Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 58 (1989)

Artikel: Uncertainty treatment in a vulnerability-assistant expert-system

Autor: Casciati, Fabio / Faravelli, Lucia

DOI: https://doi.org/10.5169/seals-44898

Uncertainty Treatment in a Vulnerability-Assistant Expert-System

Traitement d'incertitudes dans les systèmes experts

Behandlung von Unsicherheiten in Expertensystemen

Fabio CASCIATI
Professor
University of Pavia
Pavia, Italy

Fabio Casciati, received his civil engineering degree in 1972 at the University of Pavia, where he became professor of Structural Mechanics in 1980. Co-author of two books and author (or co-author) of more than 100 scientific papers, his main research interests are in reliability and risk assessment and stochastic dynamics.

Lucia FARAVELLI
Associate Professor
University of Pavia
Pavia, Italy

Lucia Faravelli, received her mathematics degree in 1972 at the University of Pavia, where she became associate professor of Structural Safety in 1983. Author (or co-author) of two books and more than 80 scientific papers, her main research interests are in structural safety, seismic engineering and stochastic FEM.

SUMMARY
This paper illustrates the «Vulnerability Assistant» Expert System prepared for the study of existing masonry buildings in the framework of the GNDT (Italian National Group of Seismic Mitigation) activity. Its extension to reinforced concrete buildings and historical churches is also discussed. Finally the paper emphasized the inadequacy of the present commercial «shells» in dealing with uncertainty and shows how this can be obviated by building additional rules into the decisional process.

RESUME
Cet article concerne le système expert «Vulnerability Assistant» développé pour l'ètude de la vulnérabilité des bâtiments en briques, sous le patronage du GNDT (le Groupe National Italien pour la Prévention Sismique). L'extension à des bâtiments, en béton armé et aux églises classées monuments historiques est discutée. Les difficultés à étudier les aspects aléatoires du probleme sont examinées.

ZUSAMMENFASSUNG
Der Artikel beschreibt das Expertensystem «Vulnerability Assistant» zur Ermittlung der Erdbebengefährdung von Mauerwerkgebäuden der italienischen nationalen Gruppe für Erdbebenwesen (GNDT). Die Ausdehnung auf Stahlbetongebäude und historische Kirchen wird ebenfalls besprochen. Abschliessend werden die Mängel bestehender kommerzieller «Shells» zur Behandlung von Unsicherheiten erläutert und es wird gezeigt, wie diese durch den Einbau zusätzlicher Bedingungen in den Entscheidungsprozess behoben werden können.

1. INTRODUCTION

Existing structures come out to be the main object of safety evaluations during the Eighties. A valuable review of the early literature published on this topic in the United States can be found in Ref. [1]. Several investigations were also conducted in Europe, where, however, each single country focused attention on different kinds of buildings and, for them, established its own approach to the problem [2][3][4]. Old villages and monumental areas were and are the main object of the studies developed in Italy. Nuclear power plant facilities are deeply studied in Germany while North Sea Countries are investing many research resources in the analysis of offshore platforms. A synthetic review of problems and approaches is provided in the book quoted as Ref. [5]. This book, however, is mainly devoted to structural vulnerability assessment. By combining this aspect with site hazard and structural exposure the inherent risk can be evaluated.

As J.Yao state in the preface to his book [1], "much of the decision-making process has depended on each engineer's experience, intuition and judgement... To help understand how experts summarize and interpret results of measurements, inspection and analyses in reaching their decision concerning structural safety, the application of rule-inference methods" must be "reviewed and discussed". The strict connection with the Artificial Intelligence (AI) world became evident soon. Books as the one by Rich [6], among others, opended, to scientists operating outside Computer Sciences departments, the progresses in knowledge representation and in advanced problem - solving systems.

