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EXPERT SYSTEM IN BUILDING PATHOLOGY

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Abstract
The arisen methodologic problems during the pathologic examinations in buildings keep back the effective treatment of failures in many cases. The solution of the problems under discussions makes an opportunity in one to „tune" the analyses to each other, the results of the studies can be shared by several experts during the analysis process, and the experiences of them can be used by other participants of the branch of building industry during their work. The study below discusses a complex expert system, which contains the analysis method of computer networks applied to the building pathology.

Introduction

The development of built environment not only accompanied the process of the evolution of human being but it also influenced, indeed, in certain cases, often determined that. Countless elements of culture in some respects are related to buildings. Thus one can state that the social and technical progress is in interrelationship with the improvement of building. This situation is not changed until now, when the future of the civilisation can be conceivable only by having the sustainable development in sight.

Because of the special properties of the built environment (its long life span causes that buildings can not follow the social-economical changes – that leads to the frequent function changing in buildings; it represents concentrated high value; it damages also without use; etc.) and of the prevention of natural environment its protection and maintenance is essential. [1.]

Holding the technological conditions of the buildings can be executed as a part of its maintenance process. The life span of a building is divided into maintenance periods. At these periods – depending on the condition – one must make certain decisions (about renovation, function changing, pulling down, etc.). The decisions can be made only based on experts' statements. Hereby examinig the mechanical conditions of buildings the building pathology becomes an important part of the maintenance process.

Building Pathology as a Tool for Decision Making

During the building maintenance process the task of an expert performing pathological examinations is to explore failures, to name their causes and to suggest solutions for repairing the failures. Rational decision making makes certain requirements against the results of the examinations: the reports have to be professional and objective. By professional here we mean the thorough knowledge of building constructions and of the external factors which affect them.One can state that the report is objective if the failures and their causes are described impartially, as detailed as it is necessary. Thus the expert applies critique only to a certain extent (its use is inevitable, but the degree alterate in various cases)[2.].

During decision making one has to answer to a particular arisen question. Decision is valuable if one can choose from two or more alternative answers. In the system of building maintenance one has to decide about the future of the examined building or about the order of the maintenance process.

In case of complex problems or of a system containing more buildings the order of the process can be established by the assistance of building pathological examinations. If the examinations are made on different way by various group of experts than the results are often incomparable with each other, which makes the effectiveness of decision making uncertain. Summing up one can state that the diagnostical examinations of the buildings are the basics of the building maintenance systems and that is why they have to be based on facts and executed objectively.

Expert System in Building Pathology

To satisfy the claims that laid against the diagnostical examinations the application of a complex expert system can be suitable. This system ensures the use of common technological terminologies to the building constructions, the use of fault catalogue (databank) and gives instructions to several type of fault analysis methods. Besides this it has further advantage: the results obtained recently can be applied in the future through the databank.

