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173

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DEVELOPMENT OF A PROTOTYPE EXPERT SYSTEM FOR DAMAGE ASSESSMENT OF STRUCTURAL CONCRETE ELEMENTS

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DEVELOPMENT OF A PROTOTYPE EXPERT SYSTEM FOR DAMAGE ASSESSMENT OF STRUCTURAL CONCRETE ELEMENTS

by

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THESIS

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ABSTRACT

DASE, a rule-based prototype expert system, was developed as an assistant to any engineer engaged in the task of assessing postearthquake damage to structural concrete elements, such as columns and beams.

In the assessment of damage of structural concrete elements much of the decision making relies on the engineering judgement of the person in charge of the inspection and evaluation. This expert system provides a methodology for guidance in inspection as well as a criteria for evaluation and courses of action to take afterwards. The system also provides graphic files to customize the user interface and an explanation facility for the conclusions reached, so that the user learns or confirms what he already knows.

This prototype is not intended as a panacea to solve every case of damage in structural elements, and the user remains the controlling decision maker.

DASE is a first version, and was developed in the expert system shell ExSys Professional for windowed environments.

As all prototypes, it has limitations as to the quantity and quality of information used, but can be easily improved and expanded, as the knowledge of damage assessment for structural concrete elements develops.

TABLE OF CONTENTS

Page

Page

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

Immediately after an earthquake of medium or large magnitude strikes, the need for inspection, assessment and estimation of the resulting damage to building structures, is imperative and of great importance in order to evaluate their safety and determine immediate and long term measures to reduce the risk of collapse of those structures that remained standing and need repair or strengthening.

The first measure is to come up with an inspection methodology that provides, in a quick and reliable manner, sufficiently accurate information of the state of damage of the structures and a posting criterion as to the remaining safety they provide. In a state of emergency of this type, shortcomings arise in the sense that there is not enough qualified personnel, such as structural engineers or professionals familiar to the construction industry, to cover all the inspections in a reasonable short period of time, therefore seeking for additional manpower that may not have sufficient or even basic structural knowledge, nor have participated in special training programs for postearthquake emergencies.

In such situations the time and cost of training become critical, and the lack of it may or does affect substantially the effectiveness of the inspection programs. Even with trained personnel performing the inspections, exhaustion and other symptoms of emotional and physical fatigue, can impact greatly the ability to think and make judgements.

It is in this type of hazardous situations, when the technology of artificial intelligence may become useful and cost effective, by assisting in the process of or

supporting decision making.

Artificial intelligence deals with topics related to the simulation of human intelligence, branching into several areas such as natural language understanding, robotics and experts systems. Expert systems specifically attempt to simulate intelligent problem solving behavior in a computer program.

In the field of structural engineering many expert systems have been developed and some of them are operational or developmental prototypes, addressing topics such as: materials, structural analysis, code checking, structural systems and miscellaneous.

Several experts systems related to damage assessment of structures have been developed [Yao 1984, Maher 1987, Yeh et al. 1991, etc.], but to the best of the author's knowledge, none of them have addressed the assessment of simple structural elements, such as beams and columns, in a structured manner, leaving to the inspectors own judgement, the degree of damage of each and one of the structural components of a structure, to latter consider them in a global sense as to the degree of safety of a whole structure or building.

1.1 Purpose and Scope of the Thesis

Based on the need to resort to the cooperation of non-experts to aid in a rapid and reliable inspection and on the inherent state of stress in a postearthquake emergency situation, the purpose of this thesis is to provide an alternative training and consultation tool, using expert system technology, to assist in the assessment of local structural damage of beams and columns made of cast in-place concrete, not exposed to soil nor to aggressive environments, based on visual observations, identifying possible failure modes, determining a degree of damage severity and suggesting immediate actions to

take afterwards, in order to maintain an acceptable local safety level; this level of inspection assumes that the building has been previously inspected by a first level screening of damage, and resulted as being considered 'questionable' as to safety. The proposed prototype expert system is called "DASE", an acronym for "Damage Assessment of Structural concrete Elements". Floor damage classification and restoration guidelines, can also be provided, assuming that all of the structural components in a building's floor have been inspected.