Several research groups of civil engineers became immediately active on this topic. The reader is referred to the special book edited by M.L.Maher [7] for a non specialistic introduction to the basic concepts of expert system theory and, mainly, for a systematization of their use in civil engineering. In particular expert system applications are categorized into five different fields:

- applications in Structural Engineering (reviewed by M.L.Maher in Ref. [7]);
- applications in Geothechnical Engineering (reviewed by T.J.Siller in Ref. [7]);
- applications in Construction (reviewed by R.E.Levitt in Ref. [7]);
- applications in Environmental Engineering (reviewed by L.A.Rossman and T.J.Siller in Ref. [7]);
- applications in Transportation Engineering (reviewed by S.G.Ritchie and R.A.Harris in Ref.[7]);

Of course, safety evaluations of existing structures belong to the first group, where at least five further classes can be distinguished;

- applications to materials (welding and weld defect advisors);
- applications in code checking
- applications to structural design
- applications to diagnosis
- applications to analysis problems, as the safety analysis of existing structures this paper is considering.

The experience of the authors is limited to problems of analysis and, in particular, of seismic risk analysis. They were in Stanford in the pioneering period, and started "to play" with expert systems shells as "DECIDING FACTOR" [8] or "INSIGHT" [9] in a context where the different aspects of ground motion, structural vulnerability and social impact of potential damage were simultaneously considered [10]. After that the Stanford's research group oriented itself to problems wider and wider by building the expert system IRAS

[11]. It includes not only earth science, seismology, geology and structural engineering, but also risk management, planning, insurance/ banking profession and facility management. By contrast, the authors concentrated their attention on the narrower field of seismic vulnerability [12][13][14]. The National Center for Earthquake Engineering Research (NCEER) is presently pursuing the same objective in the US [15][16].

2. A VULNERABILITY ASSISTANT FOR DATA COLLECTION

2.1. The masonry vulnerability form

Benedetti and Petrini [2] proposed, a method of classifying masonry buildings in Italian seismic areas, which makes use of a numerical value, called the "vulnerability index". It represents the seismic quality of each building and is obtained as a weighted sum of some numerical values expressing the seismic quality of structural and non-structural elements. The items with which numerical values must be associated were reduced to eleven as summarized in the form of figure 1 ("Level 2 Vulnerability Form"). The elements can be either of descriptive nature or of evaluative nature. The first group is formed by the "resistant system quality" (item 2 in figure 1), the morphological "configurations" (item 6 and 7 in figure 1), the structural typology (items 5 and 9 in figure 1) and the status descriptions (items 10 and 11 in figure 1). "Building quality" (item 1 in figure 1), "conventional resistance" (i.e. item 3 in figure 1: "the total shear strength" is estimated by the approximate formula at the top of the right column of figure 1), "building site" (item 4 in figure 1) and "interwall distance" (item 8 in figure 1) are the components of the second group.

Appropriate field investigations must be planned for evaluating all these elements. The operators must follow detailed rules and instructions [17] prepared in order to minimize the discrepancies among surveyors. For this purpose, the operator must provide answers to some questions which are regarded as "evaluation elements" (second column from right in figure 1). The answers are then combined to assign the item under discussion to a class. Class A indicates situations that are in agreement with the prescriptions of the Italian seismic code. Class D characterizes the unsafe configurations.
Each answer is accompanied by the degree of confidence on it. The operator can select among four different classes of quality of the information: E (high quality), M (average), B(low quality) and A (operator's guess).

Four lines of development, from this background, were identified in the context of GNDT (the Italian National Group of Seismic Mitigation):

1) to automatize the operations of data collection by building a software capable of running on portable ("lap-top") personal computers;

2) to extend the expertise and, hence, the AI approach to other classes of buildings;

3) to improve the way by which uncertainty is treated in the vulnerability assessment process;

4) to improve the vulnerability form by gathering together a greater quantity of elements and by exploiting the computational capabilities of portable personal computers. For instance, the data necessary for a parameter identification process can be collected. The values of the parameters are then evaluated and an analytical model is builts on them. The decision making process can eventually include the indications of the model [13].

