A COLLABORATIVE ENVIRONMENT FOR BUILDING CONSTRUCTION PROJECT TOWARD COMPUTERIZATION OF TOTAL INFORMATION

Environment for building construction

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Abstract

This study aims at developing a collaborative environment for construction projects in order to computerize the project management of building construction. As a first simplification, the project management team is assumed to consist of the following staffs, manager, planning staff, technical staff, production staff, quality staff, material staff and financial staff, each representing a function for the project. It is proposed in this study that, a collaborative environment is provided and that each staff works on the environment to fulfill his own work, to share the project information with other staffs according to predefined rules for information access, and to coordinate with them. Domain models have been established, and a prototypical collaborative environment, which is used to manage the total project information in the proposed pattern and works on a client/server database management system on Local Area Network (LAN), has been developed.

Keywords: building, construction, information technology, project management

1 Introduction

In recent years, more and more computers have been used for construction management in China due to the improvement of their ratio of performance to cost. Softwares have been extensively used for such works as cost estimating, scheduling and accounting. Some projects have established LAN in the construction site office for sharing resources such as files and printers and some companies have even constructed intranet systems. The government is now accelerating the computerization of the national economy, which urges the effective use of computers

in industries to raise the productivity. It is recognized that it is necessary to establish strategies for applying computers in view of integration in order to realize the computerization of the building industry (Ma and Chen 1998).

In the field of Computer Aided Engineering for Architecture/ Engineering/ Construction (AEC), many researchers are promoting the study on Computer Integrated Construction (CIC). In addition, the concept of Computer Continuous Acquisition and Lifecycle Support (CALS), which has been adopted by the military, are finding use in AEC. CIC and CALS are expected to contribute tremendously to the computerization of the building industry (Ma 1997). The proper modelling of the application domain is the key in order to take advantage of CIC and CALS. Many models have been established, and many prototypical systems have been developed as verifications of the models (Brown et al. 1998, Froese 1996, Stumpf et al. 1996, Rezqui et al. 1998). These works have provided many invaluable insights into the drive toward the implementation of CIC and CALS in AEC. However, many problems are still open for further study, one of them is how to apply the general models that have been proposed to specific domains in order to initiate the development of commercial applications.

Since a construction project is the basic cell of the building industry, it is proper to deal with it at first when promoting the computerization of the industry. This study focuses on the computerization of construction projects and proposes a new pattern of management of the total project information. Domain models have been established and a prototypical collaborative environment, which corresponds to the pattern and works on a client/server database management system on LAN, has been developed.

2 Patterns of management of total project information

As a first simplification, the project management team is assumed to consist of the following staffs, manager, planning staff, technical staff, production staff, quality staff, material staff and financial staff, each representing a function for the project. This simplification is basically in agreement with the project management organizations that are commonly in operation in China.

The total information management work that the staffs have to do, can be divided roughly into two stages, i.e. preparation stage and construction stage. In the preparation stage, the staffs are responsible for making the overall construction plans and schedules according to the design and the construction contract. In the construction stage, the staffs are responsible for making detailed plans, allocating relevant resources, organizing the production and guaranteeing the quality for every process of construction. The information that reflects the management work may flow among the staffs and is accumulated to form the construction documentation in different formats. Some of the documents must be submitted to the government administration as archives, to the owner for reference in the later stage of facility management, and to the representative of the owner and quality assurance agency as the proof of the construction quality, respectively. And other documents must be kept by the company for later use as reference.

2.1 Traditional pattern of information management

Traditionally, the staffs of the project team collects, stores and handles the project information using various forms while being in charge of certain processes of the construction project. Although computers have been used in some processes, for example in scheduling, the result (say, the schedule) needs to be prepared in paper form to be used by other staffs or by other organizations, such as the representative of the owner. In the construction documentation, some information is quoted in different forms, while others have to be transformed in several forms. As a result, not only the staffs have to do repeated works, but also it may cause redundancy and inconsistency in data and thus may invalidate some of these data. A collaborative environment provides an efficient solution to the problem.

2.2 New pattern of information management

2.2.1 Meaning of several terms

Before explaining the new pattern of information management, which we adopted in this study, two critical terms, i.e. collaborative working and environment, have to be clarified. In general, collaborative working means a situation, in which each staff fulfills his work and then the results can be obtained by other staffs immediately and the work can be continued. In this way, all staffs can share each other's information, and can cooperate intimately to carry out the work. On the other hand, by environment, we mean a common place where each staff may find the tools that he needs for his work, and at the same time, he can exchange data with other staffs conveniently. Such a collaborative environment usually involves a unified central data platform.