1.2 Content and Organization of the Thesis

After this introduction, Chapter 2 provides an overview of expert system technology and applications to the civil engineering discipline. Chapter 3 reviews damage assessment methodologies and rehabilitation techniques for damaged structures and expert system applications in this particular field. Chapter 4 describes the preliminary phases involved in the development of DASE, followed by Chapter 5 where the methodology used to develop DASE is presented. DASE's implementation strategies in Exsys Professional software are discussed in Chapter 6. In Chapter 7, DASE's validation process is discussed and the validation results are presented. Chapter 8 finalizes with conclusions and recommendations. Appendixes A to E document the expert system's development, use and validation.

Chapter 2

EXPERT SYSTEMS OVERVIEW

The attempt to simulate or reproduce intelligent problem-solving behavior in a computing machine has received considerable attention among professional and academic groups. The search for a solution to a specific problem requires specific knowledge (numeric, symbolic, heuristic, algorithmic), that may or may not be readily available due to the fact that much of the knowledge resides in the experience and intuition of experts in the field of interest and/or there are problems in finding the best source of specialized knowledge in a timely manner.

The traditional use of computers to solve engineering problems that are formal and analytical in nature requires a list of sequentially executable statements that are formulated before the computer can solve the problem. This requirement has restricted the use of the computer to problems that have solutions that are well understood. The desire to use the computer to aid in a solution of engineering problems that are less formalized or understood has lead to recent interest in expert systems techniques.

2.1 Definition of Expert Systems and characteristics

The following is a good standard definition of expert system [Kostem and Maher 1987]:

"Expert systems are interactive computer programs incorporating judgement, experience, rules of thumb, intuition, and other expertise to provide knowledgeable advice about a variety of tasks".

Conventional programs can be interactive, and contain judgement and rules of thumb, yet they are not expert systems.

Table 2.1 illustrates a comparison between the characteristics and capabilities of experts systems and conventional systems.

Table 2.1 Comparison between Conventional systems and Expert systems [Turban 1990].

Conventional systems	Expert systems
Knowledge and processing are combined	Knowledge base is separated from the inference mechanism
Programs do not make mistakes	Program may make mistakes
Do not (usually) explain why input data are needed or how conclusions were drawn	Explanation is a part of most ES
The system operates only when it is completed	The system can operate with only a few rules (as a first prototype)
Execution is done using algorithms and numerical data	Execution is done using heuristics through symbolic representation
Needs complete information to operate	Can operate with incomplete or uncertain information
Effective manipulation of large databases	Effective manipulation of large knowledge bases
Representation and use of data	Representation and use of knowledge
Deals with quantitative data	Deals with qualitative data
Captures and gives access to numerical data	Captures and gives access to judgement and human expertise
Efficiency is a major goal (perform in the right manner)	Effectiveness is the major goal (arrive at the right conclusion)

2.2 Expert Systems Architecture

According to Maher [1987] "the basic architecture of an expert system exhibits

a separation of domain knowledge, control knowledge, and knowledge about the specific problem currently being solved; this leads to the identification of the following basic components:

1. Knowledge base: contains facts and heuristics associated with the domain in which the expert system is applied. The facts are represented as declarative knowledge, and heuristics take the form of rules.

2. Inference mechanism: part of the expert system that contains the control information such as backward or forward chaining (see section 2.4.2 'Implementation strategies' of this theses).

3. Context: component of an expert system that contains the information about the problem currently being solved.

Additional components needed to make the system usable and friendlier are:

4. User interface: highly interactive component, with "HELP" facilities and transparency of dialogue that explains the reasoning process used.

5. Explanation facility: This facility varies from the trace of execution to the ability to respond to questions about the reasoning process used to develop a solution.

6. Knowledge acquisition: component in an expert system that facilitates entering knowledge into the knowledge base. In the simplest case, this facility acts as an editor".

The relation among this components is illustrated in figure 2.1.

Variations of the basic architecture have been developed, such as the production system model and the blackboard model, and more are expected to develop in the future.