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Knowledge engineering approaches to processing earthquake engineering knowledge

H. Adeli, S. L. Hung & T. T. Shwe
Department of Civil Engineering, The Ohio State University, Columbus, Ohio, USA

Abstract: This paper presents knowledge engineering approaches to processing earthquake engineering knowledge. Several prototype knowledge-based systems developed by the authors are described briefly. They are EXQUAKE1, EXQUAKE2, EXQUAKE3, WQUAKE, and OQUAKE.

1. INTRODUCTION

During the past several years many knowledge-based systems have been developed in the area of structural design (see for example, Adeli and Balasubramanyam, 1988, Adeli and Mak, 1988, Paek and Adeli, 1990). In this work, our objective has been application of knowledge engineering approaches for electronic processing of earthquake engineering knowledge and lessons learned in earthquakes. The domain knowledge in this case is in the form of written texts or graphic sketches. This is in contrast to structural design expert systems where extensive numerical processing is required in addition to the symbolic processing of heuristic knowledge. This paper summarizes our efforts in this area. In particular, we describe five prototype knowledge-based systems employing various knowledge engineering approaches.

2. EXQUAKE1

EXQUAKE1 is a prototype knowledge-based system for evaluation and selection of building configurations in seismic regions (Adeli and Shwe, 1990). The knowledge base of EXQUAKE1 contains lessons learned from earthquakes and published in books and papers. EXQUAKE1 has been developed on an IBM personal computer using the expert system shell INSIGHT 2+ (Level Five Research, 1986). The representation of textual knowledge is through IF-AND-OR-THEN-ELSE rules in a language called Production Rule Language (PRL). For displaying various building configurations, EXQUAKE has a graphics interface developed in Turbo Pascal. EXQUAKE1 can point out the problems in building plans and elevations and recommend suitable shear wall arrangements for rectangular, triangular, and circular building plans.

3. EXQUAKE2

EXQUAKE2 is a prototype knowledge-based expert system for earthquake damage evaluation and knowledge of performance of a common class of buildings, that is tilt-up buildings, in California earthquakes. EXQUAKE2 has been developed on an IBM personal computer using the expert system shell EXSYS Professional (EXYS, 1988). EXQUAKE2 has a graphics interface, developed in Turbo Pascal, for displaying various building configurations and structural details. The knowledge base of EXQUAKE2 has a hierarchical structure. This hierarchical structure makes addition, deletion, and modification of the knowledge base easy. At the top level, there are seven knowledge modules: elements of tilt-up construction, damage to tilt-up buildings in the 1971 San Fernando Earthquake, revisions to the UBC code after the 1971 San Fernando earthquake, design and construction trends since 1971, damage in the 1987 Whittier-Narrows earthquake, non-structural damage, and summary of lessons learned.

4. EXQUAKE3

Design codes represent the experience of designers and researchers accumulated over a long period of time. They include a wealth of information expressed mostly in textual and linguistic form. EXQUAKE3 (Shwe and Adeli, 1991) is a prototype knowledge-based system for presenting the earthquake resistance building design requirements of the Uniform Building Code (UBC, 1988), a commonly-used earthquake design code. A combined network-hierarchical architecture is proposed for code processing. Such an architecture makes it possible to access various portions of the code quickly and conveniently. The knowledge base of EXQUAKE3 consists of a network of eight main knowledge bases as shown in Figure 1. EXQUAKE3 has been developed on an IBM personal computer using the expert system shell INSIGHT 2+. EXQUAKE3 is intended to be a user-friendly electronic version of the code.

