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TOWARDS A COMPLEX APPROACH TO PRESERVATION AND SEISMIC PROTECTION OF MONUMENTS

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ABSTRACT

Problems connected to preservation and seismic protection of historical buildings and monuments evidentiate the fundamental need of both preserving architectonic and cultural values and ensuring structural safety against external actions. The rigidity and inadequacy of most of the existing codes, generally conceived with reference to recent constructions, seem sometimes to frustrate the reconciliation of these two often conflicting goals, not to mention the fact that normative prescriptions are frequently uncritically applied by inexperienced operators who do not possess the appropriate scientific and cultural background.

Scope of this report is to suggest a systematic approach to the management of the complexity of such problematic issues starting from a multidisciplinary conceptual framework, in order to take the manifold aspects related to the set of processes leading to the knowledge, maintenance and proper utilization of historical buildings into account.

KEYWORDS

Complexity; historical buildings; information systems; monuments; multidisciplinarity; uncertainty.

INTRODUCTION

Questions relevant to the definition and selection of correct strategies of intervention on the cultural heritage, be it constituted of single monuments or groups of buildings forming a historic town, dramatically underline the conflict between the exigencies of conservation and restoration, on the one hand, and safety against external actions, seismic events in particular, on the other hand. Design and realization of the interventions should actually be characterized by concurring specialistic and multidisciplinary contributions, which ought to allow to take decisions so as the safeguard of historical, cultural and architectonic values is ensured in conjunction with the protection of both the construction itself and human lives potentially involved from structural instability. Functionality and usability requirements, as equipments housing, possibility of access by disabled people, and so on, should also be fulfilled.

However present day difficulties in outlining methodologically sound conservation and strengthening procedures leading to reliable solutions have resulted in the circumstance that many interventions, in an

attempt to reduce an effective or supposed proneness to structural damage, alter the nature of the architectural configuration. The historic integrity of the building is hence threatened, protective purposes though being sought. As a matter of fact even safety prerequisites are often left unsatisfied, as it may happen that neglecting or ignoring the effects of dynamic loads on reinforcing structural elements coupled with traditional construction materials repeatedly exposes the building to further damage.

Such a controversial scenario is to be ascribed to a twofold order of reasons. First of all it should be recognized that research into the behavior of traditional structures and materials has up to recent years been disregarded. Designers are therefore induced to make use of those computational tools they are more familiar with, even though developed almost exclusively with reference to current construction procedures, and to adopt materials and solutions which introduce traumatic modifications, thus leading to an unrepairable loss of the original identity of the historic fabric.

It should also be remarked that what presses operators to resort to standard calculation methods and design schemes, in a scarce awareness of valid alternatives, is the actual rigidity of building codes, together with an unnecessarily strict interpretation and uncritical application of regulations themselves. The prescribed formal numerical verifications are consequently achieved according to a *modus operandi* that seem incompatible with the goal of conservation of the architectural heritage.

THE MANAGEMENT OF PROBLEM COMPLEXITY

Questions related to monumental and historic fabrics preservation and seismic protection then represent a vast field of investigation. It cannot be faced fruitfully but through a multidisciplinary approach, so as to enable an effective control over the whole series of activities associated to the knowledge of the cultural heritage, to the design and realization of the interventions, to the correct utilization and maintenance of the buildings themselves, thus setting the basis of a complex management of the varieties, uncertainties and singularities of real world situations.

Problem complexity becomes manifest as the large amount of information required in order to characterize and solve such a multifaceted task is taken into consideration, together with the different forms of uncertainty it is necessary to cope with, and the consequent difficulties in constructing quantitative exhaustive representations of the events under examination. The considerable obstacles operators have to overcome in trying to express comprehensive evaluations taking both aesthetic artistic values and historic significance into account, not disregarding structural stability aspects, reflect the way issues of complexity arise when approaching the management of the monumental heritage.

Resorting to the attention of the various competencies exclusively under the professional profile of each of them in the analysis of complex questions does not open any perspective to the protection of an heritage, which on the contrary seems to be lacking the most qualified specific contributions from each disciplinary field. It is therefore indispensable that operators from each domain lend the necessary care to the demands and values of the counterparts, which implies sufficient understanding, if not a diffuse knowledge, of the totality of problems posed by the safeguard exigencies. Indeed it is neither methodologically nor operationally meaningful to treat complexity as an intrinsic property of monumental or architectural features; instead complexity necessarily is to be viewed as related with the way in which a multiplicity of observers interact with these objects (Morin, 1983).

Focusing on a multidimensional thought should therefore be seen as a primary goal, in the awareness of the fact that different disciplinary specialized categories represent a variety of aspects of the same reality, which must be kept distinguished but, at the same time, allowed to communicate and interact. Similar task requests the design of a model which characterize the problem of concern giving account of its complexity, reproducing the multiplicity of points of view and allowing to circulate productively from one point of view to a different one.