G.N.D.T. - SCHEDA DI VULNERABILITÀ DI 2° LIVELLO (MURATURA)

Codice ISTAT Provincia [1] ☐☐☐ Codice ISTAT Comune [3] ☐☐☐☐ Scheda No. [6] ☐☐☐☐☐☐

	PARAMETRI	Classi	Qual. Inf.	ELEMENTI DI VALUTAZIONE
1	TIPO ED ORGANIZZAZIONE DEL SISTEMA RESISTENTE (S.R.)	11	22	[33] Norm. nuove costruz. (cl. A) 1 Norm. riparazioni (cl. A) 2 Cord. e cat. tutti livelli (cl. B) 3 Buoni amm. fra mur. (cl. C) 4 Senza cord. cattivi amm. (cl. D) 5
2	QUALITÀ DEL S.R.	12	23	(vedi manuale) [34]
3	RESISTENZA CONVENZIONALE	13	24	[35] Numero di piani N [37] Area tot. cop. A_t (mq) [41] Area A_x (mq) [44] Area A_y (mq) [47] τ_k (t/mq) [50] Alt. media interp. h (m) [52] Peso spec. par. p_m (t/mc) [54] Carico perm. sol. p_s (t/mq)
4	POSIZIONE EDIFICIO E FONDAZIONI	14	25	[56] Pend. perc. terr. [58] Roccia fond. si 1 no 2 Terr. sc. non sp. fond. si 3 no 4 Terr. sc. sp. fond. si 5 no 6 [59] Diff. max di quota Δh (m)
5	ORIZZONTAMENTI	15	26	[62] Piani sfalsati si 1 no 2 [63] Orizz. rig. e ben coll. 1 Orizz. def. e ben coll. 2 Orizz. rig. e mal coll. 3 Orizz. def. e mal coll. 4 [64] % or. rig. ben coll.
6	CONFIGURAZIONE PLANIMETRICA	16	27	[66] Rapp. perc. β_1 = a/l [70] Rapp. perc. β_2 = b/l
7	CONFIGURAZIONE IN ELEVAZIONE	17	28	[74] % aumento (+) / riduz. (−) di massa [77] Rapp. perc. T/H [79] Perc. in sup. port. [81] Piano terra port. si 1 no 2
M8	D_{max} MURATURE	18	29	[82] Rapp. massimo l/s
M9	COPERTURA	19	30	[84] Cop. non sp. ∅ poco sp 1 sp 2 [85] Cord. in copert. si 1 no 2 [86] Cat. in copert. si 1 no 2 [87] Car. perm. cop. p_c (t/mq) [90] Lungh. app. cop. l_c (m) [93] Perim. cop. l (m)
10	EL. NON STRUTT.	20	31	(vedi manuale)
11	STATO DI FATTO	21	32	(vedi manuale)

SCHEMI - RICHIAMI (MURATURA)

Parametro 3. Resistenza convenzionale.

Tipologia struttura verticale	τ_k (t/mq)
______	______
______	______
______	______
______	______

Minimo fra A_x e A_y A (mq) ______

Massimo fra A_x e A_y B (mq) ______

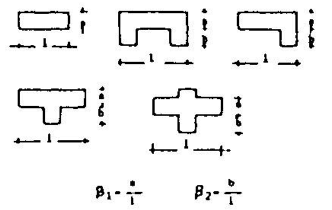
Coeff. a_o = A/At ______ Coeff. γ = B/A ______

$q = (A_x + A_y)\, h.\, p_m/At + p_s$ ______

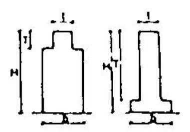
$$C = \frac{a_o \cdot \tau_k}{q \cdot N} \cdot \sqrt{1 + \frac{q \cdot N}{1.5 \cdot a_o \cdot \tau_k \cdot (1+\gamma)}}$$ ______

$\alpha = C/0.4$ ______

Parametro 6. Configurazione planimetrica.



Parametro 7. Configurazione in elevazione.



Parametro M9. Copertura.

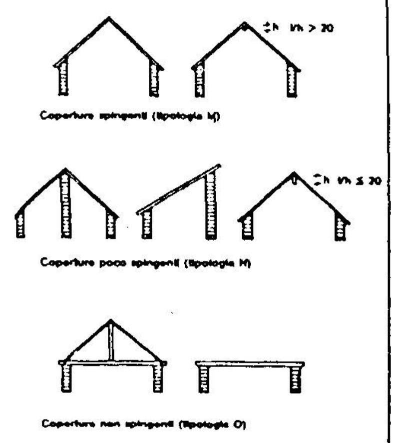


Figure 1

codice ISTAT Provincia 1[ ][ ] codice ISTAT Comune 3[ ][ ][ ] scheda n° 6[ ][ ][ ][ ][ ] n° schede P 11[ ][ ] n° schede V 13[ ][ ]

