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Toward the systematic use of expert systems in seismic risk reduction

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ABSTRACT: Many operations related to the evaluation of seismic risk and to the definition of policies for its reduction may find suitable tools in the field of Intelligence Techniques . The present paper describes some works undertaken in such a direction, in four different application fields: 1) Emergency decisions about the usability of buildings after an earthquake (Expert System AMADEUS); 2) Vulnerability assessment of masonry and reinforced concrete; 3) Definition of a general environment for the survey, the control and the maintenance of monuments (in italian: CAtalogazione, RIlevazione, Sorveglianza e MAnutenzione of monuments = CA.RI.S.MA); software for the direct collection and management of data; definition of a priority scale for interventions on monuments under seismic risk (Expert System EXPRIM); 4) Global organization and management of the vulnerability data concerning the buildings of an historical center or village.

INTRODUCTION

The studies aimed to seismic risk reduction deal generally with a great amount of data: it is indeed necessary, in most cases, to consider in a first phase entire populations of buildings, possibly constituting districts, villages or towns; and the data are of any kind: numerical and graphical, related to materials and typologies; historical and artistical; related to human beings and their activities; and so on. One must first gather such data, then load them in suitable Data Bases, then elaborate them in order to define some indexes regarding the measure of seismic risk; after this, i.e. the assessment of risk, there will be the phase of risk reduction, to obtain through several kind of interventions: modifications in occupancy, strengthening of buildings, demolition and reconstruction of buildings, on the same spot or on a new one, application of artificial devices aimed to base isolation or energy dissipation. In order to obtain the best results it is very important to give a great attention to the studies at a global level, before starting with punctual design regarding the single object, and for such a purpose it is essential to have at disposal appropriate informatic tools as:

- well defined and structured Data Bases;
- friendly softwares for the systematic examination of data;
- suitable tools for the study of possible intervention designs and for the quick verification of their effects in terms of risk reduction;
- methodologies and criteria for assessing priorities.

It seems quite evident that most of the above mentioned tools might be built up as Expert Systems, within the so called KBE (Knowledge Based Engineering). But if the final goal may be conceived, to define the general environment and the implementation of the tools is not at all an easy problem.

Some initiatives have been taken till now by our research team, and in the present paper we will give an outline of the general approach we have in mind and present some results obtained.

Four sectors of interest have been considered, with the following characteristics and results:

- Assistance to non specialized engineers in the emergency condition assessment of buildings damaged by an earthquake: a specific KBS provides a detailed guide to the survey and the usability evaluation of buildings, to be used on the spot on a battery powered Lap Top.
- Vulnerability assessment of masonry and reinforced concrete buildings using forms or Expert Systems; quick evaluation of the lateral resistance of reinforced concrete buildings and study, with conversational technique on the computer (graphically supported), of the possible retrofitting designs.
- Preliminary definition of a general system/ environment for the survey (architectural and structural), the control and the maintenance of monuments (CA.RI.S.MA); definition of a methodology and a form for the seismic vulnerability survey at level I; in alternative to the form an informatic program enables the direct collection of data on the spot and their loading in the data base, another program enables the friendly consultation of the collected data and finally an Expert

System enables the seismic risk evaluation of the single monument on the basis of a simplified typological model.

- Global organization of the vulnerability data concerning the buildings of an historical center or village, in order to allow the global evaluation of the situation, in terms both of individual risk of the buildings and of urban risk as a whole, with the possibility to study and to evaluate quickly mitigation provisions.

The studies undertaken are far from being completed, but the approach seems to be promising; and a general principle comes out evident: the informatization of methods and tools in every sector of knowledge cannot be a matter of informatic specialists only, but it does involve the active partecipation of the experts in that very sector.

EMERGENCY DECISIONS ON BUILDINGS

The question has been the object of a previous paper of the author (Gavarini 1985), containing a proposal for a decisional process implemented via a suitable form. Successively the method has been implemented as an Expert System called "AMADEUS": **A**dvisory **M**ethodology for **A**ssessment of **D**amages after **E**arthquakes and **U**sability of **S**tructures, proposed by Pagnoni, Tazir and Gavarini (1989), written with the Shell Texas PC PLUS. The ES has been used recently in Sicily, after the earthquake of december 13, 1990, both on masonry buildings and on reinforced concrete buildings. The main features of the method/ES are (see fig. 01 and 02):

- consideration of a seismic scenario, related to the expected aftershocks;
- consideration of a geotechnical scenario, related to the ground properties and the damages;
- consideration of the structural damage and its relation to the seismic scenario;
- evaluation, requested from the operator, of the possible temporary provisions able to allow the immediate usability of the building;
- implementation of a Data Bank with the informations on all the visited buildings.

