AN A.I. APPROACH TO AUTOMATING THE RECOGNITION AND EVALUATION OF LOGIC CLASSES IN CONSTRUCTION SCHEDULING

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ABSTRACT

Construction schedules exist in many forms to serve many purposes. They are prepared by various means by different individuals either manually or aided by computer software. Work which is underway to automate the production of schedules is now being supplemented by the development of an evaluation package for general usage. Outlined in this paper are aspects of a research project which uses artificial intelligence techniques for the purpose of automating the evaluation of construction schedules. In particular the early stages of the project, which recognise and utilise the logic in schedules, are detailed. Different classes of logic are identified and a general activity logic model is introduced. Techniques for interpreting activity names and for building and using knowledge bases are explained and illustrated with simple examples. The application of the early work to the objective of automated schedule evaluation is discussed.

INTRODUCTION

In recent years there has been some interest in automating the production of construction schedules and a number of approaches using artificial intelligence techniques have emerged for tackling the problems (1,2). Any developed system emerging from these approaches should be capable of self -evaluation for users to have increased confidence in the results.

At present schedules are produced by individuals (or small teams) working from their own base of knowledge using algorithmic computer software for the benefits of speed and presentation. Evaluation, if it occurs at all, is likely to be little more than a brief check by a colleague or a rudimentary appraisal by a client's representative. Checking may only be for gross errors because of the considerable diversity in end results which different individuals could achieve. The end results could also be presented in many forms such as

* a barchart
* a network
* a space time diagram.

Schedules may also be produced to meet the needs of different groups such as

* the client
* the consultant
* the contractor.

They may further contain information represented to different levels of detail such as

* a master programme (or contract programme)
* a weekly programme
* a daily or hourly programme.

The problem of analysing construction schedules has been considered using a knowledge based system where the knowledge base is built from the construction knowledge of 'experts' and their rules for making decisions, the results being applied to the evaluation of contractors' schedules from a client's viewpoint (3,4).

Evaluation should comprise many careful considerations of, for example,

* timing
* resource utilisation
* cash flow
* completeness
* logic.

A general approach to evaluation suitable for application to different construction schedules produced by various means is described in this paper with particular regard to logic, its recognition and interpretation. The work is being carried out with the assistance of a research studentship from the UK Science and Engineering Research Council and supplementary support from Tarmac Construction, a major contracting organisation based in the U.K., which is interested in the results.

OBJECTIVES

The overall objectives of the research project are:

* To provide a knowledge based system for the automated evaluation of construction schedules

* To develop a system which can be applied to any type of schedule with identifiable activities

* To link the system to one being developed in parallel, but independently, for the automation of schedule production from contract documents (5,6).

The current phase of the work, as reported in this paper, involves:

* Identifying a feasible methodology

* Determining the classes of logic appropriate to construction scheduling

* Modelling the relationships between activities and logic

* Developing an inference engine to interpret input data for a schedule

* Facilitating the use of the acquired knowledge in the automated evaluation procedure.

LOGIC

Fundamental to the concept of schedule evaluation is the need to understand the logic links between the activities which comprise a schedule. Logic here spans many aspects of scheduling and exists to represent, for example, the technology envisaged for doing the work, the constraints imposed by time or resources, the requirements for the safe execution of the work and the available working space. Furthermore logic may be portrayed explicitly in a schedule (as in a network) or it may be ascertained only implicitly (as in a barchart). The reasons for the existence of logic links (of any type) are seldom stated but must be inferred. With this in mind, the authors suggest that logic links can be categorised according to the following 'S' classes:

* Structural
* System
* Specified
* Safety

Structural logic exists to account for the need to build a structure with due regard to the end result as perceived from the project documents. For example the construction of a concrete bridge abutment requires certain earthworks and foundation work to be carried out previously. This is structural logic. Once constructed, bearings, placing beams, fixing deck formwork or backfilling may be carried out as a result of structural logic.

System logic exists to account for the flexibility of construction methods available for different types of similar project where different resource types and levels can be used. For example, bridge abutments may be constructed in series or in parallel depending on the resource availability of, say, excavators, cranes, concrete gangs or joiners.

Specified logic exists to account for situations where no alternatives are allowed, or where specific constraints are imposed on the project by, say, the client. For example construction of a bridge abutment on a new embankment may be scheduled to allow a period of settlement for the embankment as designated in the project documents. It may also be specified that a whole stretch of embankment be constructed before subsequent excavation for the abutment.

Safety logic exists to account for supplementary system logic where matters such as work space and adjacency of hazards are important considerations. For example a short span bridge may present too congested a working space for both abutments to be scheduled simultaneously.

