Developing Decision Support Tools for Confronting Seismic Hazards [*]

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Abstract: Following a natural disaster, such as earthquake, there are two critical factors for consideration; damage assessment and decision-making. In order to address these issues, a system for post-earthquake damage and usability assessment of buildings has been designed and implemented, in cooperation with the Greek Earthquake Planning and Protection Organization (EPPO). Using GIS technology and an expert system for analyzing building reliability parameters, the system serves as a decision making tool for setting up and carrying out efficiently an operation of post earthquake emergency building inspections. This work describes the design of the system components, current implementation status and outlines plans for further development.

1 Introduction

One of the difficulties that civil protection authorities have to deal with in order to confront emergency conditions such as an earthquake, is the management of the information coming up from the field that the earthquake takes place. The difficulty becomes bigger due to the fact that after an earthquake the demand for urgent intervention is huge. Emergency response actions must be taken immediately by civil protection authorities and a framework plan for planning and execution of post earthquake operations is essential. One of the most critical actions that must be taken by civil engineers after an earthquake is the usability assessment of post earthquake damaged buildings.

PEADAB: “A System for post-earthquake damage and usability assessment of buildings” [2] has been designed to address the above issue. The architecture of the system and the current implementation status are described in this paper with the emphasis on modules of computer science background, such as the database, the module for the support of Geographical Information, and the Expert System (ES) included. Still there are many areas of future work, some of which we have already indicated, such as the extension of the system, in order to support pre-seismic provision and other post-seismic confrontation activities.

The paper is organized as follows. In Section 2, we briefly provide the problem background. The PEADAB system architecture is described in Section 3, while Section 4 overviews the current implementation status and tasks for further development.

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2 Problem Background

Setting up and efficiently carrying out an operation of post-earthquake emergency building inspections in populated areas stricken by a damaging earthquake has been always a major problem for civil engineers. The problem gets even more complicated if the number of affected buildings is large, therefore the success of building inspection operation depends upon the way it has been designed and planned in advance.

In [1], a computer system for post earthquake emergency assessment of damaged buildings was developed. The fundamental aim of the system was to outline an operation plan for organizing emergency damage inspections of buildings in populated areas stricken by a catastrophic earthquake. This operation plan has been tailored around several procedures, which were based on experience gained from earthquakes in Greece during the last 20 years. Practical guidelines were developed for the engineers carrying out the emergency inspections, including safety classification criteria, descriptions of typical levels of damage for different types of buildings and the relation of such damage to safety. These guidelines have been incorporated in an integrated package, which uses GIS technology in order to add geographical capabilities to the system and an expert system for automating the usability assessment of buildings [2].

Following the feedback from user (i.e., civil protection authorities and civil engineers composing inspection teams) and the advances in computer science, the system developed in [1] is expanded in the current project [2] in order to provide:

a) Easy access to an assemble of information
b) Friendly user interface to feed in data to the system coming up form building inspections
c) Modification of pre-existing data
d) Composition of queries using a query editor. The queries supported are of two types: i) geographic queries (e.g. range queries, distance calculation, etc.) and ii) selection queries on descriptive attributes whose results can be graphically depicted on the map (e.g. selection of building satisfying some user specified criteria)
e) Calculation of statistics
f) Integration of digital maps in the level of building blocks and buildings
g) Classification of buildings by their inspection results (GREEN / YELLOW / RED marks)
h) Automation of the usability assessment of the damaged buildings using an expert system.

3 The Peadab Architecture

Figure 1 illustrates the architecture of the PEADAB system under development. In the sequel, we describe each component in detail.

3.1 The User Interface

The user interface allows for textural and graphical user interaction. The Graphical interface consists of a map window and corresponding themes. For ease of use a simplified set of control commands such as zoom-in, zoom-out, pan, identify tool, find (Figure 3) were developed on the menu bar. On the other hand, the textural interface provides a friendly way for entering data to the system, updating existing data and searching into the system's database.

3.2 The Database

The database is the integrated repository for all data required by the system. Two types of data are stored: traditional alphanumeric data stored in the so-called *thematic database* as well as related geographical data, which are stored in the *spatial database* (Figure 1)

- Thematic DB: This database is the major repository for the following categories of data: a) built-in descriptional data such as equipment lists, inspection guidelines, b) data that provide the sources from which the required personnel for the operation will be obtained, c) data of the personnel that will be used for the operation, d) building data and damage data, recorded in the inspection forms by the inspection teams.
- Spatial DB: Geographical data such as the position (coordination) of buildings or building blocks on map are also stored. Attributes including address and city of building are attached. This allows flexibility in searching and spotting a building on a map using a "Find" feature.