1 — TIPO ED ORGANIZZAZIONE DEL SISTEMA RESISTENTE

ELEMENTI STRUTTURALI PRESENTI 15[ ]16[ ][ ][ ]
1) pareti e/o nuclei c.a.
2) telai in due direzioni
3) telai assenti o carenti in una direzione
4) telai assenti o carenti in due direzioni
5) presenza tamponature tipo A
6) presenza tamponature tipo B
[indicare uno, al piu' tre elementi]

DISEGNI STRUTTURALI DISPONIBILI 19[ ]20[si][no]
REGIME L. 02/02/74 n° 64 21[ ]22[si][no]
GIUNTI STRUTTURALI NON SISMICI 23[ ]24[si][no]
PRESENZA PIANO FLESSIBILE 25[ ]26[si][no]
ANNO DI COSTRUZIONE 27[ ]28[ ][ ][ ][ ]

2 — TECNOLOGIA DEL SISTEMA RESISTENTE

SISTEMA RESISTENTE 32[ ]33[ ]
1) gettato in opera a travi e pilastri
2) gettato in opera a setti e/o casseforme tunnel
3) prefabbricato a pannelli portanti
4) prefabbricato a travi e pilastri

3 — POSIZIONE EDIFICIO E FONDAZIONI

TIPO DI TERRENO 34[ ]35[ ]
1) roccia
2) compatto
3) sciolto

PENDENZA PERCENTUALE TERRENO 36[ ]37[ ][ ]

TIPO DI FONDAZIONI 39[ ]40[ ]
1) fondazioni profonde
2) plinti isolati
3) plinti collegati
4) travi rovesce
5) platea

FONDAZIONI A QUOTE DIVERSE 41[ ]42[si][no]

4 — ORIZZONTAMENTI | **5 — STRUTTURE VERTICALI**

	43	44	48	49	51	53	56
24	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
23	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
22	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
21	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
20	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
19	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
18	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
17	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
16	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
15	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
14	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
13	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
12	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
11	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
10	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
9	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
8	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
7	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
6	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
5	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
4	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
3	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
2	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
1	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
0	[ ]	[ ][ ][ ][ ]	[ ]	[ ][ ]	[ ][ ]	[ ][ ][ ]	[ ]
L	+/-	Quota	P	L_I	L_s	M	V

7 — QUALITA' DI MATERIALI ED ESECUZIONE

QUALITA' 67[ ]68[ ]
1) buona
2) media
3) cattiva

8 — STATO DI FATTO

FONDAZIONI
presenza di cedimenti di fondaz. 69[ ]70[si][no]
lesioni nelle strutture in c.a. del cantinato 71[ ]72[si][no]

TAMPONATURE E TRAMEZZI
lesioni diagonali 73[ ]74[si][no]
lesioni orizzontali 75[ ]76[si][no]
lesioni verticali 77[ ]78[si][no]
lesioni su tamponature aggetti 79[ ]80[si][no]
distacco rivestimento per schiacciamento tramezzi 81[ ]82[si][no]
malte degradate 83[ ]84[si][no]

NODI TRAVE-PILASTRO
presenza segni di danneggiamento 85[ ]86[si][no]

ORIZZONTAMENTI
sensibili frecce nei solai 87[ ]88[si][no]
lesioni nei pavimenti 89[ ]90[si][no]

STRUTTURE IN VISTA
rottura spigoli balconi 91[ ]92[si][no]
rottura spigoli gronde 93[ ]94[si][no]
rottura spigoli pilastri 95[ ]96[si][no]
scollegamento parapetti 97[ ]98[si][no]
fessurazione parapetti c.a. 99[ ]100[si][no]
armatura travi in vista 101[ ]102[si][no]

6 — COPERTURA

TIPO DI COPERTURA 57[ ]58[ ]
1) piana
2) portante a falde inclinate
3) non portante a falde inclinate

ALTEZZA MINIMA 59[ ]60[ ][ ][ ]
ALTEZZA MASSIMA 63[ ]64[ ][ ][ ]

Figure 2

Figure 1 - Form for the level - 2 vulnerability assessment of masonry buildings, from Ref. [2]. For sake of clearness, the eleven items can be summarized as follows:
1) builiding quality; 2) resistant system quality; 3) conventional resistance; 4) building site; 5) horizontal element features; 6) plan configuration; 7) vertical configuration; 8) interwall distance; 9) roof type; 10) nonstructural elements; 11) actual state (maintenance conditions).