Classifying logic in these ways enables the schedule evaluation to proceed towards specific goals, but the logic model alone is not sufficient. The above examples have related logic to particular activities in a schedule. The relationship between logic and activities is now considered.

ACTIVITY LOGIC MODEL

Much information can be gleaned from schedules by examining their activities. Activities are the itemised elements of work which the scheduler considers appropriate to the requirements of the schedule. Experienced personnel can deduce what sub-activities lie behind the more global descriptions which are sometimes used. An automated system must be able to do the same. For example a schedule for a highway project may contain the activity CONSTRUCT BRIDGE 'A', or maybe BRIDGE 'A' ABUTMENTS or maybe FIX ABUTMENT FORMWORK. Whatever the level of detail the activity can be related to any or all of the four types of logic link.

It can be reasoned that activities exist in a schedule owing to a logic connection with a preceding activity. In other words an activity requires logic links (RILS) with preceding activities before it can be executed. Similarly as a result of an activity being carried out other possible logic links (GOLS) are generated. A general model of an activity can thus be created by incorporating the required and generated logic links (Fig 1).

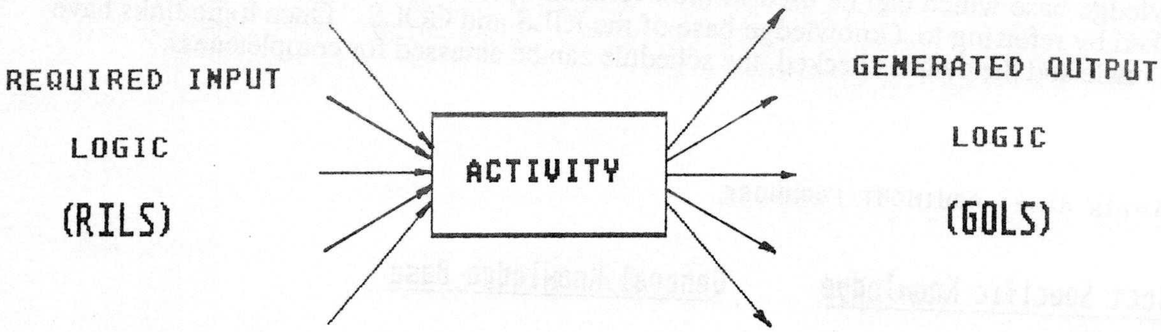

Figure 1 - Activity Logic Model

The RILS can emanate from any of the GOLS of preceding activities, similarly GOLS can be picked up by any subsequent activity. Not all GOLS need be connected to succeeding activities, but all the RILS must be supplied by preceding GOLS. The automated system must be capable of making the logical links in its inferences about the schedule being evaluated.

ACTIVITY NAME INTERPRETATION

An automated evaluation system clearly needs to understand and interpret a great deal of information contained or implied in the activity names. This information is structured in separate knowledge bases containing general rules and project specific data which is expanded as the scheduling data is input to the system. This fulfils one of the fundamental requirements of a true knowledge based system, namely that it can learn from experience, and as a consequence improve the user's confidence in the automated system.

Information is extracted from the activity names by a process called 'parsing', the recognition of words or phrases in the activity name. Once identified the system attempts to categorise the 'word' by searching through a tree structured knowledge base to match it with a 'word' about which it has some knowledge. This is an interactive procedure because one 'word' can have more than one interpretation. For example CONSTRUCT ROAD BRIDGE means construct a bridge not a road, so 'road bridge' would be a 'word' taken into a project specific knowledge base.

Several levels exist to define the detail which may be contained in the activity name. The various levels range from types of structure (e.g. bridge), particular type(e.g. suspension etc.), structural element (e.g. abutment), component of work (e.g. formwork) and item of work (e.g. fix) (Fig 2). There can be as many levels as necessary to define the work element in the activities. This approach is similar to classification systems used in knowledge based scheduling systems (2,7). Particular information on, for example, which bridge of several on a project would also be extracted and held in another, project specific, knowledge base.

As an example, for an activity name ABUTMENT FORMWORK the system searches for and finds abutment in its knowledge base, knows implicitly that the structure is a bridge and the items of work associated with abutments and with formwork, (e.g. fix, strike) and confirms whether others (e.g. make, clean) are included. It would need to ascertain by query what type of bridge etc it was if that information were not known to it. Figure 2 shows a representation of how project specific knowledge links with the general knowledge base which can be used in the evaluation procedure. Logic links can then be checked by referring to a knowledge base of the RILS and GOLS. Once logic links have been made and the details checked, the schedule can be assessed for completeness.

