CONSTRUCTION INFORMATION SYSTEM: INTEGRATING DATA/INFORMATION SYSTEMS AND EXPERT SYSTEMS

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ABSTRACT

Within the academic and construction communities, there has been growing concern about how to deal accurately with the ever-changing nature of the whole construction business. In order to deal with the hostile construction environment, there is a great need in the construction industry to develop and implement a practical monitoring system which can handle the data bases, information systems, and management support systems such as an expert system. The Construction Information System (CIS) model is proposed to achieve integration of the knowledge-based expert system into the current, installed data/information systems to enhance the quality and efficiency of both computerized systems. This paper describes the rationale underlying the design of the CIS, and discusses the relevant issues relating to their integration, and describes briefly the architecture of a prototype system of knowledge representation facility called the Knowledge-Based Expert System (KBES).

1.0 INTRODUCTION

Presently the American construction industry is concerned over future labor supplies in the year 2000 and beyond. The industry is weighing the potential benefits to be gained from robots and increased automation. These two considerations offer challenges and future benefits worldwide.[8] The field of construction automation has recently been receiving considerable attention both from industry and academia all over the world.[13] Expert systems represent one of the most exciting new developments in construction information technology. Although expert system should be regarded as being in an embryonic phase in the construction industry, reports of successful applications are increasing.

Broadly speaking, information and expertise are key assets of the construction industry. But the transferability of information and expertise from one project to another is extremely limited in the construction industry. There is a great need in the industry to develop and implement a generalized, practical monitoring system, which is able to accommodate the information and facilitate the accumulation of expertise into the user-friendly system.

The Knowledge-Based Expert System will be able to formalize and structure the bulk of expertise. The expertise will then be accessible and of use to the end user. It is common knowledge that the historical data from construction projects is a valuable tool. The advent of the personal computer has made the bulk of expertise available and

usable with similar projects. The Knowledge-Based Expert System (KBES) is able to accomplish much more than just access this historical data.

The second stage of this bulk information system is the Construction Information System (CIS). This interfacing system allows the constructor or computer professional to access the data bank and apply the knowledge that are stored in knowledge frames. The CIS can be thought of as the user friendly part of the system. Again, the advantages of this system are the interfacing with the bulk frames, synthesis of information available and information selection for job site application.

The objectives of this paper are to: (1) show that the architecture of a frame-based representation facility contributes to a knowledge system's ability to reason and can assist the system designer in determining strategies for controlling the reasoning; (2) study the feasibility of integration of the developed expert system into an existing computer-based data/information system, and especially into a data base-decision system, in order to create even more powerful and useful computer-integrated systems; and (3) discuss the relevant issues and current uses of the integrated systems.

2.0 THE CURRENT, INSTALLED DATA/INFORMATION SYSTEM

The conventional computer-based data/information systems which many construction companies are currently using are interactive data/information systems that utilize decision rules and models, coupled with a comprehensive database. These systems include Decision Support System (DSS), Management Information System (MIS), and Data Base System (DBS), which provide the following support:[14]

1. Retrieve a single item of information,
2. Provide a mechanism for ad hoc data analysis,
3. Aggregate prespecified data,
4. Estimate the consequences of proposed decisions,
5. Propose decisions,
6. Formulate strategies.

The first five are typical computer-based data/information functions. The last one, which requires judgement and creativity, can be done by an expert system. The expert system can supplement the computer-based data/information system by using a built-in associative memory with knowledge of business and inferential rules. While current computer-based data/information systems support quantitative, mathematical, and computational capability, computer-based data/information systems should also be developed to support qualitative analysis based on analogical reasoning (e.g., deduction), explanation capabilities for procedures, solutions, and closed-system assumptions. The problem domain is circumscribed and the system's functions are confined to boundaries.

3.0 KNOWLEDGE-BASED EXPERT SYSTEMS

The Knowledge-Based Expert System (KBES), which is in the conceptualization stage of the development process, is a computer program that includes a knowledge base containing an expert's knowledge for a general purpose domain for construction project management research, and a reasoning mechanism for propagating inferences over the knowledge base.