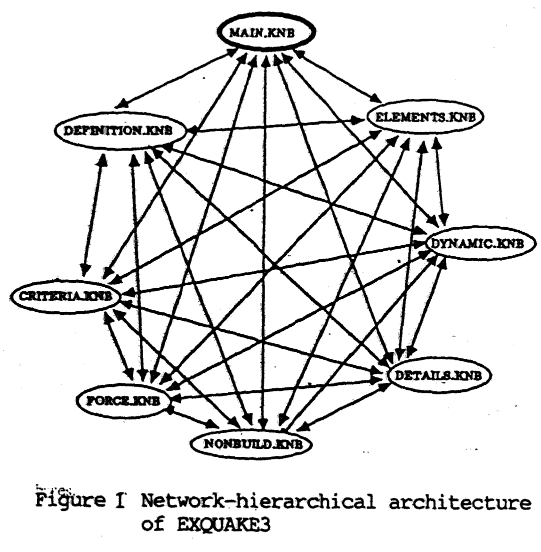

Figure 1 Network-hierarchical architecture of EXQUAKE3

5. WQUAKE

Adeli and Hung (1990a) present a novel approach for processing the lessons learned from earthquakes and the knowledge of earthquake-resistant design by integrating the production system model, relational databases, and interactive computer graphics. The feasibility of this approach has been demonstrated by developing a prototype knowledge-based system, called WQUAKE, for processing the earthquake engineering knowledge learned in recent California earthquakes. WQUAKE has been implemented on an IBM Personal Computer using the expert system development environment GURU (MDBS, 1987) and Turbo C language.

Two methods of knowledge representation are used in WQUAKE for representing the knowledge of structural damage and behavior. They are production rules and relational databases. GURU does not provide a frame knowledge representation. However, the relational database capability of GURU is used to represent the knowledge in a structure similar to frames.

The relational databases are set up to store explicit relationships between records as well as implicit relationship among them created during the information processing. The problem domain is decomposed into independent sub-domains created separately. In order to create, modify, and query the knowledge base, relational databases are used to store information in defined formats. For example, for the problem of structural damage during a strong ground motion, the damage information must be related to earthquake event and the type of the structure. Thus, we create three independent relational databases, **Earthquake**, **Structure**, and **Damage**, to store the relevant information individually. The structure and the relationship between these databases are shown in Figure 2.

In order to describe the domain problem in detail, we create secondary databases, which are related to the main databases. For example, in Figure 2, database **StructSpecial**, related to the main database, **Structure**, is a secondary database containing detailed information about specific structures, such as the roof system of tilt-up buildings.

For effective interaction with the user, WQUAKE provides four types of user interface: menu-driven interface, query interface, graphics interface, and natural language processor. Developed in Turbo C, the graphics interface can display the elements and damage mechanisms of structures. The integration of production rules, relational databases, and interactive computer graphics provides an effective means of processing the knowledge of earthquake-resistant design which is documented in numerous reconnaissance reports, papers, and books, mostly in the form of descriptive texts and figures.

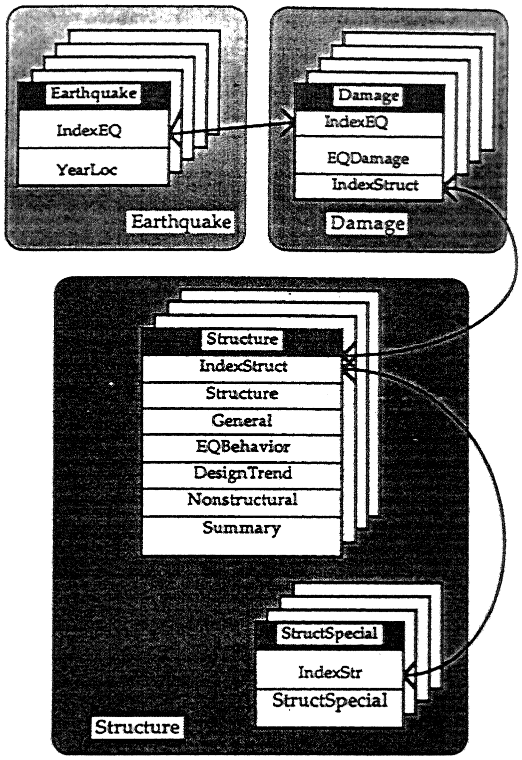

Figure 2 Relational databases in WQUAKE

6. OQUAKE

Adeli and Hung (1990b) present an object-oriented model for processing the knowledge of earthquake damage and structural behavior electronically. The model has been implemented in C++ in a prototype system, called OQUAKE, on a SUN workstation. Knowledge representation in OQUAKE is through a combination of frames and scripts. Two general-purpose object classes provide support for developing and managing frame and script knowledge bases.

