An Intelligent Knowledge Based System for Strategic Evaluation of Building Design

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KEYWORDS

Expert systems, construction, design, cost, time.

ABSTRACT

In his thought provoking paper, 'Construction Planning - Beyond the Critical Path', - George Birrell encapsulated a growing view that construction is a process for which there is a series of rules to control the way it is executed. Birrell did not express the rules but the research, which this paper describes, develops them so that the significant activities of any building design can be analysed. The activities also interact according to a code of rules, which describe the relationship between the selected activities.

Subsequently, an Intelligent Knowledge Based (IKBS) computer program has been developed combining the construction process rules with a knowledge base containing the process data specific to categories of component, eg, structural steelwork. The program is written in PROLOG enabling the IKBS to be interrogated to build a specific construction process model for each building design or variation of a design. Time periods calculated from the process model automatically input into a cost analysis IKBS, which contains other/more IKBS's to calculate the costs. Rapid evaluation of alternative design scenarios is possible as the data base contains details of the available solutions to particular construction problems, for example, the eight generic types of pile system and five types of reinforced concrete floor system.

Un Système Intelligent Basé sur Connaissance qui Évalue Stratégiquement la Conception du Bâtiment

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MOTS-CLÉS

Systèmes experts, la construction, le dessein, le coût, le temps.

SOMMAIRE

Dans son article excitant, L'Organisation de la construction - Au-delà du chemin critique', George Birrell a résumé l'opinion croissant que la construction est un processus dont l'exécution est controlée par une série de règles. Birrell n'apas décrit ces règles. Pourtant les recherches que cet article décrit, les développent afin que les activités importantes de toute conception puissent être analyser. Les activités réagissent réciproquement selon un code de règles, qui décrirent le relation entre les activités choisies.

Par Conséquent, un programme intelligent basé sur connaissance a été développé qui allie les règles du processus de la construction à la base de connaissance. Celui-ci contient des données quant au type de composant, par exemple, acier de construction. Le programme est ecrit en PROLOG alors qu'on puisse demander au système intelligent basé sur connaissance de construire un modèle du processus de construction pourchaque conception ou changement de conception.

Les durées calculées automatiquement du modèle du processus contribue à une analyse du coût du système intelligent basé sur connaissance, qui contient autres systèmes intelligents basé sur connaissance qui calculent des coûts. Il est possible qu'autres scénarios de conception soient evaluées rapidement parce que le base do données contient des détails des solutions possibles de certains problèmes de construction. Par exemple, il y a huit sortes génériques du système des pieux, et cinq sortes dy systèmes de plancher de béton armé.

INTRODUCTION

The construction industry is almost unique in that the design process is divorced from the manufacturing process. This is largely due to historical reasons but often reinforced by geograpnical separation. It is rarely possible to use prototypes to test design and construction concepts, therefore the industry's knowledge and experience is held by the individual practitioners. One particular set of knowledge, that of the construction process, is generally not available to the designer with the consequence that the ease of manufacture and assembly is not considered. It is conservatively estimated that if it were, the cost of construction could be cut by over 15%.

This project has responded to the demands of the construction industry's clients to bring together the designer and the constructor to produce more cost effective buildings. The research is addressing the problem of Buildability. To be effective the implications of Buildability must be considered during the evolution of the initial design concepts and scheme design but is for practical purposes isolated from the contractor. However, construction expertise must be available to evaluate the full construction implications in any design. Tools of analysis must be developed which embody the implications of the construction process and are robust enough to be used by design team members as an aid to their decision making.

Buildability can be addressed at two levels, the strategic and the detailed. Within the UK the strategic level has still to be mastered and therefore forms the focus of the research work. The evaluation is essentially one of the effects upon the construction time and its consequential cost implications to produce the method/time/cost trade-off. This requires that in any design proposal:

(a) The significant construction activities are identified.
(b) Their interrelationship is identified.
(c) The activity duration is calculable.
(d) The cost implications of varying construction durations is calculable.

THE CHARACTERISTICS OF THE CONSTRUCTION INDUSTRY

The existing techniques

Those familiar with the construction industry may wonder why the existing techniques of network analysis are not used to solve this problem. In theory they are certainly capable of handling sequence, time and to a limited extent cost. However, in practice a network is generated for each problem which requires extensive analytical ability and experience. This experience is held by the contractor but separated from the designer, who requires it, by time (sometimes years from design to execution) and practice (contractual commitment and responsibility which prevents contact between designers and contractors).