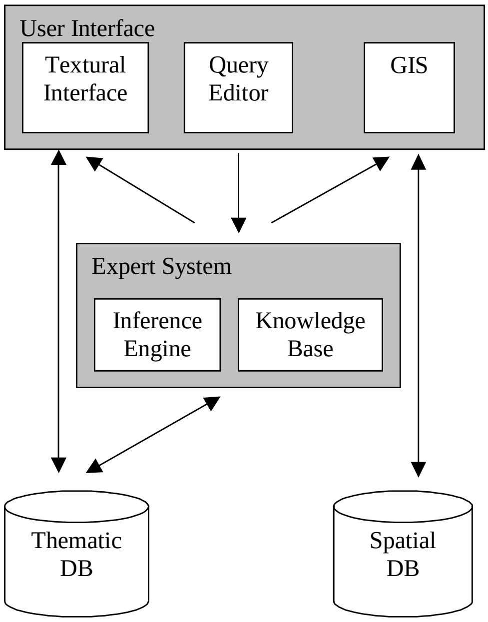

Figure 1. Description of system components

3.3 The Expert System

The role of the Expert System (ES) is to assist the user in the process of categorizing buildings according to the inspected damage. Specifically, prior to any user assessment for each inspected building, the ES suggests an appropriate ranking, based on the DB recorded building parameters and an inference engine, which communicates with the knowledge base. The knowledge base is build during a preparatory step that contracts a decision tree based on a set of problem specific instances (Figure 2). The underlying form of knowledge of the expert system is a *decision tree*. We use a variant of ID3 called C4.5 [3], which uses a "divide-and-conquer" approach to growing decision trees.

Only a brief description of the method is given here. This algorithm generates a decision tree from a set D of cases:

- If D satisfies a stopping criterion, the tree for D is a leaf associated with the most frequent class in D. One reason for stopping is that D contains only cases of this class, but other criteria can also be formulated.
- Some test T with mutually exclusive outcomes T1,T2,….,Tk is used to partition D into subsets D1,D2,……, Dk, where Di contains those cases that have outcome Ti. The tree for D has test T as its root with one subtree for each outcome Ti that is constructed by applying the same procedure recursively to the cases in Di.

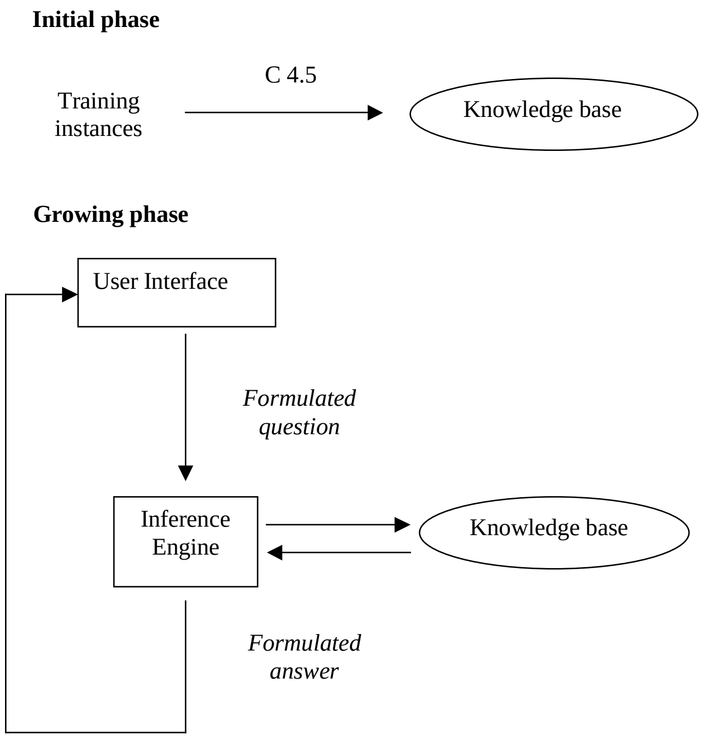

Figure 2. Using decision trees to feed the knowledge base

The benefits of the expert system approach are two-fold: a) initially, errors due to mistyping are eliminated. b) Additionally, for non-crisp user assessments, a coarse suggestion made by the ES may be of help towards the final categorization.