The defined model should also appropriately convey forms of heuristic knowledge and subjective aspects in addition to objective quantitative data, also providing an adequate representation of uncertainty. The need for the merging of complementary methodologies and the requirement to integrate theoretical knowledge and practical experience should hence be fulfilled in order to obtain significant benefits in complex systems modeling and interpretation. Identification of the model unavoidably involves simplifying complexity, by making a satisfactory trade-off between the available information and the amount of uncertainty to be allowed (Le Moigne, 1985).

Accordingly it should be noted that problem complexity hardly gives way to axiomatic characterizations nor can easily be codified by means of rigid criteria. Excessive schematizations tending to eliminate what is not immediately referable to those categories from time to time assumed as privileged should anyway be avoided. The previously mentioned trend to an unnecessarily strict interpretation of technical codes constitutes an instance of unsuccessful attempt to rationalization of a complex reasoning task. Regulations for seismic protection of valuable historic constructions should actually outline principles and recommendations rather than a set of prescriptions, retaining enough flexibility in the realization of the interventions while preserving the identity of the monument. Such concepts are contained in recent documents (Ballardini and Gavarini, 1989; Gavarini and Giuffrè, 1991; Recommendations - Skopje '88, 1988; State Historical Building Code, 1990), and are discussed in Corsanego *et al.*, 1993; Gavarini, 1994a, b. Authorities should promote the development of codes of practice related to specific historical centers, providing designers with manageable guidelines. Codes of practice have successfully been issued in Italy (Chirico *et al.*, 1992; Cremonini and Foschi, 1992; Giuffrè, 1993); Ballardini and Gavarini, 1989, give the criteria to follow when intervening on single monuments, as discussed by Corsanego *et al.*, 1993.

AN INFORMATION SYSTEM AS A PREMISE TO A MULTIDISCIPLINARY APPROACH

The realization of an appropriately conceived information system could effectively contribute to attaining a compromise between the contrasting goals of conservation and structural safety. Adequate data definition and organization should in fact allow to remove those conflicting aspects often arising when a multiplicity of exigencies and a wide range of disciplines are involved at a decisional and methodological level. Owing to the considerable complexity of questions characterized by the need to manage a large amount of data, and to reconcile a multiplicity of disciplinary fields, languages and normative environments, mistakes and omissions are in fact quite systematically made during the preliminary phases of planning and priorities definition, which generally involve a population of objects.

Defining a suitable collection of significant information constitutes the first step towards problem formalization. According to what is stated in the Recommendations - Skopje '88, 1988, the creation of a data bank on the conditions of historical buildings as a part of the cultural heritage of certain regions and the development of a methodology for uniform and systematic processing of data constitute one of the fundamental prerequisites for information exchange in contemporary media. Such a methodology should also provide an available tutorial support, aimed to let each operator participate the process of knowledge diffusion and acquisition.

An attempt towards such a goal has been undertaken by Gavarini *et al.*, 1995. More specifically, data packets have been individuated, on the basis of the degree of close similarity among different kinds of information. Once defined, data have to be structured within an information system appropriately designed in order to facilitate consultation, updating and use of data themselves. Seeking to model problem complexity, use of Artificial Intelligence techniques allows knowledge representation and uncertainty treatment. Essential to this purpose are *a)* the possibility to organize information according to formal schemes which permit to explicitly take uncertainty and data reliability into account; *b)* the multidisciplinarity of approaches; *c)* the availability of friendly computerized environments for investigating situations, performing evaluations, looking for possible intervention solutions, and managing the permanent phases of inspection and maintenance.

Nevertheless data pertinent to a certain construction undergo variations in time, which constitute the history of the monumental building in question. It is therefore essential to reach a historic-evolutionary perception of

the information stored in the packets; in other words, the information system should render a series of photographs showing the content of the packets at the various significant dates of the history of the fabric.

The concept of level then intervenes referring to the degree of depth requested in collecting data contained in the single packets. Levels definition also is to be accomplished intensively encouraging an as hard as indispensable communication through distinct disciplinary domains.

Data Packets. As previously stated, information have been organized in data packets, representative of different mutually interacting disciplinary fields. Packets then express the interdisciplinary features of any projectual intervention hypothesis, which represent the linking elements among the various scientific communities.

The following packets have been individuated

1) *urban context data*;
2) *geognostic data*;
3) *climatic data*;
4) *administrative data*;
5) *functional data*;
6) *typology data*;
7) *construction data*;
8) *equipment data*;
9) *artistic data*;
10) *state of maintenance data*.

