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DESIGN COORDINATION IN DISTRIBUTED ENVIRONMENTS USING VIRTUAL REALITY SYSTEMS

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ABSTRACT

This paper presents a research project, which investigates the use of virtual reality and computer communication technology to facilitate building design coordination in distributed environments. The emphasis of the system, called VR-based DEsign COordination (VRDECO) is providing a communication tool that can be used by remote designers for settling ideas before they fully engage in concurrent engineering environments. VRDECO provides the necessary design tools, library of building elements and communication procedures, for designers from remote places to perform and coordinate their initial tasks. It has been implemented using available commercial software packages, and is used in designing a simple house.

VRDECO facilitates the creation a preliminary design and simple communication with the client. There are, however, some difficulties in the development of the full version of VRDECO, i.e.: creating an adequate number of building elements, building specification database with a sufficient number of choices, and establishing a systematic rule to determine the parts of a building that are updateable.

Keywords: Design coordination, virtual reality, communications.

INTRODUCTION

Each stage in the design process produces output information of data that is transferred to the next stages. Participants screen out the data relevant to them and produce new information. This process frequently fails under a strict schedule because of the problems of co-ordinating the design efforts. Alterations made by one designer are not copied immediately onto other designers' information. Owing to lack of detailed procedures for verifying and recording drawings, reports and database, mistakes are unavoidable. Furthermore, the extra time needed for these procedures adds to the cost and time of the design process. Creating an integrated building model for all the project's participants provides the possibility of reducing the impact of these problems and increasing the total productivity.

Using computers as the design tools may improve communication during the design process. It is now possible to build computer models with design objects that show real world characteristics and manners, i.e., shapes, sizes, behaviours, etc. [1]. Designers concentrate on supplying solutions to the construction of the same building by adding, changing or deleting objects in their particular tasks. Much of the work of transferring information and interpretations could be avoided by installing a 3D building model at the centre of all tasks. This approach is illustrated in Figure 1.

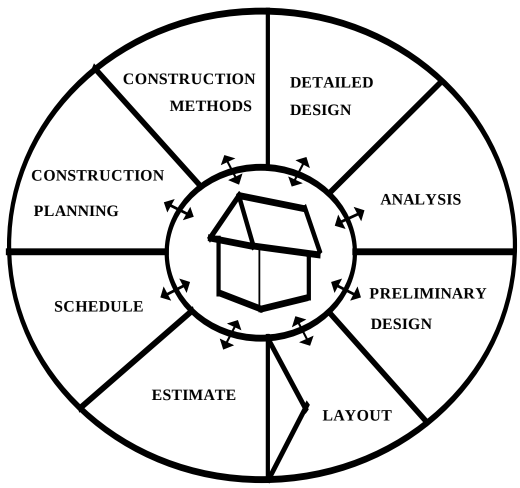

Figure 1. The Building Model at the Centre of the Tasks (Adapted from [1])

The different design stages in a design project are now common to be accomplished by the

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different firms. If the firms are globally dispersed the coordination at the initial stages of design is very expensive. Before they fully engage in concurrent engineering environments, systems or procedures are required to accommodate the coordination at these stages.

VIRTUAL REALITY SYSTEMS

Virtual reality (VR) systems are a relatively new development in information technology. A VR system is the computer system that can generate a synthetic environment within which users can navigate and interact with the virtual objects as the users in the real world [2]. The VR system generates three-dimensional and interactive environments i.e., virtual worlds.

There are two types of VR systems, namely immersive VR systems and non-immersive VR systems. Immersive VR systems are designed to present information as directly as possible to human sensory organs. They use special output devices such as a head-mounted display (HMD). The HMD surrounds the user and gives an audio and visual presence. It also provides virtual environments by shielding the user from the actual environments and cutting out external information. The non-immersive VR system is similar to a conventional computer system. It uses input and output devices such as a keyboard, monitor and mouse. Compared to the immersive system, the non-immersive VR system gives a lower level of spatial awareness. However, despite that drawback, its more conventional approach means the user does not have to use a HMD, which is still bulky and uncomfortable [3].

A typical VR system consists of two main components i.e., hardware and software [2]. Both components are very important for setting up the VR system and achieving a high level of realism. The hardware component comprises of three parts i.e., main processor, input devices and output devices. The main processor accomplishes the task of producing the virtual environment (i.e., creating the virtual worlds) and controlling the interactions with the user. The user in interaction with the virtual environment uses input devices. The devices may be 2D devices such as a mouse or 3D devices that provide the appropriate tools for 3D virtual worlds, such as glove, position tracker, digitiser and voice input.

