MPCP: COMPUTER INFRASTRUCTURE FOR A COMPONENT-BASED BUILDING SYSTEM

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ABSTRACT

Total control over the design, management and construction of a building eludes most project teams. The magnitude of the design problem and the multitude of practical issues that must be resolved prevent it happening. Certainty is sought but rarely achieved because of the ill-defined nature of the design problem. Rekindled interest in component-based modular building systems provides a timely opportunity to explore ways of reducing uncertainty through better control over a building design from inception to handover. Powerful desk-top computers and software tools are now available to aid the intelligent design, management and construction of a building. With these developments in mind, a Master Project Coordinating Program is proposed and described. Its aim is to provide, on a modular basis, a set of tools that will help clients, designers, managers and constructors to achieve total project control.

1. Introduction

A new approach to building construction based on the use of a factory-produced parts-set especially matched to a range of purpose-designed robots, aimed at the provision of high-tech buildings, has been outlined in [1]. Complementary papers presented at this Symposium describe how some of the automation systems and robotic tools could be implemented and how a typical building might be decomposed into discrete components. This paper describes how the building design process might be automated by the use of a suite of computer programs collectively called the Master Project Coordinating Program, MPCP.

It is the authors' belief that the use of a well-defined kit of parts is, in principle, no different from specifying one of the modularised building component systems which are currently on the market. By structuring the range of parts which are available and constraining the ways in which they come together, designers and manufacturers can benefit directly from the use of the computer-aided building design packages which are proposed in this paper. Thus, the procurement of components can be formalised and embodied in the same software as is used to design the buildings. Furthermore, manufacturing requirements can be taken into account when project planning is being undertaken.

There is a move towards the use of a parts-set approach to building, in that architects and engineers are building up libraries of standard details for their CAD systems. This means, of course, that details are not reinvented for each project and can be recycled once proven in practice. Most construction CAD packages now have facilities for creating and using libraries and it is not difficult to envisage a component-based building system embodying them. From this it follows, somewhat naturally, that design data should be made available to the suppliers of the components. Indeed, if manufacturers actually supply the libraries, it is logical to suggest that the database would inevitably contain much of the data that they would need to begin production of the parts. Moreover, it becomes possible to mass-produce commonly used items, leaving just the one-off parts to be made to order. In this way, the automotive industry and the construction components supply industry would be almost identical in terms of their production methods.

2. The Master Project Coordinating Program

Serious consideration of the computer as a design tool began in the late 1960s when attempts were made to describe components of current building systems, thereby automating the design and/or evaluation of projects. Development work continued throughout the 1970s and culminated in the production of working computer systems such as OXSYS [2], TechCrete [3], CompuCon [4] and SHSS [5]. The main features of these systems were that they allowed the designer to progress from a conceptual design to a detailed design, through the process of assigning components to the production of working drawings. This culminated with the listing of components which could then be ordered and subsequently erected on site. At all stages, the design was visualised by computer, helping the designer to keep control over what the computer was actually doing. Additionally, it was possible to explore alternative design strategies and evaluate variations on a particular theme, rather than simply automating the design of one building [6].

Unfortunately, the computer technology of the day could not keep pace with the storage and processing demands of the building models which were created. Consequently, most of the systems did not survive when work on the building system for which they were designed was terminated. A notable exception, however, was OXSYS which was marketed subsequently as GDS by ARC in the UK [now McDonnell Douglas Information Systems]. Despite the set backs, interest in the ideas behind discrete, component-based building design has continued, for example ORBIC-1 [7], GOAL [8] and the MPCP discussed here. With current levels of computer storage and processing rates, there is good reason to re-examine the potential for component-based building design systems and to extend them to planning problems such as on-site resource management, and error analysis and recovery.

2.1 Scope of the Proposed System

The MPCP is intended to provide an environment for building design which is geared to the use of components defined in the parts-set [1]. To this end, an object-oriented approach has been adopted which allows the components to be progressively selected and designed. The building is represented as a set of objects, each of which is later described as a component when sufficient information is known about the materials of its composition, loads placed upon it and so on. Ultimately, it is intended that the MPCP model will be based around a central, relational database, from which all of the design data will be drawn and to which all of the participating members of the design team will have access.

