provide fully structured knowledge. Spatial data mining supports the deduction of knowledge that is not explicitly stored in a given spatial data model (Anders, 1999). In this chapter, some concepts are presented to deduce knowledge relevant information from image analysis results.

3.1 Resource Motion Planning

The path planning problem for the transport of resources is first and foremost, a problem of knowing about obstacles and mobility resistance. For the disaster management, often the existing computer aided dispatch systems are used (Mitschke, 1997). These systems employ simple graph based routing algorithms for motion planning. A basic presupposition for these algorithms is that in the case of a disaster, the existing street network is not affected by the catastrophe. Moreover, these graph based algorithms do not take into consideration the fact that a "feasible path" must not only mean a network of streets and roads.

In the case of an emergency, one is not always bound to use the regular street network. For instance, if the street is blocked by debris, the vehicles may use open areas next to the street, for example grassland. In this paper, an approach is used, that takes these open spaces into account.

The target is not only to find any feasible path, but also to find the best feasible one. It is understood as the geodesic line. As a simplification, the affected region is represented by a plane. To find the feasible paths, this plane is segmented into non overlapping regions each of which is linked with a certain mobility resistance (Antony, 1995). This mobility resistance is influenced by all factors that determine the mobility of a rescue unit for example, the features of the transport vehicle, the characteristics of the underground, among other factors.

The boundaries of the regions of different mobility resistance may be represented by polygons. In Fig.2, this concept is demonstrated using buildings as obstacles that cannot be manoeuvred through at all. The grey line represents the geodesic line in a plan with obstacles. This shortest path is determined without using a graph of predefined channels.

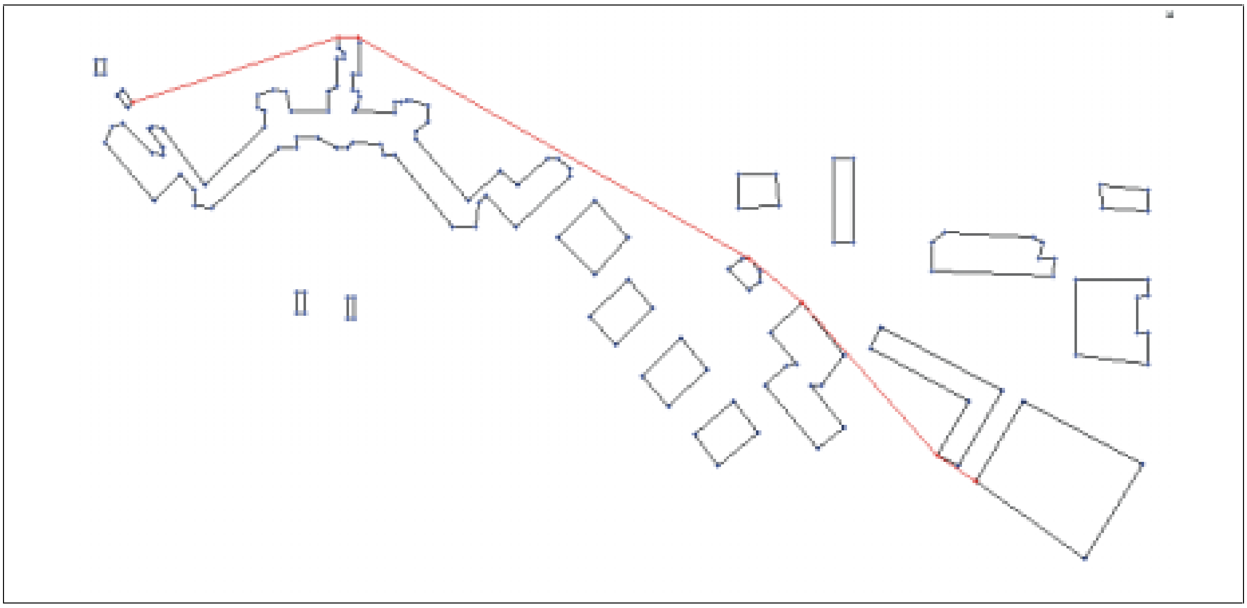

Figure 2. Geodesic line in plane with obstacles

3.2 Campaign Areas

One task in disaster management is to divide the entire disaster area into feasible campaign areas. The campaign areas are regions in which search and rescue teams are supposed to work. These areas should be non overlapping, cohered, and the rescue teams that operate in this area should not have to cover long distances between different damage events. Algorithms that are able to perform such tasks are called spatial data mining techniques. The existing graph-based clustering algorithms for spatial data mining are described in (Anders, 1999). In this study, a graph based geometrical clustering algorithm, as opposed to the well known geometrical clustering methods (MacQueen, 1967), is used. Here the function that has to be minimised is the overall sum of covered distances. But the distances are not the Euclidean distances, they are computed by a graph based shortest path algorithm, using the weights of the edges as distances. Figs. 3 and 4 illustrate an example for an application of this algorithm.

Figure 3. The bright buildings indicate damaged ones.

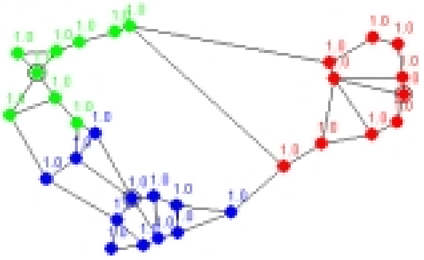

Figure 4. The nodes indicate the damaged buildings (Fig. 3); nodes of same color belong to same cluster.

4 Conclusions

In this paper two basic tasks that need to be addressed in Earth-quake loss mitigation are highlighted. Firstly, the need to search for admissible paths. And secondly, the necessity of aggregation of damage events to campaign areas. The importance of integrating image analysis results in technical information systems is demonstrated. This needs to be further developed before it can be fully implemented in practice.

Acknowledgements

The work presented here is done within the CRC 461: "Strong Earthquakes", funded by the Deutsche Forschungsgemeinschaft. The authors wish to sincerely thank their colleague Eberhard Steinle for his kind support in the preparation of this paper.

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