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CONSTRUCŢII. ARHITECTURĂ

CREATING SCENARIOS FOR SEISMIC RISK REDUCTION USING GEOGRAPHIC INFORMATION SYSTEMS

BY

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This paper presents a GIS-based methodology for monitoring the seismic performance, while taking into account the deteriorations revealed during GIS-based scenarios aiming at the identification of the seismic serviceability of the structure. By applying the geographical information system (GIS) containing geo-spatial data, one can develop useful scenarios to improve the knowledge of structural vulnerability of the urban built infrastructure. Scenarios of modelling, simulation and non-linear seismic analysis are described and applied to a class of damaged models for some of the structures typical of the existing urban infrastructure of Jassy, Romania. The management of GIS-based seismic vulnerability of existing concrete structure is presented as a tool for awareness and mitigation of seismic effects of possible future events in the urban area.

1. Introduction

Natural hazards, and especially earthquakes, are often recurring phenomena. Therefore, there is a permanent need for solutions to reduce earthquake losses by developing technologies, procedures, knowledge, and tools for seismic design and rehabilitation of buildings and infrastructure. A key point to an effective decision making process that aims at mitigating their effects is building a model of the underlying facts. A Geographical Information system (GIS) is a framework able to assemble, keep, process and display specific information, identified by geographical location, which can combine layers of information to give the user a better understanding about that location. By using a GIS containing geo-spatial data, one can develop useful scenarios to reduce natural disaster risk and vulnerability of structures. In this paper, we describe a way of applying data mining techniques from the artificial intelligence field to earthquake analysis in order to make a better investigation of the available data. These methods are capable of finding "hidden" correlations among different subsets of data, which cannot be revealed by means of simple statistics [4].

The whole process of digital management for the vulnerability of constructions in built urban environment is an integrated activity with multidisciplinary features.

involving civil engineers as well as architects, IT administrators, and the public administration sector. The strategic objective of this process addresses the following purposes [4]:

a) vulnerability assessment of existing infrastructure for planning the preventive measures of human safety against earthquake;

b) creating instruments for the emergency management of situations based on a possible seismic scenario;

c) education goals for enhancing the social culture in management crises during and post catastrophic events;

d) building of safety patterns to seismic hazard in various urban samples, which will lead to a digital city map for evaluation of seismic vulnerability.

2. Data Mining Techniques for Creating Seismic Risk Scenarios

Many times, in real databases some attributes (fields) are symbolic and others are numeric. To apply the ID3 [7] algorithm for building a *decision tree*, one needs to transform the numerical attributes into symbolic ones as a phase of preprocessing data.

Discretization transforms continuous attribute values into a finite number of intervals and associates a discrete value to each of them. This process usually has two steps. First, the number of discrete intervals is determined (often, the user specifies this number directly or provides a heuristic rule for finding it). The width or the borders of each interval must be computed, given the range of values for each continuous attribute being processed.

In literature there are many approaches regarding the discretization method. Equal width discretization divides the range of values into k intervals with equal width. Equal frequency discretization divides the sorted values of the attribute into k intervals such that each interval contains n/k adjacent (possibly duplicated) values. Both methods, although simple, can lead to important information loss. In our work, we used a more efficient discretization method, based on *unsupervized clustering* techniques [3].

Arranging objects into groups is a natural, necessary skill. There are many possible rules that we can use to assign objects to groups, *i.e.* to classify them. Cluster analysis is a rather loose collection of statistical methods that can be used to assign cases to groups (clusters). The members of a class will share some common properties, in order to maximize the intra-categorial similarity and to minimize the inter-categorial similarity. The classification also has the effect of reducing the dimension of data by reducing the number of instances being processed.

The *k-means* algorithm [5] is a well-known clustering tool. Suppose that we have n example feature vectors, $x_1, x_2, ..., x_n$, and we know that they belong to k clusters, $k < n$. Let m_i be the mean of the vectors in cluster i. If the clusters are well separated, we can use a minimum-distance classifier to separate them. That is, we can say that an item, x, is in cluster i if $\|x - m_i\|$ is the minimum of all the k

distances. The use of the Euclidian distance proved to yield good results in practice.

3. Applications

The previously described method was applied for the analysis of the maximum relative displacement of structures. The collected data are presented in Table 1 [1], [6].

Table 1
Earthquake Data Used for Analysis

Earthquake	H, [km] (focal depth)	PGA, [%g] (peak ground acceleration)	Maximum relative displacement, $\delta_{\max}$, of the structure, [cm]
Bucureşti 1977	109	0.1987	4.41
Focşani 1986	133	0.2934	3.08
Bucureşti 1990	89	0.1008	1.80
Bucureşti 1977	109	0.5551	12.32
Focşani 1986	133		5.83
Bucureşti 1990	89		9.92
Bucureşti 1977	109	0.9369	20.79
Focşani 1986	133		9.84
Bucureşti 1990	89		16.72
Bucureşti 1977	109	1.0729	23.87
Focşani 1986	133		11.27
Bucureşti 1990	89		19.14

The structural model, coresponding to a reinforced concrete structure, is described in [6]. The time history analyses have been performed using SAP200 software [8]. The results of the time history analyses for the types of loadings are listed in Table 1 in terms of maximum relative displacements.

