AUTOMATING AND INTEGRATING THE MANAGEMENT FUNCTION

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ABSTRACT

Today's construction robots are largely machines which simply carry out a construction task. Fully robotised construction must include automation and integration of the numerous management functions together with robotisation of the construction task. Important management functions, including planning, scheduling and budgeting, are discussed with a view to their automation using powerful microcomputers. These functions are shown to be suitable for automation using artificial intelligence techniques and the subsequent integration of these automated functions into a robotised construction project system is proposed.

1. INTRODUCTION

Construction robots are machines which carry out construction tasks. True robots should be able to apply some intelligence to their operations. In the manufacturing industry a high degree of robotisation can be achieved owing to the repetitive nature of much of the work carried out which makes the decision-making and instruction-giving processes simpler and more predictable. In the construction industry a similar level of robotisation is difficult to achieve for various reasons, which include:

- the unique nature of almost every construction project
- the exposed environment in which construction usually takes place
- the changing work environment which is also the product under construction
- the diversity of work tasks involved
- the numerous ways of ordering and organising the construction tasks.

It is currently possible to develop construction robots to perform specific tasks but the whole will only become integrated in a robotic sense if the management function is also automated. Key areas of management which help significantly with scheduling the construction tasks are:

- project planning and scheduling
- plan evaluation and validation
- coordinating the work execution
- materials management and stock control

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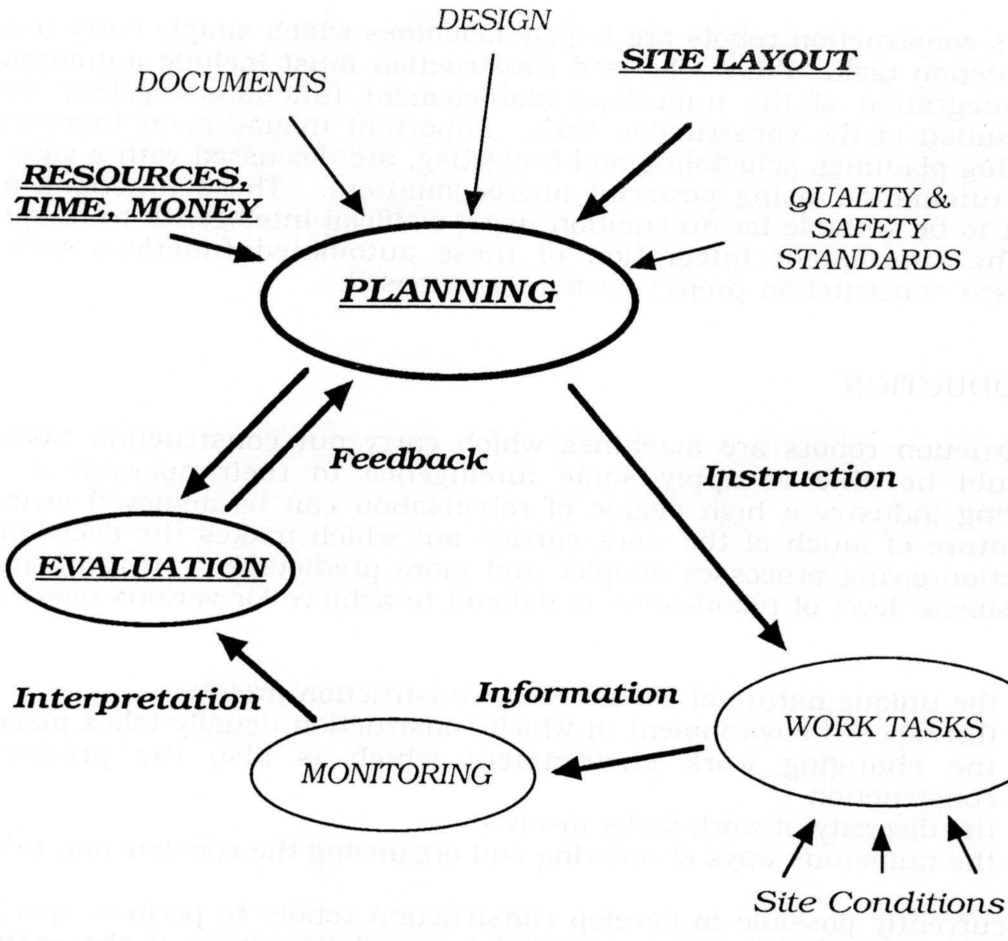
- budgetary control
- financial monitoring.