INSPECTION FORM FOR EMERGENCY DECISIONS ON BUILDINGS AFTER AN EARTHQUAKE

GENERAL DATE TEAM BUILD PROV
TOWN ADDRESS
OCCUPANCY BUILDING IMPORTANCE
AREA No APP OCC FREE No FAM PEOPLE
PREVIOUS EMERGENCY DECISIONS
SEISMIC SCENARIO
MAIN SHOCK AFTER SH BUILD POS
GEOTECHNICAL SCENARIO GROUND DAMAGE FOUNDAT.
GEOTECHNICAL RISK
STRUCTURAL VULNERABILITY AND DAMAGE
VERT HOR ROOF V LEV DAMAGE
STRUCTURAL RISK
NON STRUCTURAL DAMAGE EQUIPMENT
NON STRUCTURAL RISK PROVISIONS
INDUCED RISK PROVISIONS
EXTERNAL RISK ESCAPE
SUMMARY AND FINAL DECISIONS GLOBAL RISK
GEOT. RISK STRUCT. R COMPL. RISK IND. RISK
PROV. RISP REPORT COLOUR GREEN YELLOW ORANGE RED
DATA ON THE TEAM SIGNATURE

Fig. 01

DECISIONAL PROCESS

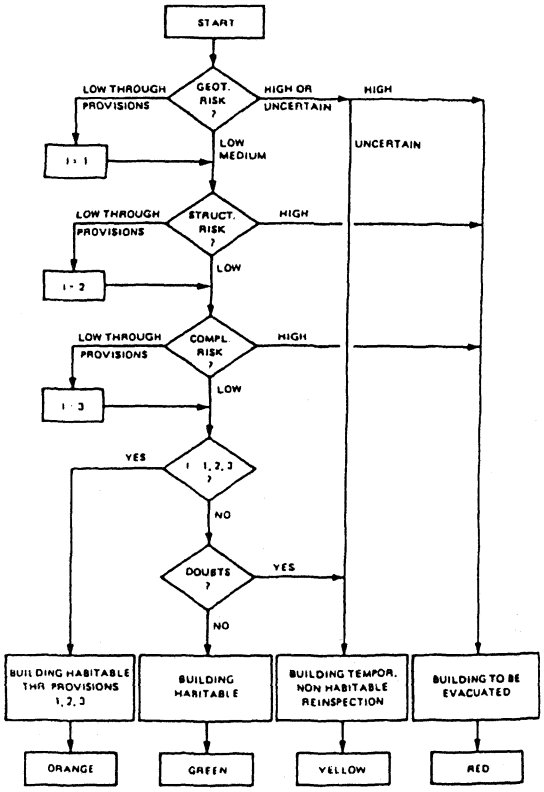

Fig. 02

SEISMIC VULNERABILITY ASSESSMENT

For vulnerability assessment a series of forms has been proposed by the National Group for the Earthquake Loss Reduction: for ordinary masonry buildings, for reinforced concrete buildings, for industrial buildings, for churches. Presently the first of such forms has been implemented as an ES for the direct collection of data on the spot, by Casciati and Faravelli (1989). As to the second form such an instrument isn't available for the present, but an efficient informatic tool has been prepared for the evaluation of data, a software which allows:

- to represent the reinforced concrete building in plan and 3D view, with emphasys on the structure;
- to calculate, via a code called PORTAM, the two ground accelerations corresponding, respectively, to the beginning of damage and to the collapse;
- a further possibility to offer to the operator is being prepared: the possibility to try some strengthening modifications to the structure (for example infilling walls) and to get immediately the results in terms of new limit accelerations.

The software PORTAM is based on the hypothesis of shear behaviour at any story; the methodology has been published in Italy (Gavarini and Paolone, 1991a, 1991b, Gavarini and Nisticò, 1991).

More details on this topic are given in a companion paper in this Conference (N. Nisticò - T. Pagnoni).

SEISMIC VULNERABILITY AND RISK OF MONUMENTAL BUILDINGS

When monuments are concerned many differences exist with respect to the problems of ordinary constructions: while for the common buildings, risk patterns expressed in terms of material quantities, as the volume, or the money, or the number of hours/persons/years of occupation are suitable, for the monuments the "value" is a quantity very hard to define, the architectural identity must be cared, the history must be kept in mind, often new occupancies, different from the original ones, must be found or accepted; and two other variables" must be taken into account: the degradation and the carelessness.

So a first instrument of work has been defined, consisting in a form for the first level survey of the seismic vulnerability of monumental buildings; such a form, together with other means, should be considered only as a part of a much larger series of tools and operations, precisely the general System CA.RI.S.MA mentionned in the introduction, a system which has the structure shown in fig. 03.