Figure 2 - Main form for the level - 2 vulnerability assessment of reinforced concrete building, from Ref. [17]. For sake of clearness, the eight items on it can be summarized as follows:
1) building quality; 2) resistant system technology; 3) building site; 4) horizontal element features; 5) vertical configuration; 6) roof type; 7) material and construction quality; 8) actual state (maintenance conditions).

2.2. A "Vulnerability Assistant" expert system

The short presentation of Sub-Section 2.1 shows that the data collection cannot be automatized by algorithmic computer codes since they are unable to account for the descriptive (qualitative) elements. Non-algorithmic (linguistic) procedures (expert systems) are therefore required in order to implement a "Level 2 Vulnerability Assistant" software. On the other hand the presence of algorithmic steps (see the approximate formula of item 3 in figure 1) makes unsatisfactory the first generation of expert systems. They, in fact, were not able to alternate qualitative and quantitative steps (see [12] and [18] among others).
A particular shell of the second generation running also over (portable) personal computers is the INSIGHT 2+ [9]. It was used by Faravelli [19] for building her "Masonry Vulnerability Assistant" prototype of expert system.

A consultation can be described as follows:
- the operator is asked to select the item to be considered in the form of figure 1;
- the operator is then required to provide the evaluation elements specified in the second column of the form for the row (item) he selected. The process stops when the inference process reaches a conclusion (i.e. provides the class (A, B, C or D) to which the building under investigation belongs;
- some questions require an illustration is dispayed. This is obtained by the "explain" help facility, which can be activated for the following items: plan configuration, vertical configuration and roof type (see the third column in figure 1);
- to estabilish the conventional resistance means to collect the data listed at the top of the third column in figure 1. These data are then automatically combined in the formula there specified, whose result leads to the aimed classification;
- when all the items have been considered, the appropriate numerical values are associated with each of them, as well as the corresponding weights, and the numerical estimate of the vulnerability index is found.

The resulting number will represent that building in successive statistical studies, cost-benefit analyses of retrofitting and so on.

3. EXTENSION TO DIFFERENT TYPOLOGIES OF BUILDINGS

3.1 Reinforced concrete buildings

The expertise on reinforced concrete buildings led to propose the form of figure 2. It should be completed by two additional groups of sheets. The first set concerns the configuration plan and the second the vertical structures. The square brackets are reserved to a specification of the quality of the information (again by one of the four letters E, M, B, A).

There is one main difference between the forms in figure 1 and 2. The form of figure 1 aims to collect data in order to select an answer among 4 classes (A, B, C and D). The form of figure 2 only aims to collect data, the conclusion being delayed to a successive stage. The translation of this second form in a data-collection expert-system is therefore simplified since the inference part can be missed. However, the consultation becomes much more tedious, since all the questions must be answered. There are not branches for which the investigation is shortened as it occurs for the form of figure 1 when a conclusion (the assignement to a class) is reached.

Nevertheless, the expert system will have in this case, an additional task. The check of conflicts between answers, in fact, will give the analyser a complete confidence in the data he is collecting.

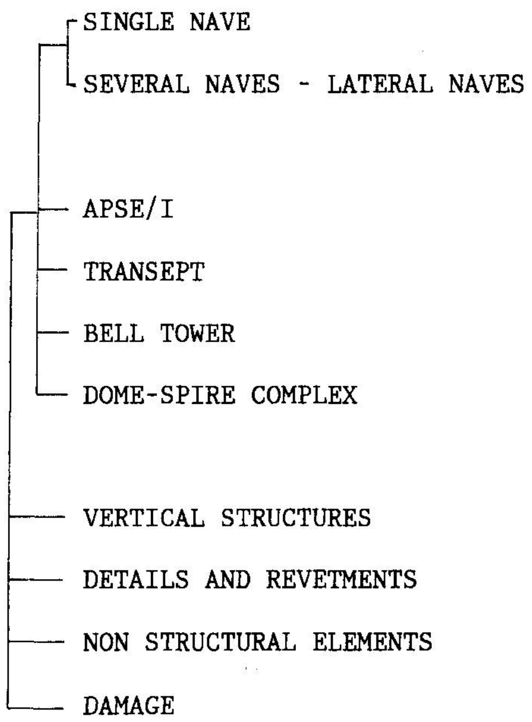


Figure 3 - The set of forms, and their links, to be filled for a "Vulnerability and Damage Assessment" of churches [21].