These management functions help with the overall coordination of the project, and with the management and attainment of quality, through a system of information collection, instruction, interpretation and feedback covering the planning, monitoring and evaluation stages of management (Figure 1). The automation of these functions can be achieved, currently in varying degrees, and thus an automated management system for the whole construction project can be developed. In this scenario project documentation could be interpreted directly through computer systems which would have the knowledge to make management decisions and relay the information directly to the robot work schedule with details of place, time and task. The execution of the task would then be monitored by the system which would learn from it and feedback the information to the management process.



A MANAGEMENT SYSTEM FOR INTEGRATING WITH WORK TASK ROBOTISATION

FIGURE 1

This paper discusses the automation of various aspects of the management function with a view to fully automating the construction phase from planning to construction completion. It concentrates on current projects (underlined in Figure 1) in the Construction Management Research Group at the University of Nottingham which are concerned with the following areas:

- automatic generation of schedules of work from project drawings
- resource movement and site layout
- general evaluation of project plans
- checking compatibility of different models of a project
- automated budgeting
- automatic network generation.

The Group is also examining an aspect of the integration of the design and construction phases by developing a computer-based system for the optimisation of the layout of routings for building services - a source of many problems in planning and coordinating the construction phase. This work is covered elsewhere (1).

The above research areas are covered briefly in this paper. All of the topics use artificial intelligence (A.I.) in some way and approach the limits of the processing capabilities of the microcomputers on which the software is designed to run. The work is discussed with regard to the contribution in automating the management function and becoming part of an integrated system for fully robotised construction.

2. AUTOMATION OF CONSTRUCTION PLANNING

This research is an on-going development of a 'finite element' based, project planning and scheduling package which uses knowledge bases, inference engines, heuristics and algorithms to produce schedules of work from project drawings. The system is designed for subsequent integration with the C.A.D. systems which are available for construction design.

Throughout the 1980s research projects with similar objectives were being followed (2, 3, 4, 5, 6) using different techniques to the Nottingham method for which network-based procedures were found to be limiting, principally because of their unsuitability for modelling linear and repetitive projects adequately and their inability to take account of site layout. The 'finite element' concept was introduced and it was found to be possible to generate plans of work which were validated on simple projects by comparison with plans produced by human experts (7).

The basis of the technique involves superimposing a rectangular grid on the (plan) drawings of the construction project. Each element in the grid needs to be sufficiently small so that only one resource can work within it at any one time. The work in this area forms a rectangular prism from the lowest point in the structure to the top of the finished structure. The algorithms and knowledge bases combine to produce a plan of work for a construction project.

The research developed algorithms to model resource movement around site from which work schedules were produced. This was extended with further algorithms for grouping work into activities (8). The knowledge bases were introduced to provide the ability to determine the work to be done and also deriving activities from the identified work. This was enhanced by other knowledge bases which helped model resource movement around site (9, 10).

A separate database contains information about the performance capabilities, costs and sizes of the resources available. The resulting schedules define the resource movement around site and the site layout.

Difficulties and limitations associated with the system which will be tackled in future developments include:

- The size of the project data files and the processing time required
- The project drawings are currently supplied to the package manually using a specially written interface
- A lack of knowledge (research) on the reasoning behind site layout decisions
- The grouping of work to form activities
- Resource performance.

For future development the current system needs more advanced computer technology, which could probably be provided by parallel processing, and an appropriate graphical interface for taking data direct from drawings and enhancing the supplementary user interface. The technique of using knowledge and data bases with inference engines linked with algorithmic procedures works well but requires much processing for reasonable results.

A separate approach to automating project planning by generating a network automatically is also being researched. This approach draws on other techniques for understanding activity names. These techniques were developed in a research programme on the evaluation of plans of work. The automatic network generation project is using neural networks in its approach.

3. AUTOMATING THE EVALUATION OF WORK PLANS

The evaluation of project plans in construction is seen to be an important task which will become more so as project complexity increases and computers become used more and more, initially as aids to planners and ultimately as automatic generators of plans of work. The problem of analysing construction schedules has been considered by others (11, 12). in one case 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.

The work which is underway at Nottingham to automate the <u>production</u> of schedules is now being supplemented by research which uses data base and artificial intelligence techniques for the purpose of automating the <u>evaluation</u> of construction schedules. Techniques have been developed for interpreting activity names and for building and using knowledge bases.

The research attempts to evaluate any plan of work which could be prepared by any interested party for any purpose and in almost any form, such as:

- a simple list of work elements
- a barchart
- a network
- a space time diagram.

Evaluation should be as thorough as possible in areas such as timing, cash flow, completeness, safety and logic.