There are two types of visual devices. The first type is the head mounted display. It has two liquid crystal displays (LCD) that give two different images to both eyes to create a 3D view of the virtual world. The second type uses a normal display monitor. The user experiences a lower degree of reality because it does not completely cover the user from the surrounding environment. However, it is relatively cheap and convenient. Another version of this type of visual device is using the screen that surrounds the user. This may be a dome [4] or a cube as used in the CAVE system [5].

A computerised design is usually created and presented using a CAD software system, which allows a designer to create and edit a complicated design. The traditional CAD systems however, restrict the interaction between the user and the computer system. The adaptation of VR technology to CAD systems brings a new dimension. The obvious advantage of the virtual CAD is that a higher level of visualisation of the design can be reached. In addition, the communication between designers and the client is easier using the virtual CAD and alterations may be made to the virtual building that reduce the costs of design and construction.

The VR system is also used in construction management. A prototype system for generating project plans and schedules, and the visualisation of the construction progress has been developed [6]. The prototype system uses (1) knowledge-based modules for creating site activities and their schedules from the building components and (2) the VR module for creating project visualisation.

COMMUNICATIONS TECHNOLOGY FOR VIRTUAL ENVIRONMENTS

The advancement of communications technology allows the creation of virtual environments such as virtual organisations, virtual teams, virtual offices, virtual shops, etc. Virtual teams are defined by Guss as groups of working professionals, separated by geographical, psychological and temporal distance [7]. These groups of professional and social communication, use telecommunications tools to fulfil business and job requirements and to reach common goals. Virtual teams provide new possibilities in the construction industry of replacing 'face-to-face' meetings which are very expensive and time consuming for distant participants.

There are several ways in which communications technology may be used to support virtual teams, including Public Video Conferencing Systems, Desktop Videoconferencing and the Internet. The public video conferencing system provides video network services. In which team members use it to hold meetings from different places, as they are being in the same room.

Desktop video conferencing is another version of video conferencing. In which PCs are used. This version may use either Integrated Services Digital Networks (ISDN) or Ethernet channels. ISDN is better for video conferencing, but the number of frames per second that can be handled is limited. Guss [7] believes that Desktop video conferencing is more suitable for the construction industry because of its capability, transportability and ability to operate in Windows environment.

The Internet-based collaborative applications can be built and used at very low cost. These applications are well adapted for use in virtual teams because they provide straight, rapid and easy world-wide connections. Another application of the Internet is Electronic Meetings. It brings people from separate locations to one meeting room.

THE VR-BASED DESIGN COORDINATION

The prototype system, named VR based DEsign Coordination (VRDECO), is intended to be used as a communication means for remote designers to settle design ideas and to produce the concept design based on a client's brief. It replaces the need for conventional physical meetings. VRDECO should have the following features: (1) enable designers to create a design model that may be explored visually and managerially, (2) allow designers to access and update the design variables and make decisions on managerial and engineering aspects of the design model, (3) produce the concept design and the process documents, and (4) provide communication means for remote participants.

The Framework of VRDECO

VRDECO consists of two subsystems i.e., the coordination hub and the distributed subsystems (Figure 2). The coordination hub provides the design model, the initial design information and coordination procedures. It connects directly to the coordinator or the project manager. The distributed subsystems provide design environments for designers. Each design environment receives the design model and specific design information from the coordination hub.

The project manager is either the head of the designers, the coordinator, or the client's representative. Firstly, he creates a design model using the initial design information in the coordination hub and then presents it to the designers in the distributed subsystems. He coordinates the discussion, and takes the decisions regarding the design model. The initial design information includes the requirements statement (derived from the client's brief), project site information, Codes of practices, guidance documents (SK-SNI, SNI, CIRIA, RIBA, Trade Associations, etc.) and manufacturers catalogues.

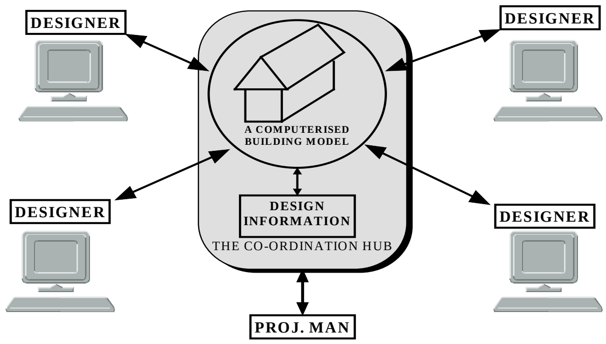

Figure 2. The Framework of VRDECO

The Distributed Subsystems

The distributed subsystems are a collection of the designer environments that are spread in the different remote places. All environments are connected to the coordination hub using communication media. They receive the design model and the initial design information from the project manager. If the design model does not fit the designer's requirements, the designer then sends requests for updating it. This process may be repeated until an optimum model is reached.