Particular importance has been given to the fact that packets describe what can be regarded as a complex system, as the fabric is necessarily to be considered in view of the evolution and modification of its relations with the outer world, through the study of its interactions with natural or anthropic events which might have produced partial or total modifications, and with those vicissitudes directly related to the life of the construction, having caused functional or technological variations.

In an attempt to meet the exigencies enlightened by the previous considerations two distincts modes of data consulting are allowed. More specifically, fixing the attention on a particular instant of time a photograph of the values simultaneously assumed by data in the various packets at that date is returned (*synchronic* data reading), while fixing the attention on one of the packets an evolutionary representation of data through the significant dates is obtained (*diachronic* data reading). Similar methodological premises must therefore result in a sequence of portraits which allow to navigate both through the time dimension of the history of the fabric and through different possible levels of detail.

Levels. The possibly different grades of detail in the knowledge of the monument has led to the definition of the concept of level. More explicitly:

level 0 (register) identifies objects;

level 1 (catalogue) provides some information concerning:

historic significance and artistic value;
state of maintenance;
seismic vulnerability;
priority of intervention;

level 2 corresponds to a deep survey of the building, and analyzes construction typologies, structural elements and constituent materials;

level 3 aims to meta-design, *i.e.*, the study of feasibility of possible interventions;

level 4 consents to proceed with the realization of the interventions.

Finally, when selecting data to include in the packets at the various levels it cannot be left out of consideration the perspective possibility to resort to multimedia technology for the management of information, according to the requested degree of detail in the description of the object under examination. It would consequently be provided the opportunity to consult collections of graphic material, written documents, videos, oral sources and sound archives, and to make an appropriate use of virtual representations of reality.

Representation of Uncertain Information. Data Base Management Systems (DBMS) have generally been built in order to represent a crisp reality, in which relevant variables are assigned unambiguously defined values. Nevertheless, surveyed data are very often affected by uncertainty.

Uncertainties in the knowledge of structural behavior of constructions have traditionally been treated by means of probability theory. However probabilistic techniques do not allow to manage uncertainty not random in nature, which plays an important role within the processes of data surveying, typically involving both measuring and describing numerical deterministic parameters, and expressing qualitative judgments, these often asserted as verbal statements and unavoidably influenced by the competency and expertise of the operators. Trying for effectively overcoming such restrictions, various approaches have recently been proposed. Particularly Fuzzy Set Theory has been recognized as a powerful tool in modeling the imprecision that is characteristic of natural language, since it possesses an intrinsic vagueness or *fuzziness* which eludes the usual ordinary set representations.

The concept of a fuzzy set introduces vagueness with the aim of reducing complexity to an acceptable level (G. J. Klir and T. A. Folger, 1988). More specifically, Fuzzy Set Theory supplies a mathematical background to deal explicitly with data uncertainty and to handle incomplete definition of certain parameters, as it models the semantic flexibility inherent to linguistic terms and qualitative evaluations. It thus provides the possibility to utilize this kind of data also, preventing operators from rejecting or forcing them to assume certain determined values, with the consequent loss of part of information.

Management and Use of Data. Resorting to appropriate mathematical frameworks and use of Artificial Intelligence techniques allow to design a Data Base Management Systems enabling the treatment of incomplete, non-deterministic, vague information. Such a system consents to store and subsequently handle both univocally defined parameters (*symbolic elaboration of information*) and subjective judgments, specified by means of the meaning assigned to linguistic expressions (*semantic elaboration of information*). Aptitude for control of this kind of information, which involves embodying and representing uncertainty, requires extreme flexibility in data base access operations. Use of relational algebras should then enhance and facilitate queries formulation and search modes.

Collected information are then made available by the system for use within appropriate diagnostic models or assisted design tools which aid operators in defining strengthening, repair an conservation interventions. The previously stressed need to integrate theoretical knowledge and practical experience implies resorting to both qualitative and quantitative modeling techniques. It is thus indispensable that the system can be utilized both 1) as decisional support in the resolution of problems remarkably characterized by the presence of subjective empirical factors and in the development of knowledge-based systems representative of a multiplicity of heuristics in mutual comparison, and 2) as data bank made available for use within traditional calculation procedures (Bruno *et al.*, 1994). It is anyway essential that the system allow to propagate the level of uncertainty in a proper way.

CONCLUSION

The philosophy at the base of the approach outlined above mainly focuses on the two complementary questions of how to utilize information and to deal with uncertainty in the form of general principles and representations. It constitutes an effort to explore the multiplicity of aspects of real world problems in the light of their common issues of handling knowledge and complexity. It finally gives way to place emphasis on the fact that the various activities connected with the selection, organization and structuration of information concerning the architectural and historical heritage, requiring discussion and multidisciplinary debate over the major concepts of seismic risk, human lives protection, cultural value and conservation, contribute to obviate the present inadequacy of the existing technical codes, and to define new courses and guidelines.

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