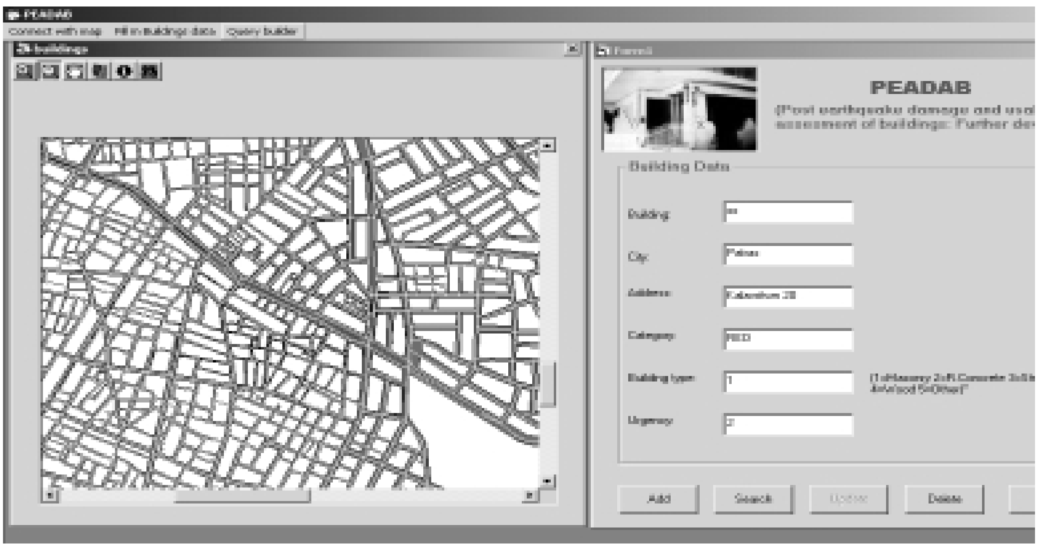

Figure 3. A screen-shot of the PEADAB software

3.4 The Geographical Information System

The software has been tailored around a geographical information system, which offers a user-friendly way to access, visualize and analyze data geographically. The heart of the system is an ActiveX component library, which provides desktop mapping and geographic analysis capabilities. For a sensitive application such as earthquake damage assessment, up-to-date geographic information is a key factor for fast and intuitive decision-making. The advantage of using a geographic processing engine is manifold: First, it offers a global view of building conditions through advanced visualization features in relation to information stored in the data base. Second, it can effectively process geographic queries, such as distance calculations, range queries, routing and travel time estimations, etc. Last but not least, it helps the user perform significant geographic analysis, like a) geographic overlay and data combination of relevant thematic layers, like roads, geological data (soil, faults) etc. b) buffer analysis, for example indication of hazardous areas around unsafe buildings and c) identification of locational patterns (e.g. cluster analysis).

4 Current Status and Further Developments

To facilitate installation and efficient operation of the PEADAB using desktop or laptop computers with typical processing capabilities, we have adopted Microsoft Visual Basic and ESRI Map Objects geographic ActiveX component library as the programming environments, and Microsoft Access for the database repository. Figure 3 provides a screen-shot of the software under development.

The main capabilities of the system in its current implementation phase are the following:

a) *Friendly user interface to feed in data to the system coming up from building inspections*
b) *Classification of buildings by their inspection results (GREEN / YELLOW / RED marks)*
c) *Composition of queries using query editor.*