The Design Presentation and Representation

The design model that is created in the coordination hub has an important role. This model is presented to designers and used as a medium in the discussion. The design model should have the following features, (1) can be created easily and systematically, (2) can be explored geometrically and managerially and (3) the design variables of some components, such as geometrical and managerial information, may be updated as in normal design environments.

The design presentation consists of two modules (Figure 3). The first is the design visualisation module which enables one to create, visualise and explore the design model. The module allows users to discuss the design model by updating it, and records all users' actions. The second is the database management module. This module receives data from the design visualisation module and creates the reports and update.

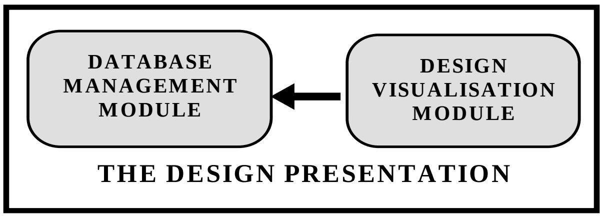

Figure 3. The Design Presentation Structure

The design visualisation module

The design visualisation module consists of the design tools, the library of building components, the design model that is created using the design tools and the library of components, and the user interface. This module is a virtual reality system that is able to show the complete design visualisation. A designer can interact with the design through the user interface. This module is illustrated in Figure 4.

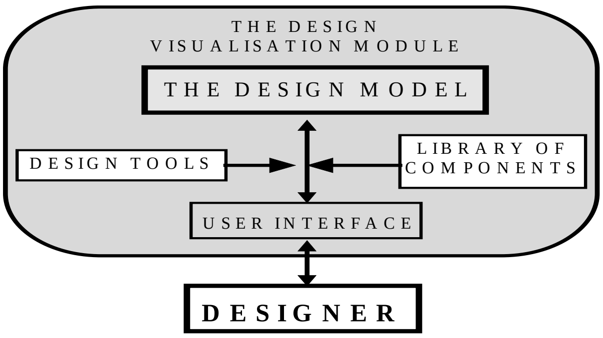

Figure 4. The Design Visualisation Module

The design model is built up from components and assembly of components. The components are composed from objects. Figure 5 illustrates the elements of the design model. Objects may be constructed from basic shapes or complex shapes. The basic shapes are a cube, sphere and cylinder. Complex shapes are created using programming procedures such as rotate, extrude or a combination of them. An object may have attributes of colour or texture to give a specific appearance. To form a component, an object should have size (dimensions) and orientation.

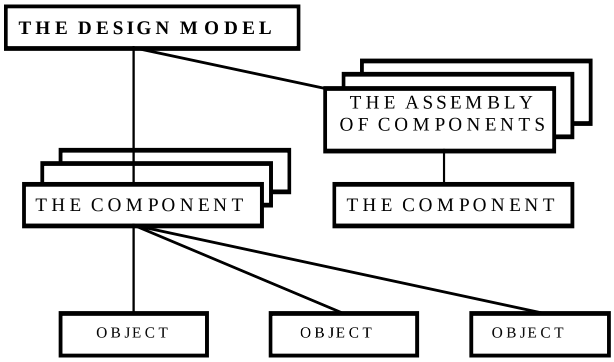

Figure 5. The Elements of the Design Model

There are single-object components, for examples column and wall; and multiple-object components such as door, window and stairs. Components have a number of variables i.e., positions, orientations and attributes. The attributes of components are used to characterise them. There are two types of attributes that may be attached to components i.e., text and programs. Text attributes are used for giving textual characters to the components such as qualities, prices, names, etc. Program attributes are used for furnishing components with certain behaviours such as movements, expansion, shortening, changing the visibility, etc.

Creating a design model needs a number of components, which include the fixed and updateable components. The updateable components may be updated on their attributes or positions (movable). Creating the design model can be automated by building a library of a large number of components. The design model is then built by inserting, copying, placing and manipulating the components.

To make a component movable, it should be grouped with other components to form an assembly of components. For example, a movable window consists of a window, surrounding walls and a program attribute. When the window moves, the sizes and the positions of the surrounding walls are adjusted to match with the new position of the window so that the overall size of the assembly of components is constant (Figure 6).

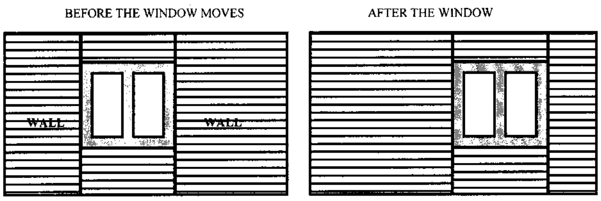

Figure 6. The Movable Window

The user interface is a mediator between the designers and the design visualisation module. Several forms of controls may exist as parts of the user interface; they could be dialogues, prompts, alerts or instruments. The dialogues provide the possibility for users to change the design variables. The dialogues may present discrete choices in form of the value options, or continuous choices using a slider. The prompts give users hints and a choice of actions that may draw the user's attention to continuing/aborting a process or displaying information. The alerts provide necessary warnings and used if the options are vital. The instruments display the current values of design variables or the results of calculations. The current values of design variables are important because they are used as references when users interact with the design. The results of calculations show users the effects of the actions.