Need for rapid evaluation

It is during the initial development of the design when many concepts are considered, reviewed, discarded or settled upon to create a building. The process is very rapid and is in fact too quick for the conventional time, cost and planning techniques to function and extensive use is made of rules of thumb, experience and parametric estimating of dubious value. Designers, therefore, require high quality accurate information in hours instead of the normal days or weeks.

Response in meaningful terms

The response that: 'given a particular design problem solution A will be more difficult to construct that solution B', does not meet the demands of the client or design profession because traditionally it is left to the contractor to overcome the resulting problems in any design detail. This is done at a cost which is being questioned by many clients. The demand therefore is for a response in meaningful cost terms, ie, because solution A is more difficult it will cost £x more than solution B.

Problem solving in this context, is an immense task because of the large number of variables operating simultaneously giving rise to very large and complex decision systems. Even to consider, let alone solve even a small problem in a building requires that the context of the problem is considered which eventually involves considering the implications on the whole building. For example whether a steel frame or a precast frame is the more suitable solution to providing an economically constructed structure of a building requires a knowledge of the site process attributes of the available systems for both the steel and precast frame. Equally each system requires different configurations of foundations and the cladding will differ in its detail. Inside the building the services will be affected as the precast structure offers less flexibility than the steel frame structure. The variation in the services affects the finishes and so on. Making a comparison let alone an optimization with so many interlinked variables is inordinately complex hence the use of the immense power of the PROLOG language to develop the expert system.

THE EXPERT SYSTEM

The work has taken advantage of the method of inferencing within PROLOG to develop a first prototype program able to satisfy the demands of the design team detailed above. The system is essentially a data base of construction systems with a routing device. For each part of the building for which the industry provides a choice of components or systems, the program requests a decision on which is to be considered. This is done to create a model of the building to be analysed. When components are chosen the relationships between them are automatically coupled and their durations and overlaps calculated in relation to the size of each section of the building. The program comprises three parts:

The data base

Primarily the knowledge of construction components is held in a data base containing their implicit site activity. This is only one aspect of the total knowledge available about a component. As shown in figure 1 the knowledge comprises information about itself - the duration calculation and resource level - and how it relates to other components.

The inference engine

The program mirrors very closely the approach taken by construction planners by eliciting general information about the building which is developed by further questioning as more information becomes available. The search of the data base is by forward chaining to select the appropriate knowledge once the components have been identified. All of the information is ordered by the program to form a network of interlinked activities representing the characteristics of the particular design. The time calculation is then made for each activity followed by the unique characteristic of this program, the calculation of the relationships between the selected activities.

At this strategic level of analysis insufficient detail is available to assess the detailed operation of each activity on site. The attempt is made to predict the worse case situation based on the principle that the activity once it commences will continue uninterrupted until completion. It is a characteristic of the UK construction industry that individual activity resource levels are very low with little ability to absorb large fluctuations in demand.

The most important consideration is therefore the relative construction speed between the two activities to ensure that the preceding activity does not disrupt the activity, as shown in figure 2(a). Activity 2, if it were to commence at its earliest start time, would be delayed at week 3 by the failure of activity 1 to release work area sufficient quickly. In practice, activity 2 would be delayed starting until week 3 to ensure continuity as shown in figure 2(b). This describes working of the lead-in link but it is more complicated in that there is a need to ensure that there is sufficient time to complete activity 2 after the completion of activity 1. Therefore, activities are linked either with a start to start link or a finish to finish link which controls the minimum overlap and the minimum completion time parameters. These parameters are used to establish the resources required by an activity. The initial activity duration is based on a resource level of 1 unit which is progressively increased until the activity duration fits within the parameters as determined above. In practice the activity duration cannot be less than that established by the parameters and so the activity duration from the previous step is used. This is a very complex interactive process of evaluation and fit to ensure each activity assumes the most appropriate time slot. In conventional planning systems these times must be stated explicitly which until now has been based on experience rather than understanding the underlying theory.