Structure of Expert System

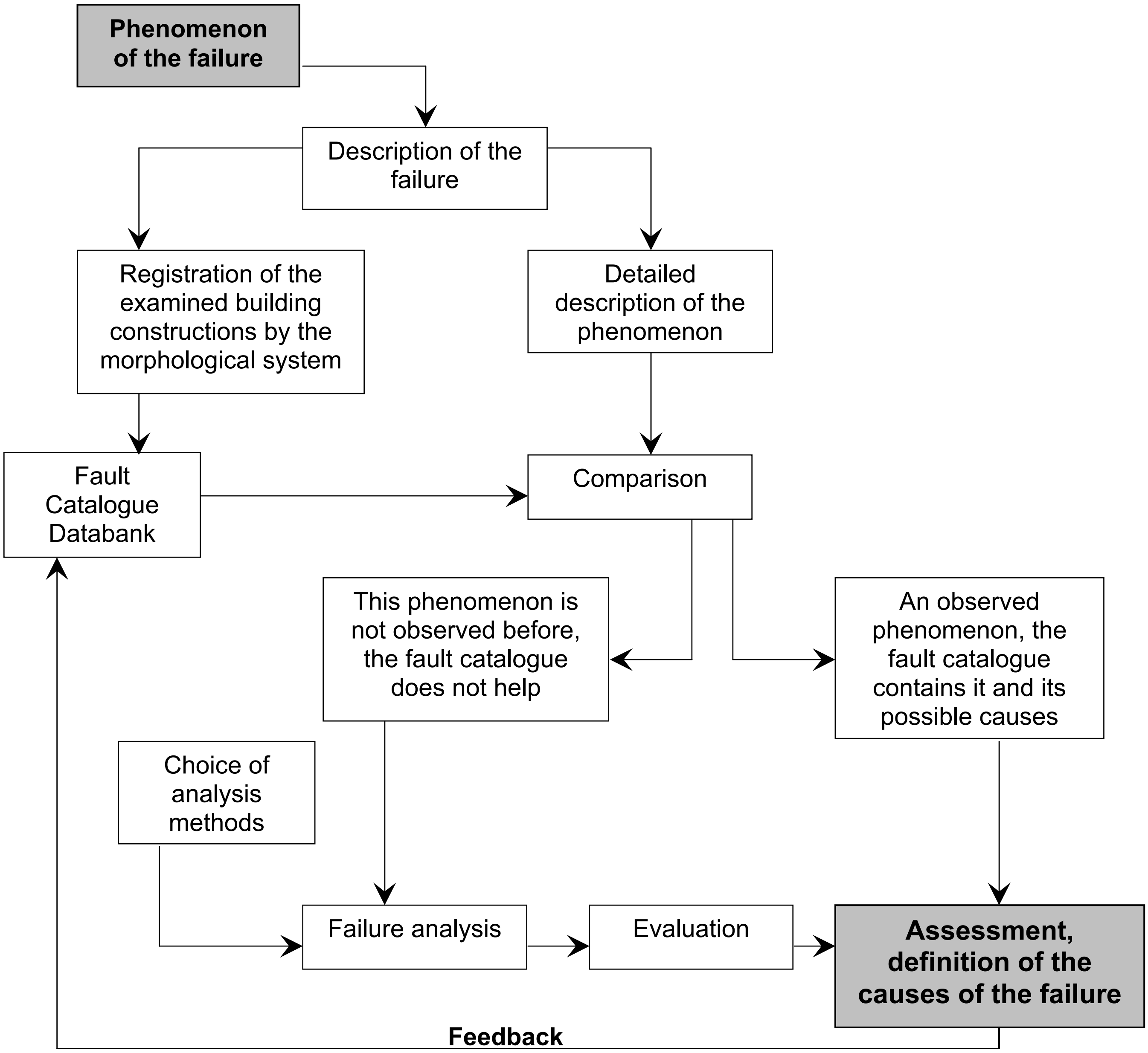

Figure 1. Expert System

Operation of Expert System
The aim of each examination is to find the causes of the experienced phenomena. By this system the process is divided into steps: first, to identify the examined construction; then to find the typical failures of it, through the fault catalogue of this construction; and then a predefined detailing analysis comes. The evaluation of the analysis enlarges the databank of fault catalogue.

Components of Expert System
Morphologic Classification of Building Constructions [3.]
Because of the continously increasing amount of applied elements in building the morphologic classification of building construction based on the theory of thesaurus [4.] has not been ready yet. However its application can be useful not only in the construction designer's work but as a part of a maintenance system it improves the effectiveness of the examinations. A proper identifcation and systemization of the subject of examination offers help in orientation in further actions. Another advantage of its use in the building pathology process that the designer is able to recognize the possible sources of failures: the experiences of the diagnostic examination can be given directly to the ingeneers.
The Fault Catalogue
The fault catalogue which contains the experienced failures of the constructions and the causes of them is based on the morphologic classification described above. This databank offers points of reference to the further examination of the broken elements in sight. Beside the description of the statements figures showing the failures of the constructions and their causes are also included in this databank which help to recognize the situation.
The failures can be compared with each other only by using the method of abstraction. It is supposed that the fault catalogue can not contain all the types of fault, that is why the condition of a well-built catalogue is to be endless enlargeable.
The Failure Analysis Methods
The main cause of that the results of diagnostic examinations are not comparable is that the analysis methods are different. For avoiding these differences in one diagnostic system it is suitable – depending on the problem and the depth of decision – to determine the method of investigation in advance.
Beyond the preparation for decision making the diagnostic studies have specific aims which depend on the considerations of the examination. These aims cannot be separated from each other, because the effective treatment of the failure and the action which forces back its appearance in the future can be solved by a many sided inspection. Beside of its complexity for obtaining a fast and effective analysis one has to define the circle of the examination.
Keeping in mind the inportance of details as well as the effectivity, one has to find a siutable method. In the next rows there is a short description of a failure analysis which is applied for a long time for investigating the reliability of special computer networks. Its application in building pathology needs careful consideration.

The Fault Tree Analysis
The fault tree technique [5.]was introduced in 1962 at the Bell Telephone Laboratories, in connection with a safety evaluation of the launching system for the intercontinental Minuteman missile. The Boeing Company improved the technique and introduced computer programs for both qualitative and quantitative fault tree analysis. Today fault tree analysis is by far the most commonly used technique of risk and reliability studies. Fault tree analysis has particularly been used with success to analyse safety systems in nuclear power stations, e.g. during the Reactor Safety Study, WASH-1400 (US Atomic Energy Commission, 1974).
As a possible failure analysis method in building pathology the fault tree analysis was introduced at the Congress of CIB W086 Building Pathology Commission in 1993, June[6.], but the methodology and the process of this analysis was not properly described.

A fault tree is a logic diagram that displays the interrelationships between a potential critical event (failure) <TOP event> in the examined system (building) and the reasons <BASIC events> for this event. The reasons may be environmental conditions, human errors, normal events (events which are expected to occur during the life span of the system) and specific component failures. The graphical symbols used to illustrate these connections are called "logic gates". The output from a logic gate is determined by the input events.

The graphical layout of the fault tree symbols are dependent on what standard we choose to follow. [7.]