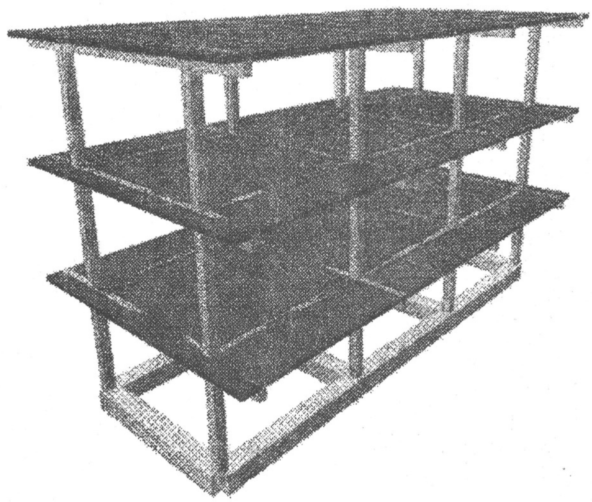

Fig. 1.– Structural model used for analysis.

As a case study, we considered the data for the structure in Table 1. The data with the numerical attributes is given as follows in ARFF (Attribute-Relation File Format), a common format used to describe data for machine learning algorithms.

```
@RELATION earthquakes

@ATTRIBUTE h REAL
@ATTRIBUTE pga REAL
@ATTRIBUTE displacement REAL

@DATA
109, 0.1987, 4.41
133, 0.2934, 3.08
89, 0.1008, 1.80
109, 0.5551, 12.32
133, 0.5551, 5.83
89, 0.5551, 9.92
109, 0.9369, 20.79
133, 0.9369, 9.84
89, 0.9369, 16.72
109, 1.0729, 23.87
133, 1.0729, 11.27
89, 1.0729, 19.14
```

First, numerical data are discretized. Because some attributes can have a greater importance than others, we chose three intervals for the H attribute and five intervals for the remaining ones, in order to ensure a better precision.

The pre-processed data are presented below:

```
@RELATION d-earthquakes

@ATTRIBUTE h {Low, Medium, High}
@ATTRIBUTE pga {VeryLow, Low, Medium, High, VeryHigh}
@ATTRIBUTE displacement {VeryLow, Low, Medium, High, VeryHigh}

@DATA
Medium, Low, VeryLow
High, Low, VeryLow
Low, VeryLow, VeryLow
Medium, Medium, Medium
High, Medium, VeryLow
Low, Medium, Low
Medium, High, High
High, High, Low
Low, High, High
Medium, VeryHigh, VeryHigh
High, VeryHigh, Medium
Low, VeryHigh, High
```

The induced decision tree is presented as follows:

```
pga=High
| h=High ⇒ displacement=Low
| h=Medium ⇒ displacement=High
| h=Low ⇒ displacement=High
pga=Low ⇒ displacement=VeryLow
pga=VeryHigh
| h=High ⇒ displacement=Medium
| h=Medium ⇒ displacement=VeryHigh
| h=Low ⇒ displacement=High
```

pga = Medium
| h = High ⇒ displacement = VeryLow
| h = Medium ⇒ displacement = Medium
| h = Low ⇒ displacement = Low
pga = VeryLow ⇒ displacement = VeryLow

By applying GIS technology, the results of the analysis can be displayed on the digital map of seismic vulnerability for the analysed structure.

4. Conclusions

The present paper highlights the concept of vulnerability assessment in an analytic manner for an existing infrastructure in big urban sites, exposed repeatedly to a various range of earthquakes and lack of continuous maintenance measures during life cycle serviceability of a building. The methodology of vulnerability assessment is illustrated on a representative pilot structure selected from the urban sample of existing damaged infrastructure. Using GIS technology, by generalization, the digital map of seismic vulnerability can be built, which is useful for the risk management of cities requested by various stakeholders at local and national level.

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CREAREA SCENARIILOR DE REDUCERE A RISCULUI SEISMIC UTILIZÂND SISTEME DE INFORMAŢII GRAFICE

(Rezumat)

Se prezintă metodologia de monitorizare a performanţei seismice structurale utilizând Sisteme de Informaţii Geografice (GIS) prin considerarea degradărilor structurale determinate de scenarii GIS capabile să identifice comportarea seismică a structurii. Aplicând metodologia GIS se pot dezvolta scenarii prin care să se îmbunătăţească nivelul informaţiilor cu privire la vulnerabilitatea structurală a zonelor urbane. Sunt descrise scenarii de modelare, simulare şi analiză neliniară aplicate unor modele de structuri degradate tipice fondului structural construit în zona Iaşi, România. Managementul vulnerabilităţii seismice, bazat pe tehnologia GIS a structurilor din beton armat existente, este prezentat ca mijloc de prevenire şi atenuare a efectelor seismice provocate de evenimente seismice viitoare în zonele urbane.