In addition, it is helpful to introduce the break down of a construction project. The construction stage of buildings consists of several phases, such as the phase of construction of main structures. Each phase consists of several processes, for example, the phase of construction of main structures consists of steel bar binding process, formwork installation process, the process of inspection on hidden work, and the process of in-site concrete casting etc. Further, each process consists of activities such as filling in certain data. Of course, since construction is carried out in space, the actual building is usually divided into many parts in each floor in construction, so that the above-mentioned processes and activities have to be iterated for each part in each floor.

2.2.2 Characteristics of the new pattern of information management

The new pattern of information management of construction project is based on the system configuration as shown in Fig. 1. According to this figure, a project team should construct a LAN in the construction site office. Then, the software of the collaborative environment should be installed in the server and in the client respectively. Here, the server is used to store the total management information of the project as a unified central data platform and to run the database management system, and the client is used to run the applications for the staffs. It is noted that the prevailing intranet technology is not adopted in this study. It is because the intranet platform is not practical in China now. However, it is only a problem of

programming if we turn to the intranet platform.

Under the above system configuration, the characteristics of the new pattern of information management can be summarized as follows.

1. The total project management information is unified and stored in the central database in the server. A client/server database management system is used to manage the database so that the staffs can access the information concurrently. It also makes it easy to develop specific applications after the collaborative environment is put into operation and to reuse the data of the project afterward.
2. The staffs work on the collaborative environment to fulfill specific works such as retrieving particular information as well as routine works, such as recording relevant data or making data summaries. All kinds documents that must be submitted to the outside organizations can be generated from the central database by using the applications provided in the collaborative environment.

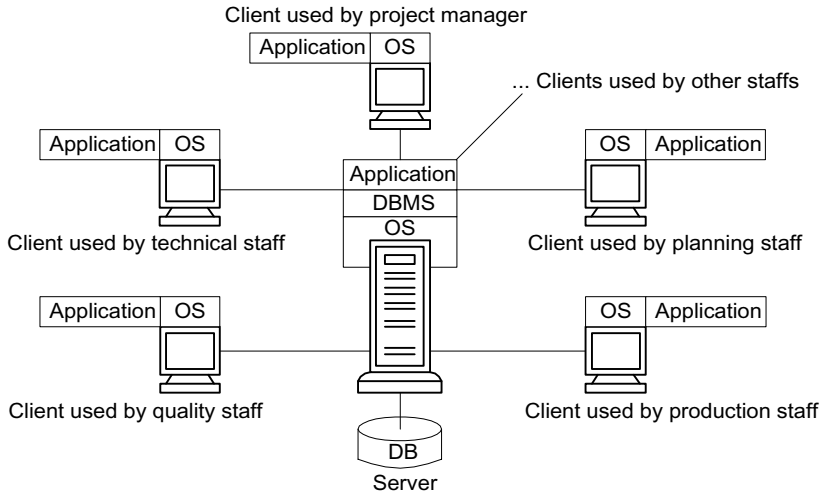

Fig. 1: System configuration of the collaborative environment

3. Through the collaborative environment, all staffs share the total project management information according to predefined rules and communicate with each other in an easy way, thus the paperless environment in the project can be realized. For example, after the planning staff produces detailed plans on computer, he saves them in the central database. At the same time, the other staffs can access the plans on their computer and then carry out their work based on the plans. Similarly, the other staffs may return a feedback to the planning staff as well. At any time, the manager can check the work of his staffs through the collaborative environment conveniently. An e-mail system is also involved in the collaborative environment to facilitate the communication between specific staffs or between the manager and the staffs.
4. The workflow of the staffs is organized automatically by the collaborative environment. For example, once the formwork installation of concrete structures is finished, the collaborative environment notifies the technical staff and the quality staff to carry out the inspection on the hidden work. This

function is helpful for the new staffs and for reminding the staffs of their work.

3 Modelling of the collaborative environment

Establishing proper models is the prerequisite for constructing a robust collaborative environment. Three categories of models have to be established, i.e. the models for the project management information that are handled in the traditional pattern of information management, that for the information needed only by the collaborative environment, and that reflecting the workflow. Among them, the first two categories of models represent static information and are used to determine the unified central database structure, and the third category of model deal with dynamic behaviors and is used to organize the workflow.

In this study, we have establish the models for the construction phase of main structures of in-site-casting reinforced concrete buildings. The models for the other phases and for other kind of buildings could be established by following the same procedure.

3.1 Adopted methods of modelling

The object-oriented technology (Booch 1994) and the Pascot's Datarun method (Pascot 1996) were used comprehensively in the process of modelling in this study. Here, the former was used to identify the objects, their relationships and the relevant attributes, and the latter was used to extract the basic data from specific management processes and to determine the database structure.