The first face of the form is presented in the following page (fig. 04); its main feature is represented by the section devoted to the "structural seismic history" of the monument: a collection of data which may allow, in the most favourable situations, to understand much more on the real seismic risk of the monumental construction than from analytical approaches. The following three faces of the form give information on the structural typology (also with the help of some drawings) and on the situation of decay. The gathered information can be subdivided in 12 classes:

- data for the identification of the monument and, if that is the case, of the part relevant to the form (in case it is necessary to have more forms) (1st face of the form);
- synthetic description (1st);
- present destination of use (1st);
- position in the environmental context (1st and a general planimetry);
- soil and foundations (1st);
- state of maintenance (1st);
- crowding (1st);
- structural seismic history (1st);
- geometric and material description (2nd, 3rd, 4th, plans and sections);
- presence of cracks (2nd, 3rd, 4th);
- decay (2nd, 3rd, 4th);
- interventions carried out (2nd, 3rd, 4th).

The compilation of the form is done according to the instructions of a handbook.

Besides the definition of the form, some informatic tools have been prepared for the implementation and the management of data: two softwares written with CLIPPER allow respectively to collect directly the data on the spot (CADISM), and to consult the data in a friendly manner (REDASM).

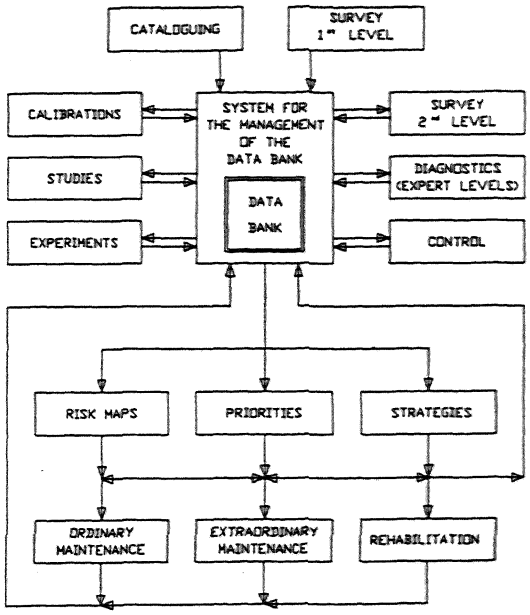

Fig. 03

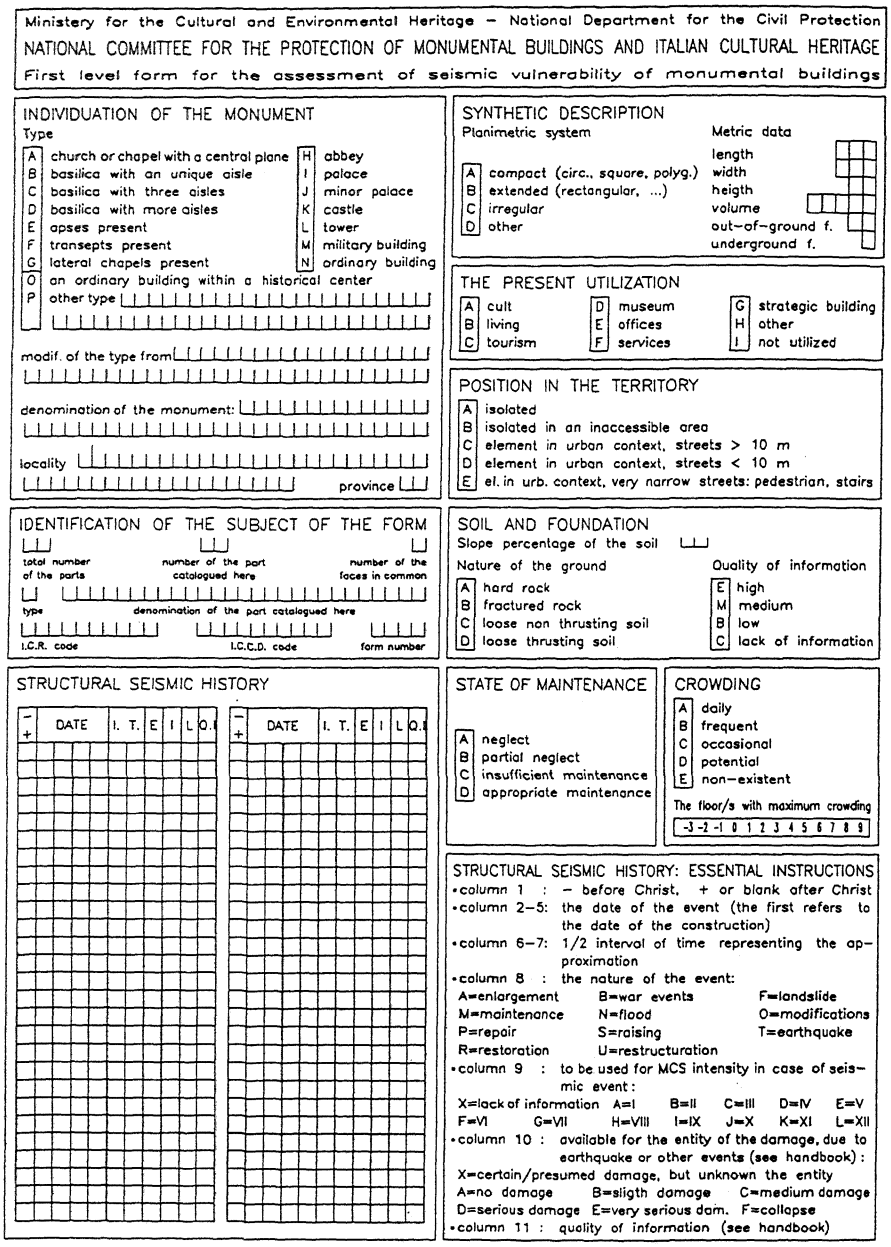

Fig. 04

An Expert System, written with NEXPERT OBJECT of the Neuron Data, allows to evaluate the priorities of intervention among a population of monuments (EXPRIM). The decision process implemented through EXPRIM is exposed in Gavarini-Padula (1992): it is based on the following main concepts:

- maximum importance given to the "structural seismic history";
- in the "most fortunate" cases such a history leads directly to the evaluation of the risk, graduated only in three levels: high, medium, low;
- in other cases the evaluation of the risk requires the previous assessment of the seismic vulnerability of the monument (also this latter on three levels);
- assessment of the above vulnerability by means of typological comparisons with other monuments included in the database;

- maximum attention to the decay and its development;
- distinct consideration of the risk regarding the people (RP) and of the risk regarding the conservation of the monument (RM);