The database management module

The database management module holds and processes the text-based design information i.e., the building specifications, design alterations and design decisions. This module has two essential files. The first is a database that contains the building specifications. The second is a database program that generates reports. Each record holds a specification of one component of building. It consists of a number of fields to store the information of the component such as name, quality, unit of measure, the description of the specifications, etc.

The number of component that is represented in the database is the same as the number of components that are used to visualise the design in the virtual reality system. The components that are hidden and not represented in the virtual reality system can be incorporated into other components. For example, if the foundations are not represented in the virtual reality system, their prices and specifications can be included in the external wall in the database file.
The database program produces reports about the design model, coordination process and the decisions. The program gets input from the specification database file and the files generated by the design visualisation module.

The Communication Systems

The final design model is obtained when the participants reach agreement. These compromises are achieved through discussions, analysing and optimisation among designers and the project manager. This process needs communication channels to link all participants. There are two communication approaches that can be used in VRDECO i.e., integrated and separated approaches. The integrated approach uses the networked virtual reality system and the separated approach uses the application of communications technology.

In the integrated approach, all participants communicate through the networked virtual reality system, and participants interact to the same design model. All alterations made by participants are therefore written to a single model and any action from one participant can be seen by the others. Using this approach, the illustration in Figure 4 changes to Figure 7.

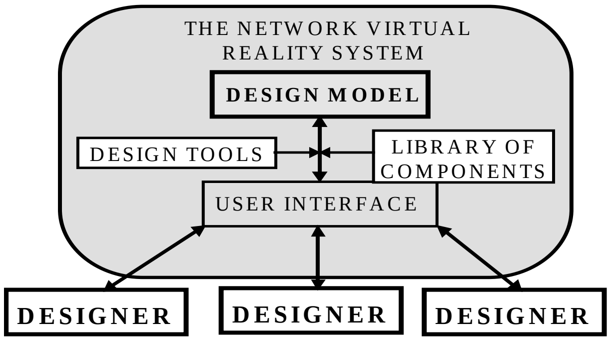

Figure 7. The Integrated Approach Communication System

This approach requires several conditions. Firstly, the virtual reality software package should have features allowing the user to update the design variables automatically and to write the output information in the computer network environment. These features are useful for users to change design variables and to record the process. Secondly, the virtual reality system should be able to distinguish between different users so that the user who makes interactions can be known.

The second approach is the application of communications technology. The project manager and the designers are separated and working on their computers. They communicate with each other using any communication media such as the telephone. The project manager and the designers discuss via the telephone while referring to the design model on their computers. This form, however, can only serve two participants concurrently. Video conferencing gives better communication perception and is able to manage more participants. The Internet may be used to exchange information for example, transferring the design model and the design information by file transfer protocols. Figure 8 illustrates this approach.

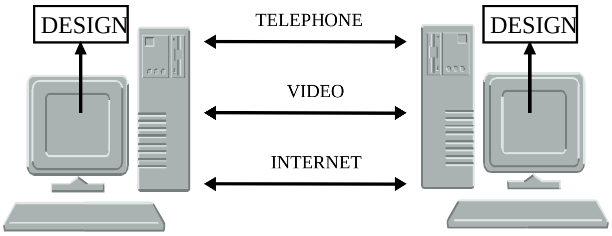

Figure 8. The Separated Approach Communication System

IMPLEMENTATION AND CONCLUSIONS

A prototype model of VRDECO has been implemented using commercial software packages. The Superscape VRT™ Version 5.00 virtual reality system is used for generating the design model. The database management system for processing the text-based information uses dBASE. Intel ProShare video conferencing is used for communication among designers.

A simple house design model has been created using VRDECO. The design model has some movable components so that designers may change the size and position of those components. Every component has a set of specification choices. The designer can activate one of them for every component to optimise the total cost of the design model. It can also be explored from different design aspects such as architectural and structural. By exploring the design model, designers can make decisions on different aspects of design.

Several benefits can be obtained when VRDECO is fully implemented. One benefit is the facilitation of creating a preliminary design. Communication with the client is also simplified, since VRDECO allows the users to explore the virtual worlds. The design process may be more efficient because the participants can discuss it through the same model.

However, there are some difficulties to be faced in the development of the full version of VRDECO. The first is creating an adequate number of elements to build the library building elements. The next problem is composing the building specification databases with a sufficient number of choices. Finally, there are problems in establishing systematic rules to determine the parts of a building that are updateable.

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