Briefly, the client describes his needs to the design team via an expert system which acts as a front-end to the MPCP, from which a standardised form of building specification is produced. The architectural modules of the MPCP then help the designer to determine the spatial arrangement which is passed to the client for approval. The next stage is to impose a planning grid on to the spatial arrangement drawings and to adjust wall, beam, column and cladding layouts to suit. Structural elements can be assigned to lie along or across the grid lines, and can be taken directly from the parts-set. Once the grid layout has been approved by the client, a more detailed structural analysis can be undertaken: members can be treated as rigidly-framed or pin-jointed, and the complete frame analysed accordingly. Electrical and other services can then be placed on to the structural grid, before any final consistency checking is carried out.

Module	Input	Output	Description
Building Specification	Site plan, floor areas, no. of people, equipment.	Standardised building specification.	Front end to MPCP, gathers data via expert system to produce a complete building specification.
Architectural Design	Standardised building specification.	Building layouts and architectural spaces.	Determines the spaces, connectivities and precedences for layouts of floors. Places a planning grid and fleshes out design with the first components.
Structural Design	Building layouts and planning grids.	Components on grids; check structural stability.	Places components and checks overall structural stability of frame.
Services Design	Building model fleshed out with components.	Services laid out on planning grid; set in components.	Overlay services on to components and check consistency, performances and efficiencies.
External Envelope	Structural grid, components, and openings.	Lists of components, fixings and joints.	Checks efficiencies of cladding types, designs layouts and assigns correct components.
Component Scheduler	Partial list of components in building.	Lists of components and manufacturing data.	Consistency checks, costs, component data and manufacturing data. Checks frequency of use - stock vs one-offs. Assigns bar codes.
Construction Sequencing	Building model and component lists.	Erection precedences for components; plans erection sequence.	Network-driven planner for erection purposes. Uses knowledge derived in the design process. Plans slack time and contigencies.
Construction Management	Building model, erection plans and resources.	Action plans when invoked by site staff.	On-site facility for managers and site staff for use in emergency situations. Re-computes networks and re-assigns resources to cope with problems.

Table 1: Example Module Capabilities in the MPCP

The building model is then examined by a components' scheduler which takes-off relevant details about the components, including for example, how to fit the services into the floor cages. The output from the scheduler is a list of components with details of manufacturing requirements and likely resource needs. Also, a breakdown of what parts are standard and which are one-offs can be produced. Costs can then be estimated as a check that the building is within budget. From the list of parts, manufacturing schedules can be derived, along with detailed erection plans. Each part can then assigned a unique identifying number which can be translated into a bar code for use on site.

On-site resources can also be determined once the complete parts-list has been produced: robots and plant can be assigned to sites or hired as necessary. Each part needs to be checked against the MPCP model as it arrives in order to eliminate errors due to the incorrect shipping of parts. The main emphasis of this part of the MPCP is the use of CAD and expert systems in order to produce components and work schedules for the on-site robots, automation aids and operatives. To this end, a knowledge of the parts-set and the performance characteristics of the robots which are available is essential.

The final function that the MPCP could fulfil is to act as an error recovery scheduler, in the case where incorrect parts are shipped or an incident delays the project in some vital area. The construction manager can rebuild the construction schedule with the knowledge about the project that was generated during the design phase. One of the underlying principles is that a geometric approach alone is not enough to generate all the information that is required for a detailed design to be developed [9]. The modules of the MPCP are summarised in Table 1 above. Obviously, the list is not exhaustive and can be expanded at a later date.

2.2 Program Design and Implementation

The purpose of the MPCP is to provide a building design environment which also initiates production of the components and assists in planning the erection of the building. It is intended to be supported with interactive, computer graphics visualisation and simulation. To achieve these objectives, the following areas need to be addressed:

1. Building models for computer-based design.
2. Library coding of information in the database.
3. Components to form the basis of the CADCAM system.
4. Program modularity.
5. Overall program architecture.

2.2.1 Building Model

In order to support the required level of detail at all stages of design, a layered, hierarchical object-oriented model appears most suitable. This has the attraction of allowing the model to be accessed transparently by software packages looking for different types of information [10]. Such an approach is not new, but what is novel is the matching of model levels to the needs of different users. To the engineer or architect who accesses the building model, the representation is irrelevant. The important point is that they get the information they want in a form they can use.