- consideration of an external risk (RE), connected with the position of the monument in the environmental context;
- consideration of the "value" of the monument, again on three levels (high, medium, low), for the evaluation of the priorities;
- definition of the priorities by means of graduated classes (three: high, medium, low), by cross comparison of the data relevant to seismic risk, decay and value;
- continuous distinction, up to the final output (included), of the single factors that concur to the definition of the priorities, in order that the process leading to final decisions were always clear.

A Flow Chart illustrating the general logic of the model is reported in fig. 05.

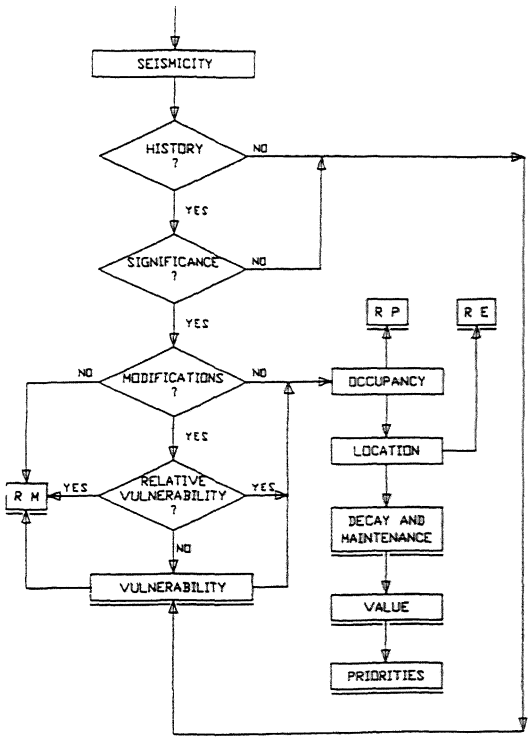

Fig. 05

URBAN RISK

When an urban center is considered, in particular an historical one with narrow streets, stairs, blind alleys, and with a cultural value to be recognized both to some individual buildings and to the area as a whole, the study of the risk considering single buildings and merely numerical indexes becomes a very poor approach. In such cases one must resort to global approaches which place all the information at disposal in the most friendly manner, and the results obtained through partial models have to be evaluated and compared synthetically, mostly on the basis of an interdisciplinary approach. It is thus evident that the creation of a suitable informatic environment may constitute an important help for the management of problems concerning the mitigation of risk in such centers. The main concepts to keep in mind during the building of such a tool should be the following ones:

- creation of a graphical environment, where the general aspect of the center and of single buildings is implemented;
- creation of a data bank with information on such aspects as:
- vulnerability data on buildings;
- historical data on buildings;
- occupancy and functional data on private and public buildings;
- data on ordinary and emergency foot-streams inside and out the center;
- data on the availability of areas for new building;
- .....
- definition and implementation of models for the evaluation of:
- the vulnerability and risk of single buildings;
- the results of retrofitting policies;
- the urban risk, related to panic effects in emergency conditions;
- the results of policies of improvment of the escape ways;
- .....

An activity toward such goals is presently in progress.

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