The effective representation of domain knowledge is generally considered to be the keystone to the success of the KBES. The most important need for an expert system prototype development is the need for techniques to examine a problem and to develop its amorphous shape into something concrete enough so that a prototype system can be created. Presented in Table 1 are the steps from initiation to implementation. This figure reveals the developmental process without inducing unnecessary bottlenecks in the system.[3]

NUMBER	STEP	PROJECT DOCUMENT
	KNOWLEDGE DEFINITION PHASE	
1	Familiarization	Paper knowledge base
2	Organizing	Knowledge acquisition
3	Representation	Internal knowledge base format
	PROTOTYPE IMPLEMENTATION PHASE	
4	Acquiring knowledge	Knowledge base
5	Inference strategy design	Inference engine
6	Interface design	Interface

Table 1. Phases of Analysis and Project Document

In the nature of the construction industry, the advantages of the role of frame-based representation in reasoning are considerable: There are considerable advantages to a frame based representation. They are designed to function in much the same way construction experts think. This frame representation provides a concise structural representation of useful relations and contains a concise definition-by-specialization technique that is easy for most domain experts to use. Frame representations are particularly useful because the taxonomic relationships among frames enable descriptive information to be shared among multiple frames (via inheritance) and allows the internal structure of the frame to semantically integrate and maintain the constraints.

The KBES has the capacity to integrate frames and production rules into a single unified representation facility. The utility of such hybrid facilities is becoming increasingly evident with experience.[2] One of the major advantages of this kind of hybrid facility is its ability to make the organizational and expressive power of object-oriented programming available to domain experts who are not programmers. The basic components of the KBES are discussed in order to highlight the role in the reasoning of a knowledge system.

The KBES has many advanced capabilities. It can implement architecturally based system, is able to integrate structural knowledge frame systems and can interact with existing computer-based data/information systems:[4]

1. Incrementalism: to start small and build incremental prototypes that service a real need in the construction industry, until construction experts became available and descriptions of additional informations are obtained.

2. Accessibility: to allow both construction experts and the end users accessibility to a fully integrated and comprehensive system. This means that the organization of knowledge in the system has to correspond closely to the organization used by construction experts and the end users.

3. User Participation: to allow the end users to participate in building the system. It is very necessary to demonstrate the prototype KBES early in order to decide if it's the best-fit solution.

4. Selectability: to have the capability to set aside the KBES system or call up specific tasks and have the system operating in a working environment.

The summary of the features of formalization and several reasoning capabilities are shown in Figure 1.

4.0 THE CONSTRUCTION INFORMATION SYSTEM

A human expert frequently uses databases. It is reasonable to assume that a computerized expert would need to do the same. The KBES should be able to access the existing computer-based data/information system to obtain factual knowledge. The Construction Information System (CIS), which is an integration of the current computer-based data/information system and the KBES, is designed to complete this task. The proposed integration diagrammed in Figure 2 illustrates the implementation process.

The CIS may be envisioned as follows: The end user works with the conventional computer-based data/information system and follows the first five steps as proposed in Section 2.0. When the KBES reaches the strategy formulation phase, it will be able to completely separate the database and assume the role of a human expert. The end user will be able to call up the system and access the expertise of the strategy formation.

5.0 RELEVANT ISSUES AND CURRENT USES IN INTEGRATION

The integration process of the CIS will require compatibility of hardware and software. If an existing expert system runs on a LISP-type machine, and the conventional data/information system on a micro computer, there are technical problems, such as the need to use different programming languages. At the present time the development tools of computer-based data/information systems and KBES are completely independent. However, there are some indications that such tools can be combined. Some commercial tools already include a universal database and a natural language interface, which combine an expert system's shell with a database management system, graphics, spreadsheet, and communications package.[10]

The dynamics of the integration process will present many management challenges. One relevant issue the CIS model faces is that construction managers have increasingly