3.2. Churches

After the earthquakes of 1976 in Friuli and 1980 in Southern Italy, several resources were invested, in Italy, in the assessment of the vulnerability of the churches. The expertise was converted into a set of forms; rather than a single form, due to the non uniform and composite nature of this kind of buildings (see figure 3).

The main form requires elements of the map configuration, a defintion of the building site and a list of structural components which form the church (naves, apse, transept ...). Each of these components, then, is the object of a separate form. A graphical illustration is also required.
As for reinforced concrete buildings, the form aims to collect data rather than to assess church vulnerability. However, three main differences must be emphasized:

1) the answers are not all of Boolean nature (either 0 or 1) but often one has to identify the most appropriate among several classes proposed. For instance, the dome structure can be in wood (class 1), in steel (class 2) in masonry or stones (class 3) or other material (class 4): an expert system approach to such a form of data collection comes out to be very convenient;
2) the interaction between qualitative/quantitative descritptions and graphical illustrations leads to extend the capacities of the expert system to offer also drawing and sketching options;
3) the specification of the quality of information is missed in order to simplify a form already complex. The adoption of an expert system policy would obviate this inconvenience without additional efforts for the operator.

4. UNCERTAINTY TREATMENT

The expert system prototype which was presented in [19] provides the resulting classification (first column from the left in figure 1) for the item under investigation. It also gives the quality of the information (second column) which led to this classification. This quality is expressed by the resulting confidence measure. A number in the range (0,100) substitutes therefore the naive concept codified in [17] of four different degrees of confidence (E, M, B and A).

This "confidence measure" is a weak point of commercial shells, as INSIGHT2+ is. The reason is that the confidence calculations are driven directly by the inference engine. In other words the expert who builds the knowledge base is unable to interact with the uncertainty treatment. For instance, a conclusion is reached when the confidence on it is greater than a value fixed by the expert, but no mention is made on the likelihood of alternative events which can significantly influence the deductive process.

Unsatisfactory conclusions are prevented by building inside the knowledge base a logic treatment of uncertainty. This is made by additional rules which condition the inference engine process. The expert system prototype proposed in [19] should therefore be modified to provide, for each item, the probability of belonging to class A, B, C or D. Probability has not any frequentist meaning, but is only a degree of belief. At the end of the consultation, the probability mass function of the vulnerability index and some central measures can be computed.

In view of the extensions discussed in Section 3, there is not reason of combining the degrees of confidence the operator assigns to each answer. The forms relevant to reinforced concrete buildings and churches, in fact, are tools of data collection rather than deductive systems. However, since the expertise is still in evolution, the basic problem here is to select, among the possible uncertainty measures, the one which better represents the deductive chain of that field. A fascinating approach, for instance, interacts with the operator by using Bayesian concepts in the attempt of reaching, during the consultation, the best quality of information. Developments in this direction are presently in progress.

5. CONCLUSIONS

This paper illustrates the expert system prototype built in order to facilitate the seismic vulnerability of existing building according to Italian expertise. Unfortunately, the way of treating the uncertainty of commercial second generation shells is still elementary. This inconvenience can be obviated by building a more sophisticated scheme of uncertainty treatment by means of additional rules without shell modifications. However, this does not exclude that the production of an "ad hoc" shell, even elementary in its inference process, may result more efficient in view of the seismic prevention of existing buildings. This possibility should be carefully checked before the policy of dealing with uncertainty is selected among the ones compatible with the expert system shell in use.

ACKNOWLEDGEMENT

This paper is part of a reasearch funded by the National Group of Seismic Mitigation (GNDT) of the Italian Research Council (CNR). It is coordinated by prof. A. Corsanego, as chairman of the national research group on Vulnerability.