2.2.2 Libraries of Data

Details about components, robot and plant availability, design codes, costs and so on need to be stored in databases which are frequently updated with fresh or more current information. These libraries will exist alongside the central model of the building and will be globally accessible by all members of the design, management and construction team. The use of libraries will allow data to be presented in a more compact form and will reduce the overall storage requirements of the building model.

2.2.3 Component Design

The design primitives of the building design system will be the components of the parts-set from which the structure is developed graphically. By adopting an object-oriented approach, the components, sub-assemblies and assemblies can be represented as hierarchical objects, and can thus inherit properties without the need for an explicit recalculation each time [11]. Consistency checking between software packages will also be easier if data about components are stored in the same way as the components; that is, in discrete packets, as opposed to being derived from global, conceptual entities such as walls which may be hundreds of metres long [12].

2.2.4 Program Modularity

Modularity in the system is assumed, since this will allow one software package to be upgraded without substantially altering another. What is required is a set of known specifications for the input/output parameters of each module and a complete and thorough description of what the module does. How the software module actually works is left to those who develop and implement it.

2.2.5 Program Architecture

It is proposed to implement a blackboard architecture (see Figure 1), that is an opportunistic planner [13] [14] supported by a truth maintenance system, TMS [15]. The reason for this is that a sequential planning system cannot easily overcome global inconsistencies in the model data, without performing numerous iterations around interleaved sets of closed loops [16]. By implementing a blackboard system, it is hoped to replicate the tradeoffs and compromises which a human design team make when they converge on a solution. Because of the computing power now available, the system will be able to explore a much wider search space than the human design team, thereby adding to the variety and richness of the architectural designs that can be produced.

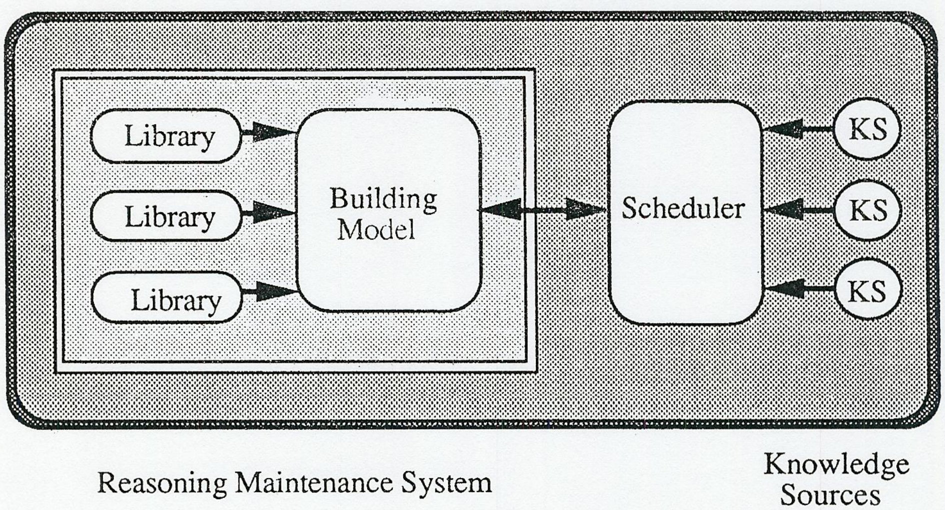

Figure 1: Blackboard Architecture

It is worth noting that the MPCP works in the way it does because of the narrow definitions of the components already in the parts-set. What is happening is that the computer system is being developed around a known building system, as was the case with OXSYS [2] and HARNESS [17]. The difference here is that the program design is sufficiently flexible to allow the parts to alter significantly without necessitating major surgery to the MPCP.

3. Conclusions

This paper has described a suite of software packages, collectively called the MPCP, which will facilitate the design and construction of buildings. The MPCP will gather data from the client via an expert system and will go on to produce component schedules and project management information. The development of the software for the MPCP is clearly an enormous task perhaps best suited to a large systems house. The authors currently do not have the resources to embark on such a venture and therefore it is proposed to develop a scaled-down version of the MPCP as a demonstrator. This will focus on the automation of the cladding process, an important aspect of building construction but one which can, at least in a sense, be decoupled from the rest of the building process. Development work on the demonstrator will run in parallel with work on the automation aids and robots outlined in [18].

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