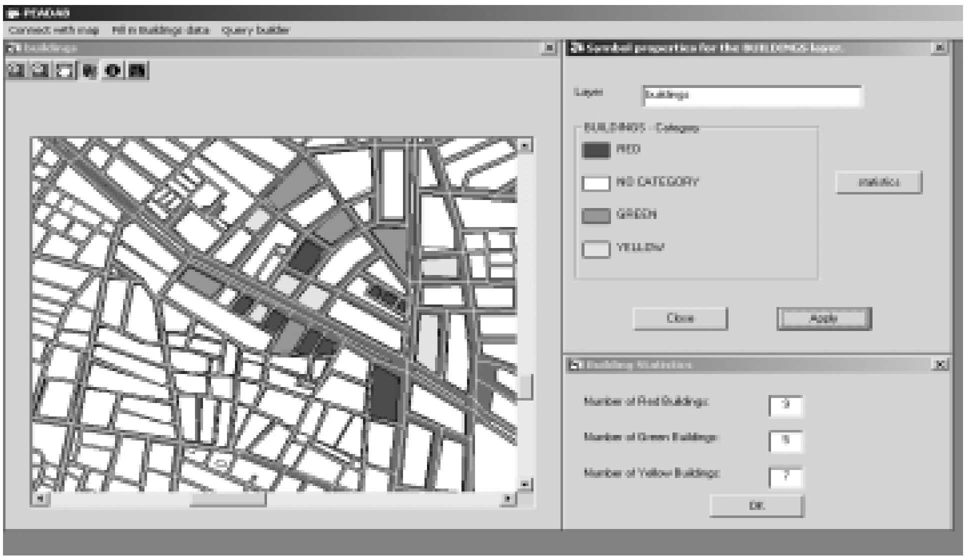

Figure 4. Categorization of buildings in GREEN / YELLOW / RED

In particular, the PEADAB software provides a friendly way of entering data into the system's database. Through the use of easy-to-use forms, the procedure of adding, searching, updating and deleting data from database is much more simplified. Adding the corresponding themes to the map window, the user can view the results of the categorization of buildings in GREEN, YELLOW or RED. This visualization of results on map enables him/her to have a quick view of current situation coming up from the inspections. As such, it is an easy way to identify the safe buildings, to indicate unsafe areas around hazardous buildings and to know the exact position of critical buildings (Figure 4).

Moreover, through the query editor, users can easily execute queries and derive data from database. Query results can be viewed both textually in a tabular form and graphically on map indicating the exact location of buildings with similar characteristics (Figure 5).

This work is the first step towards a long open road. The ultimate goal being a full-fledged decision support system for seismic hazards, our development efforts so far have focused on the core functionality of such a system, which is the effective planning and coordination of building inspections. Further continuation towards the goal system entails the support of pre-seismic provision and post-seismic confrontation activities, involving the development of modules such as, in a prioritization order:

- Regarding the user interface, a scenario management module in order to support "virtual" natural disasters and incorporate advanced building assessment algorithms,
- Regarding the expert system, automatic association of a confidence factor for each ranking suggestion, thus gaining a significant speed-up for obvious or trivial cases, spatial clustering models and location-allocation models.

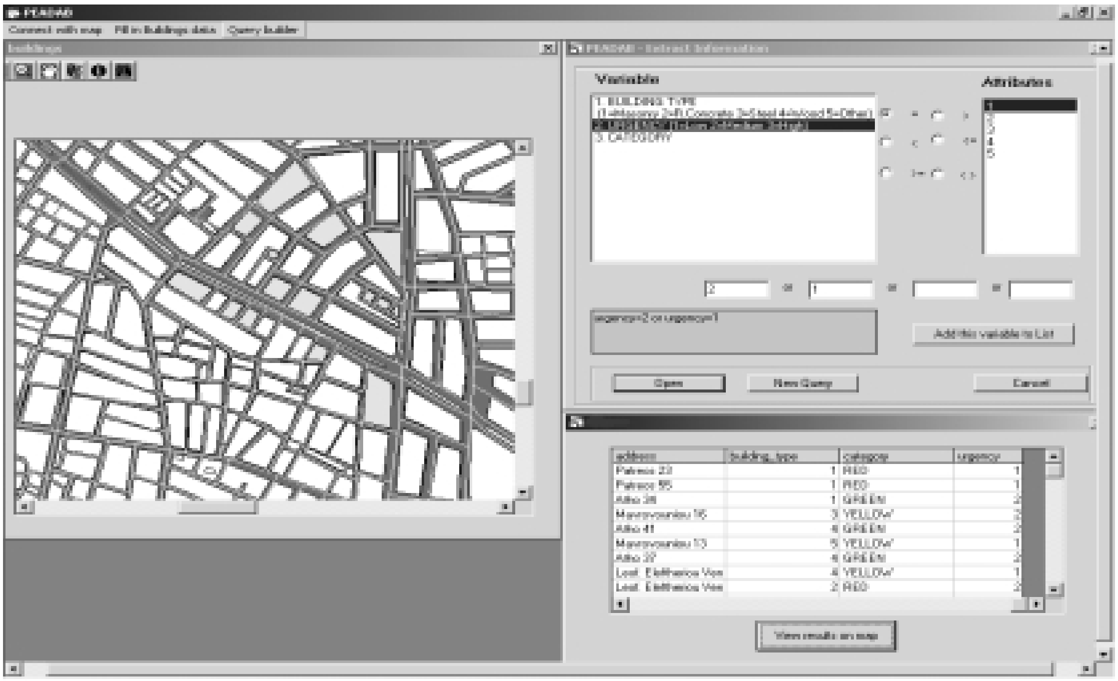

Figure 5. Presenting buildings with similar characteristics

Our next line of action is the gradual incorporation of the above modules in our system and experimental application to real-life situations in cooperation with EPPO. In particular, a test-case and pilot operation of the system by the civil authorities is planned to take place in the city of Chania, aiming to a real-life evaluation of the system (especially an assessment of the expert system's inferencing capabilities) and the inspection methodology as a whole.

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