A properly constructed fault tree provides a good illustration of the various combinations of failures and other events which can lead to a specified critical event. The fault tree is easy to explain to engineers without prior experience of fault tree analysis.

An advantage with a fault tree analysis is that the analyst is forced to understand the failure possibilities of the system, to a detailed level. A lot of system weaknesses may thus be revealed and corrected during the fault tree construction.

A fault tree is a static picture of the combinations of failures and events which can cause the TOP event to occur.

A fault tree analysis may be qualitative, quantitative or both, depending on the objectives of the analysis. Possible results from the analysis may e.g. be:

· A listing of the possible combinations of environmental factors, human errors, normal events and component failures that can result in a critical event in the system.

· The probability that the critical event will occur during a specified time interval. The qualitative fault tree analysis can not be applied in biulding pathology, because there are a lot of external causes of certain failures which can not be calculated in advance.

The analysis of a system by the fault tree technique is normally carried out in four steps:

1) Definition of the problem and the boundary conditions.
2) Construction of the fault tree.
3) Identification of minimal cut sets.
4) Qualitative analysis of the fault tree.

Definition of the problem and the boundary conditions

This activity consists of:

· Definition of the critical event (the accident) to be analysed.

· Definition of the boundary conditions for the analysis.

The critical event (accident) to be analysed is normally called the TOP event. It is very important that the TOP event is given a clear and unambiguous definition. If not, the analysis will often be of limited value. As an example, the event description "Mildew under the window" is far too general and vague. The description of the TOP event should always answer the questions: What, where and when.

What: Describes what type of critical event (accident) is occurring, e.g. mildew.

Where: Describes where the critical event occurs, e.g. in a flat on a prefabricated „sandwich" panel under the window, from wall to wall.

When: Describes when the critical event occurs, e.g. after a long period of use.

A more precise TOP event description is thus: „Mildew in a flat on a perfabricated »sandwich« panel under the window, from wall to wall, after a long period of use".

To get a consistent analysis, it is important that the boundary conditions for the analysis are carefully defined. By boundary conditions we mean:

· The physical boundaries of the system. What parts of the system are to be included in the analysis, and what parts are not?

· The initial conditions. What is the state of the subject of examination when the TOP event is occurring? Is the building under costruction or in use? What are the consequences of use?

· Boundary conditions with respect to external stresses. What type of external stresses should be included in the analysis? By external stresses we here mean stresses from war, sabotage, earthquake, lightning etc.

· The level of resolution. How far down in detail should we go to identify potential reasons for a failed state? Should we as an example be satisfied when we have identified the reason to be a "wrong drainage system", or should we break it further down to failures in the pipeline, joins of the drainpipe and waterproofing etc.? When determining the required level of resolution, we should remember that the detail in the fault tree should be comparable to the detail of the information available.

Construction of the fault tree

The fault tree construction always starts with the TOP event. We must thereafter carefully try to identify all fault events which are the immediate, necessary and sufficient causes that result in the TOP event. These causes are connected to the TOP event via a logic gate. It is important that the first level of causes under the TOP event is developed in a structured way. This first level is often referred to as the TOP structure of the fault tree. The TOP structure causes are often taken to be failures in the prime modules of the system, or in the prime functions of the system. We then proceed, level by level, until all fault events have been developed to the required level of resolution. The analysis is in other words deductive and is carried out by repeated asking "What are the reasons for ..... ?"

Identification of minimal cut sets

A fault tree provides valuable information about possible combinations of fault events which can result in a critical failure (TOP event) of the system. Such a combination of fault events is called a cut set.

A cut set in a fault tree is a set of Basic events whose (simultaneous) occurrence ensures that the TOP event occurs. A cut set is said to be minimal if the set cannot be reduced without loosing its status as a cut set.

Qualitative analysis of the fault tree

A qualitative evaluation of the fault tree may be carried out on the basis of the minimal cut sets. The importance of a cut set depends obviously on the number of Basic events in the cut set. The number of different Basic events in a minimal cut set is called the order of the cut set. A cut set of order one is usually more critical than a cut set of order two, or higher. When we have a cut set with only one Basic event, the TOP event will occur as soon as this Basic event occurs. When a cut set has two Basic events, both of these have to occur at the same time to cause the TOP event to occur.

Another important factor is the type of Basic events in a minimal cut set. We may rank the criticality of the various cut sets according to the following ranking of the Basic events:

1. Human error
2. Failure of building construction
3. Failure of attached construction element

The ranking is based on the assumption that human errors occur more frequently than inner construction failures, and that the building costruction is more failure-prone than attached construction elements.

Summary

To build the expert system up, one need a lot of research studies and therefore, a lot of time, what is a disadvantage of it. The fault trees of the failure analysis have to be made in each examination, which also means a lot of time. However its advantage is that the expert, who makes the analysis has to think systematically without the danger of routine and has to apply the method with no preconception. In this way the examinations can throw light upon new relations between events.

By means of the fast counting ability and huge memory of the computer this expert system may become a really effective tool in the building maintenance system. In this direction the building pathology offers help in decision and thus may take a significant part in building ecology.

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