The user interface

At present the inquiry is a series of questions requiring text and numeric

information although it is a long term objective to be able to interrogate graphical data direct. The output is in the form of a conventional bar chart, together with an ability to interrogate the detailed characteristics of the data generated by the simulation for each activity.

KNOWLEDGE ACQUISITION

The program outlined above is the culmination of several years analysis and research into the mechanisms which control construction time and cost. The theoretical analysis of the problem (Gray, 1983) showed that project costs comprised two elements: the unit cost of work and the costs controlled by the time it takes to perform the sequence of tasks. Detailed analysis (Gray, 1981) showed that over 80% of the time related costs were directly related to the characteristics of the building and could be quantified, however, an essential input to the calculation of their cost is elapsed time. An analysis of construction time (Gray, Little, 1985) shows that construction activity is a direct consequence of the design as is method and resource levels and is thus predictable. In such complex problems expert systems can only be developed from a sound understanding of the underlying principles.

CONCLUSIONS

Expert systems technology has opened up an ability to explore areas in the construction industry which have hitherto been regarded as either too complex or too specialist. Barriers have had to be broken down and knowledge domains breached to interconnect effectively the interrelated aspects of the construction problem. This work is taking a first step. It has broken new ground. It will enable knowledge transfer between previously separated specialists. Hopefully it will demonstrate the potential of computer technology to advise and thus improve decision making.

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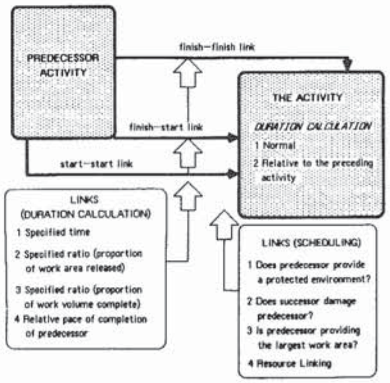

Figure 1 Data base structure for an activity

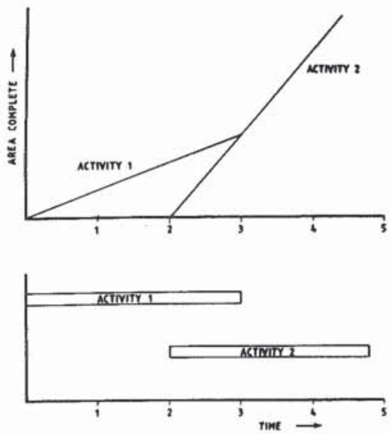

Figure 2(a) Activities scheduled at their earliest starts

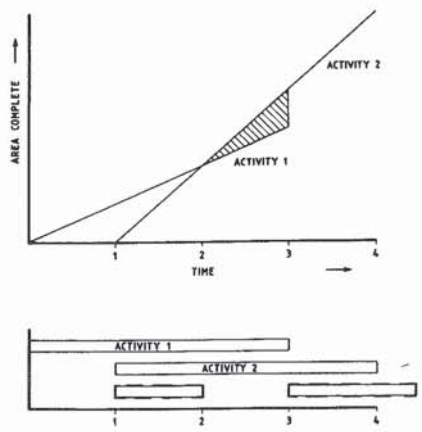

Figure 2(b) Activities scheduled to avoid interference

Knowledge-Based Expert Systems for Construction Risk Analysis

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ABSTRACT:

Construction engineering and management involves many complex decision-making problems in such areas as resource planning, cost estimating and control, design of construction process operations, risk management, and other construction management problems. Most of these tasks are highly dependent on engineering judgement. Contractors must use rules of thumb and subjective evaluations to solve the problems. Traditionally, construction management models are developed based on explicit algorithmic analysis and optimization programs. In these models the creative component of the construction management has been largely ignored. In the real construction world a large number of rules are not based on the mathematical laws, but they are based on the assumptions, limitations, rules of thumb, and management style of an expert who has a great deal of experience in construction operations, and can define the applicable conditions and corresponding actions. The main goal of this paper is to present a knowledge-based expert system for construction risk analysis which allows the unsophisticated field engineer to make decisions as if a construction field expert was providing advice and guidance based on long experience. The model describes how practitioners use, integrate, and combine elements of information and knowledge to develop an efficient and innovative management decision model.