REFERENCES

1. YAO J.T.P., Safety and Reliability of Existing Structures, Pitman Publishing Ltd, 1985

2. BENEDETTI D., PETRINI V., Sulla Vulnerabilita' Sismica di Edifici in Muratura: Proposta di un Metodo di Valutazione. (In Italian), Industria Costruzioni, Vol. 18, 1984

3. KAFKA P., The Chernobyl Accident: a Challenge of PSA as the Tool for the Predicition of Event Scenarios Beyond the Design Basis and for Safety Improvements?, Trans. of 9th SMiRT (Int. Conf. on Structural Mechanics in Reactor Technology), 1987, Vol.M, 3-10

4. VROUWENVELDER A., JCSS Probabilistic Model Code. Assessment of Existing structures, Report BI-88-010, IBBC, TNO, Delft, 1988

5. CASCIATI F., FARAVELLI L., Fragility Analysis of Complex Structural Systems, Reseach Studies Press, 1989

6. RICH E., Artificial Intelligence, Mc Graw Hill, 1986

7. MAHER M.L. (Ed.), Expert Systems for Civil Engineers: Technology and Application, American Society of Civil Engineering, ASCE 1987

8. CAMPBELL A., FITZGERAL S., The Deciding Factor, User's Manual, Software Publishing Company, 1985

9. INSIGHT, Knowledge System, Level Five Research, Merbourne Beach, Florida, 1985

10. MIYASATO G., DONG W.M., LEVITT R.E., BOISSONADE A.C., SHAH H.C., Seismic Risk Analysis System, Proc. Symp. "Expert Systems in Civil Engineering", Seattle, 1986, 121-132

11. DONG W., WONG F., CHIANG W., KIM J.U., SHAH H.C., An Integrated System for Seismic Vulnerability and Risk for Engineering Facilities, in Nelson, J.K., (ed.) Computer Utilization in Structural Engineering ASCE, 1989, 408-417

12. CASCIATI, F., FARAVELLI, L., L'Impiego di Sistemi Esperti in Ingegneria Sismica. (In Italian), Proc. 3rd Conf. "L'Ingegneria Sismica in Italia", Roma, 1987, pp.199-210.

13. CASCIATI, F., FARAVELLI, L., Individuazione di Problemi di Meccanica dei Solidi Suscettibili di Inquadramento in Sistemi Esperti. (In Italian). Proc. 9th Nat. Conf. AIMETA, Bari, 1988, pp. 553-556.

14. CASCIATI, F., FARAVELLI, L., Seismic Vulnerability via Knowledge Based Expert Systems, in Brebbia C.A. (ed.) Structural Repair and Maintenance of Historical Buildings, Comutational Mechanics Publ., Southampton, 1989, 299-307

15. FENVES, S.J., IBARRA-ARRAYA, E., BIELAK, J., THEWALT, CH., A Knowledge Based System for Evaluating the Seismic Resistance of Existing Building, in Nelson J.K.(ed.), Computer Utilization in Structural Engineering, 1989, 428-437

16. SUBRAMANI, M., ZAGHW, A., CONLEY, C.H., A KBES for Seismic Design of Buildings, in Nelson J.K.(ed.) Computer Utilization in Structural Engineering, 1989, 342-351

17. GNDT - CNR. Istruzioni per la Compilazione della Scheda di Rilevamento Esposizione e Vulnerabilita' Sismica degli Edifici. (In Italian), September 1986

18. GAVARINI, C., PAGNONI, T., Amadeus. Un Sistema Esperto per la Valutazione d'Urgenza dell'Agibilita' degli Edifici dopo il Terremoto. (In Italian), Dept. of Structural Eng. and Geotech., Univ. "La Sapienza", Roma, 1988

19. FARAVELLI, L., Expert System for Fragility Assessment of Monumental Sites, Int. Symp. on Earthquake Countermeasures, Beijing, 1988, pp. 199-210

20. GAVARINI, C., SAMPAOLESI. L., Rilevamento della vulnerabilita' sismica degli edifici in cemento armato tramite schede (in Italian), unpublished CNR-GNDT document 1989

21. DOGLIONI, F., ANGELETTI, P., BELLINA, A., MORETTI, A., PETRINI, V., Istruzioni per la compilazione della scheda di rilevamento "Vulnerabilita' e Danno delle Chiese", unpublished CNR-GNDT document, 1989