A general approach to evaluation which is suitable for application to different construction schedules produced by various means is described elsewhere (13) with particular regard to logic, its recognition and interpretation.

Logic classes have been identified and a general activity model proposed which required input logic (RILS) and generated output logic (GOLS). Whilst this general approach has not advanced the project has moved on in other areas which contribute to the same overall objective by comparing different models of the same project rather than performing a general evaluation of each model. In both approaches the 'activity' names need to be interpreted.

An automated evaluation system clearly needs to understand and interpret a great deal of information either directly contained in or implied by 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 enables the system to 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 matching it with a 'word' about which it has some knowledge. This is a user interactive procedure because one 'word' can have more than one interpretation.

The detail which may be contained in the activity name is identified against various levels understood by the knowledge bases. The various levels range from types of structure (e.g. bridge), particular type (e.g. suspension), structural element (e.g. abutment), component of work (e.g. formwork) and item of work (e.g. fix). 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 (5,6).

The computer program produced by this research operates as an automated system once the activity name data has been input. In automated scheduling systems this laborious input stage can be eliminated and the evaluation proceed more smoothly.

The parsing process allows information from any type of project plan to be represented in a basic tree structure. In terms of plan evaluation this allows duplication checks to be performed.

In future it is anticipated that linking to other management software (e.g. valuation software) will take place to expand the evaluation potential of the system.

4. EVALUATING DIFFERENT PROJECT MODELS

The above work could be used for a comparison of any models of a project (tender plans, working programmes or as-built records for claims, etc.). It was applied particularly to the traditional British construction contract system which commonly uses two project models that are usually produced independently for different purposes. Both should contain all the work to be carried out in the project. The models are:

- a list of the activity names (from a barchart or network)
- a list of work items from a bill of quantities.

These lists exist in different forms and the comparison of the elements is not straightforward. It is difficult to identify whether they contain all the elements of work necessary for the completion of the project.

In the comparison method one of the project representations is processed to form an information tree. The second representation is then processed in a similar manner and its information overlaid on the first information tree. From this procedure it is possible to identify differences in the project representations. These differences are either omissions, duplications or different levels of detail.

This approach therefore permits the evaluation of completeness without the need for the initial development of a generalised construction knowledge base. This gives a saving in storage space and removes the effort of creating and updating the stored information. If both representations of a project suffer from the same omissions the system will fail to recognise this, a situation which should be unlikely if the representations are independently produced.

This method has been implemented and tested (14). When applied to different models of the same project, comparability and relative completeness can be evaluated. It also identifies whereabouts extra work appears in later plans of the same project, thereby indicating potential sources of extra payment or time allowances.

If the two representations compared were a plan of work and a bill of quantities for the project, the comparative process should allow activities from the plan and items from the bill of quantities to be associated. The allocation of particular items from a bill to activities or vice versa is the process of 'bill splitting' (15) which permits the financial and associated resource information from the bill of quantities to be passed into a plan of work for the project. In a similar way timing information can be used in the evaluation process.

5. AUTOMATED BUDGETING

This research considers the evaluation of some financial aspects of a project contained in different models of a project: the bill of quantities and a work activity plan. It introduces a technique for comparing these models and then for automating the budgeting of construction - an important management function.

The system also permits timing as well as financial information to be carried with its associated element through the 'tree generating' procedure. This allows various calculations to be performed. For instance, the dates for each activity can be carried through the generation of a tree and the period of working for each 'node' of the tree (i.e. activity) can be automatically calculated by the system.

The production of budgets is not a simple task. For a budget forecast to be produced a mapping of the money from 'bill items' on to the particular activities of work that they are involved in must be carried out.

The results of bill splitting by the system have been reported (16). The fundamental methodology has been shown to work on simple projects.

By allowing activities to carry with them information of interest to the planner (e.g. durations and financial values) a method has been devised to compare this information between different models of a project. To do this in an automated way has meant developing various methods for splitting the information without undue recourse to the user. These are possibly in need of further refinement but the results obtained so far are encouraging.

6. CONCLUSIONS

The management process is one of gathering, using and learning from information. This can be accomplished for many management functions through modern computer technology and A.I. programming techniques. With extensive computer power, an automated management system could be developed which could form the heart of a thorough, dependable system for construction project management. Justifiable decisions based on its massive knowledge bases could be fed as instructions directly to a robot workforce which would carry out the assigned tasks, at the same time gathering more information in the process to feed back into the system.

The research outlined in this paper has shown that such a system is achievable to a limited extent with today's commonly available microcomputer technology and techniques. The next stage of the work is the further integration of the automated systems so far developed and the extension of the research programme to cover a wider range of management functions.

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