In the present implementation of OQUAKE, we have defined five categories of knowledge for storing and presenting the knowledge of earthquake damage and structural behavior in recent California earthquakes (Figure 3). These categories are earthquake information, structure information, damage during earthquake, other information, and conclusion.

A schematic architecture of OQUAKE is shown in Figure 4. A knowledge base file, called earthquake.kbs, has been created in OQUAKE for storing the five aforementioned categories of knowledge. The inferencing in OQUAKE is done through searching and matching of the slot and filler pair in frames and scripts. Frames and scripts integrated into an object-oriented model provide the most effective way of representing stereotypical sequences of knowledge in a text-based knowledge domain.

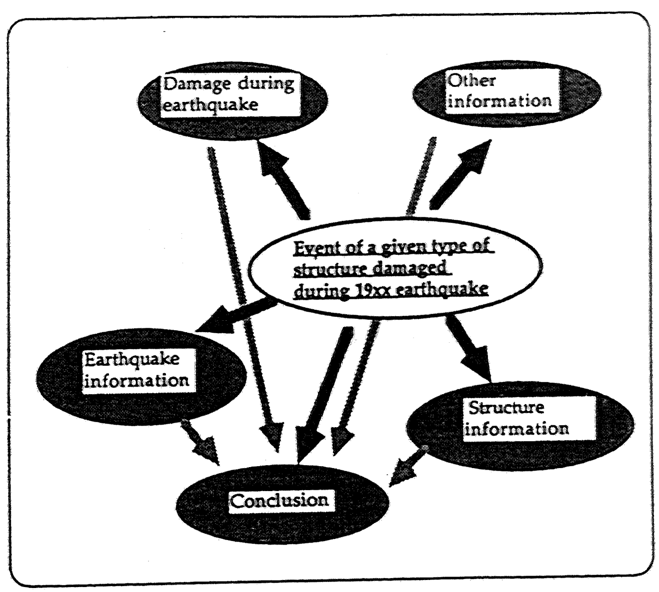

Figure 3 Categories of knowledge in OQUAKE

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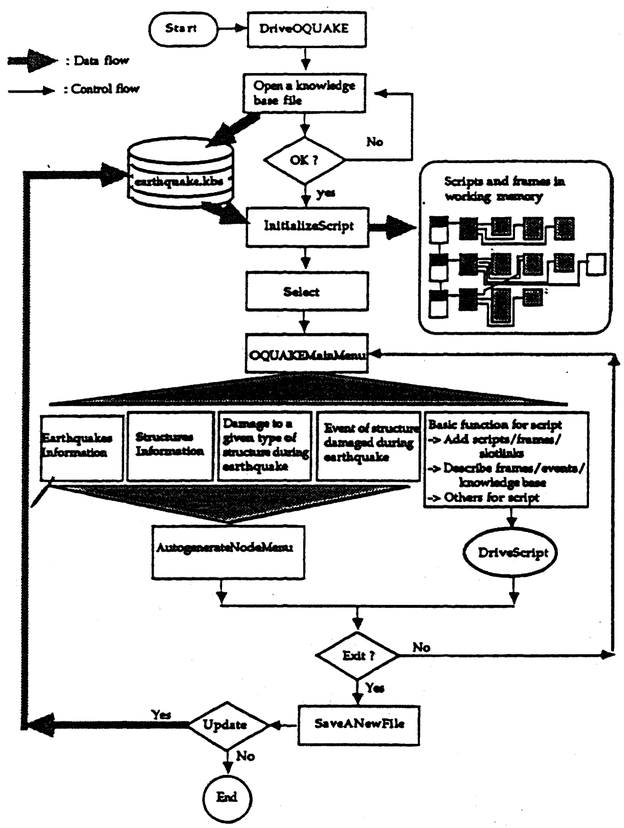

Figure 4 Architecture of OQUAKE