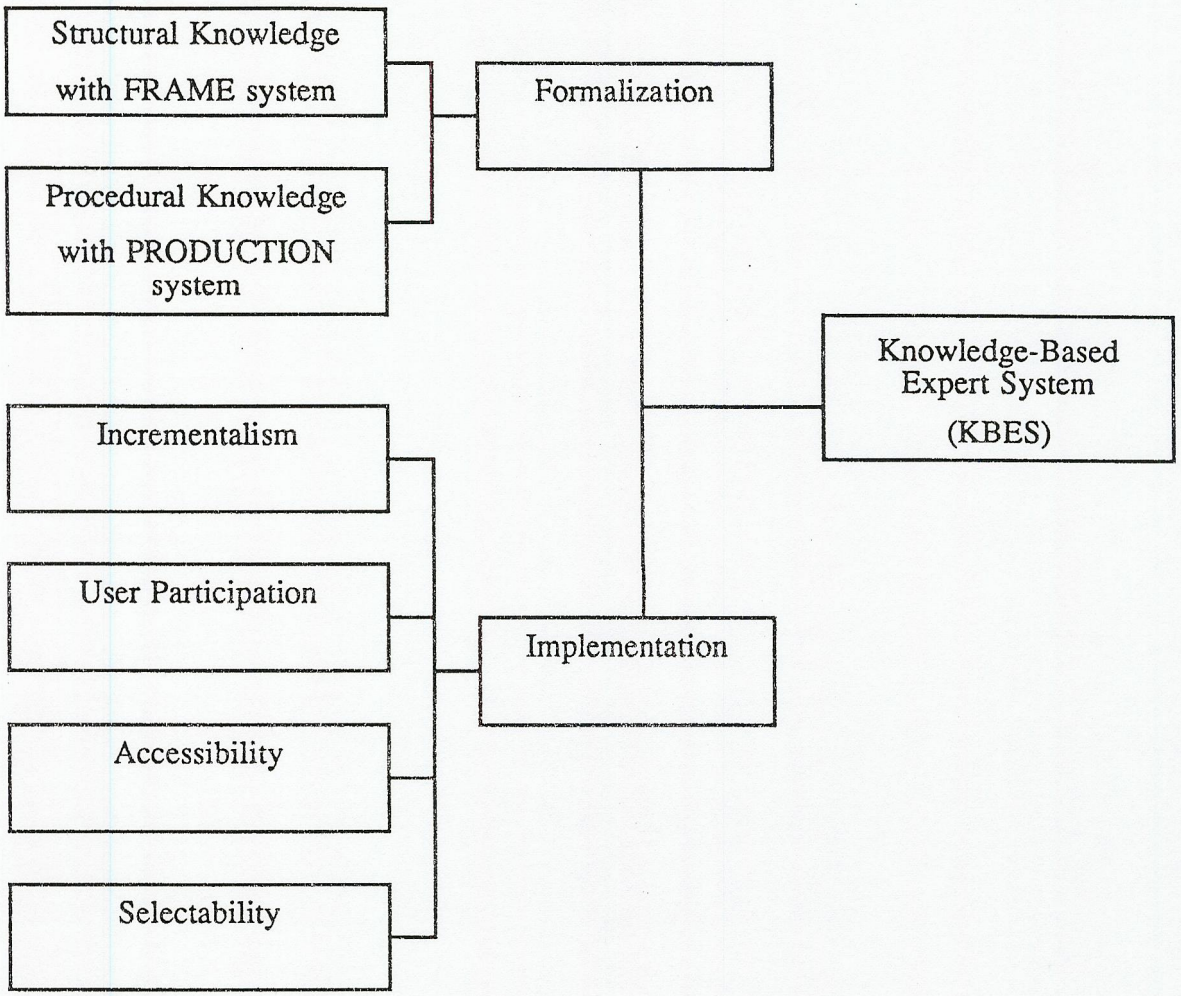

Figure 1. The Structure of the KBES

criticized computer professionals for their relative inability to deliver systems that meet the end user's sophisticated needs and that are on time and cost effective. However, there are several reasons why the CIS model will be capable of meeting these concerns. First, there is evidence that several computer-based data/information systems already are structured to the construction industry, and they are usually broader in scope, while the KBES is applied to a narrow domain; therefore, it logically follows that several small KBES may be needed to fully support one computer-based data/information system in order to meet the end user's real needs. Second, recent developments in software tools[9] could make the development of the KBES economically feasible. The development of this new system could exclusively serve current data/information systems and thus reduce the overall costs.