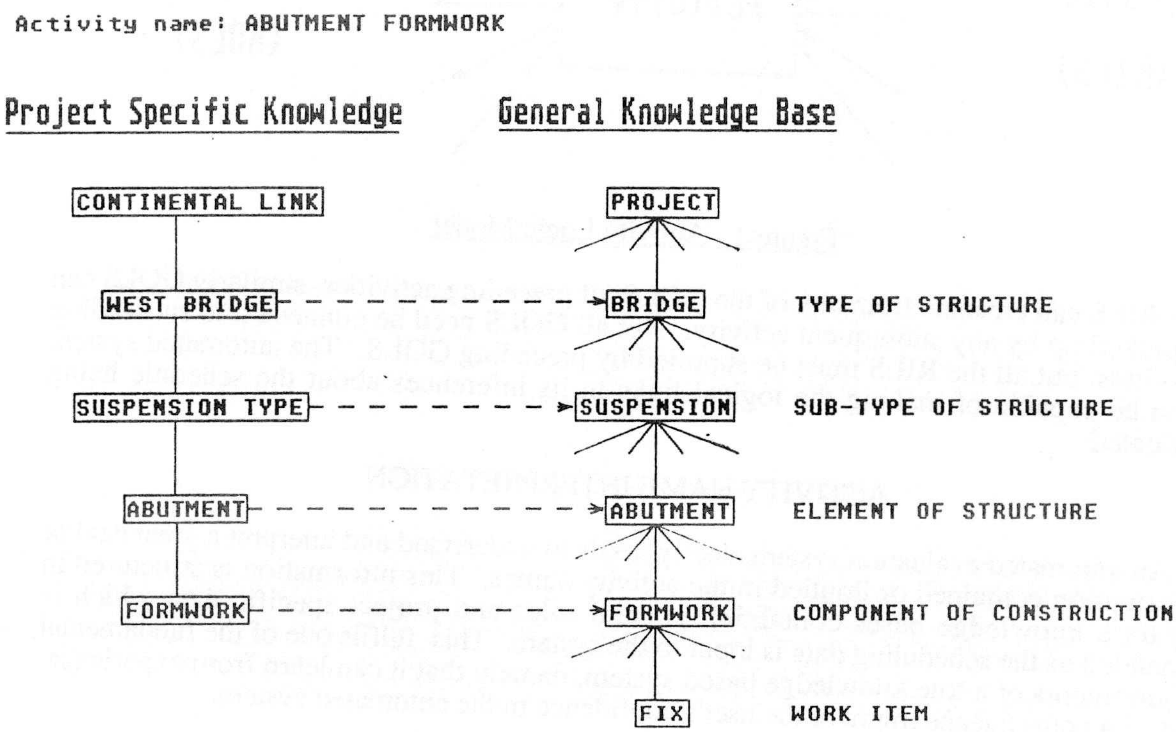

Figure 2 - Activity Name Interpretation

This system will eventually function as an automated one once the activity name data has been input. In automated scheduling systems, or simply computer based ones, this laborious input stage can be eliminated and the evaluation proceed more smoothly.

IMPLEMENTATION

The system is being developed for use on microcomputers with the Intel range of microprocessors. The early work started on an Opus PCII (8088 chip) machine at 8MHz with 1MB of RAM and a 20MB fixed disk, under MS-DOS 3.2. Current development work is on an Apricot Xen-i 386 (80386 chip) machine at 16 MHz with 1MB of RAM and a 45MB fixed disc under MS-DOS 3.3 and MS-Windows. It is anticipated that several more megabytes of RAM and possibly an 80387 chip will need to be added as the knowledge bases grow and the inferences take longer to process.

Procedural programming in Pascal is used in the front-end processing with linking to an expert system shell tailored to the project's requirements.

Work initially concentrated on making the input of data more efficient and in building the structure of the knowledge bases.

Work will continue on knowledge acquisition for the system. This is an important area of work where it is hoped that the knowledge of several experts will be used to supplement and enhance the reasoning powers of the system and add a degree of qualitative evaluation.

The means and purpose of evaluation are now better understood and indicate that the system development should continue in a general direction rather than specialise in, say, network evaluation. The work will however proceed with the objective of understanding logic links before the criteria of timing of activities, reasonableness of durations, accuracy of estimated schedule, etc. are applied. This development will follow once the understanding of the logic is more advanced.

In future it is anticipated that linking to other software (e.g .estimating, valuation, quantities, conventional scheduling) will take place to expand on the evaluation potential of the system.

CONCLUSIONS

Progress has been made on the project towards establishing a methodology for a system to evaluate construction schedules. The system displays the learning ability essential of any true knowledge based system.

The system has great potential for use with schedules of any type but a universally applicable system for any schedule is a long way off.

Linking the system with an existing scheduling package, estimating and valuation packages, bills of quantities, etc. will be possible and will enable much more extensive evaluation criteria to be applied and incorporated into the system.

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