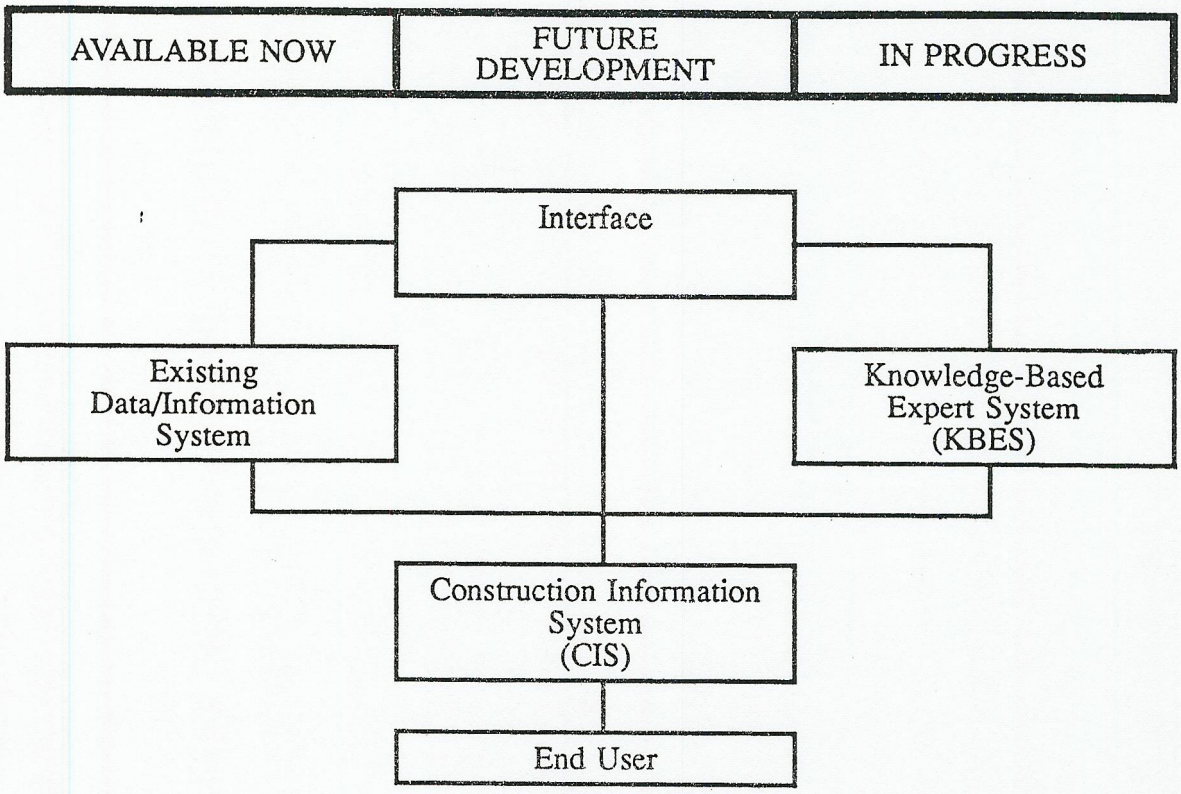

Figure 2. The Conceptual Design of the CIS

6.0 CONCLUSION

Expert systems are not a new idea. In 1958 the U.S. Navy's Bureau of Ordinance was faced with a scheduling problem for the Polaris Guided Missile Program. They developed a technique which became known as PERT (Project Evaluation and Review Technique). This system was developed and perfected on an old 360 main frame system from the 1950's. The construction industry has historically been the last production area to accept new innovations.

In order to appeal to the skeptical construction company for possible application of an expert system as a management stool and minimize the cost and time for developing the expert system, the integration of a prototype Knowledge-Based Expert System into conventional computer-based data/information system is proposed.

Expert systems are new to the construction industry and many research issues remain open. The cataloging of existing systems, tools and their uses should continue. By tracking new developments that could serve data/information users and expert system users, a perspective would be maintained on the direction and progress of this new concept. Research is in progress to develop and implement the expert system for general purpose domain for the construction project management area. Inevitably we will see the trend and significance of integrating data/information flows into the merging electronic work environment in the construction industry in the year 2000.

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