By using the object-oriented technology in the highest level, two domain vocabularies were identified, i.e. the staffs and the objects involved in the construction process. These vocabularies were broken down further until the atomic entities are obtained. The hierarchy of the classes that were formulated based on the atomic entities was then established to distinguish the common attributes shared by a number of classes from the specific ones owned only by a certain class. For example, the attribute for any resource includes quantity, quality grade etc., while the attribute for any steel bar, a kind of resource, includes type, specification, location of production, ID number, site-entry-time, site-entry-quantity, and test result etc. as well as the attributes for any resource.

By using the Datarun method, major current construction processes were analyzed to build the business model, to identify the basic data based on the model, and then to construct the central database structure. The process that was analyzed in this study includes the management of planning, material, steel bar binding, formwork installation, and in-site concrete casting etc. The basic data that must be recorded by the staffs were identified in order to realize the idea that the staffs need input only the minimum information.

3.2 Major models for the collaborative environment

Based on the above-stated methods of modelling and by referring to the existing models for construction process (Froese 1996, Brown et al. 1998), we have established the models used for the collaborative environment in this study. The

models are in different levels, where the high-level models are used as unifying references for the collaborative environment; while the low-level models are used for the actual database design and application design.

Four major models are shown in this section to illustrate the result of modelling.

3.2.1 Conceptual construction process model

As shown in Fig. 2, this is a high-level model reflecting the primary entities that are involved in the current construction process and the relationship among the entities. It is illustrated by using EXPRESS-G graphical notation (entities are represented as labeled boxes, specialization relationships are represented as heavy lines, and other association relationships are represented as labeled lines).

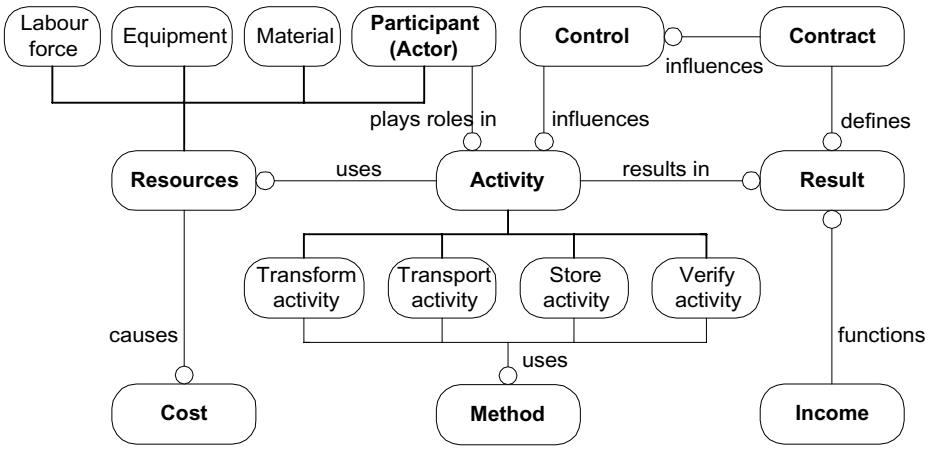

Fig. 2: Conceptual construction process model

3.2.2 Information management authority model

As stated before, in the collaborative environment, the staffs share the project information with other staffs according to predefined rules for information access. The information management authority model is used to specify the rules, as shown in Fig. 3. This model is adopted partly from a model in literature (Brown et al. 1998) and shows the entities involved in specifying the rules. In the model, the actor corresponds to each staff, the role to the function of each staff, and the authority to a set of rights that a staff possesses on an activity. For example, in the process of material test, a certain staff has the right of application for the material test, while another staff has the right to record the experimental results.

3.2.3 General system behavior model

The general system behavior model, being a high-level model as shown in Fig. 4, depicts the general behavior of all processes in project management of building construction and it can be used as a reference to establish the behavior model of each process. According to this model, processes are plan-driven. A plan for a certain process will be substantiated to the sub plans corresponding to each activity. When the process is finished, the feedback from the process is returned to the planning staff. Then the feedback can be reflected in the next plan.

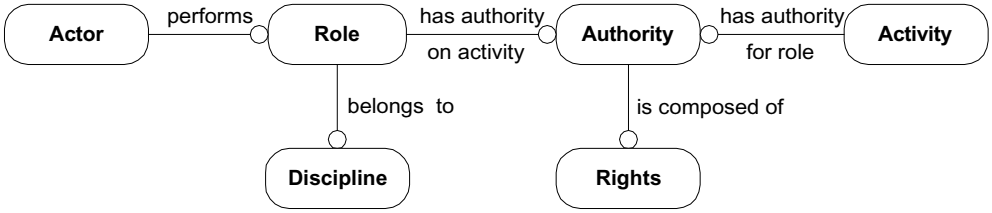

Fig. 3: Information management authority conceptual model

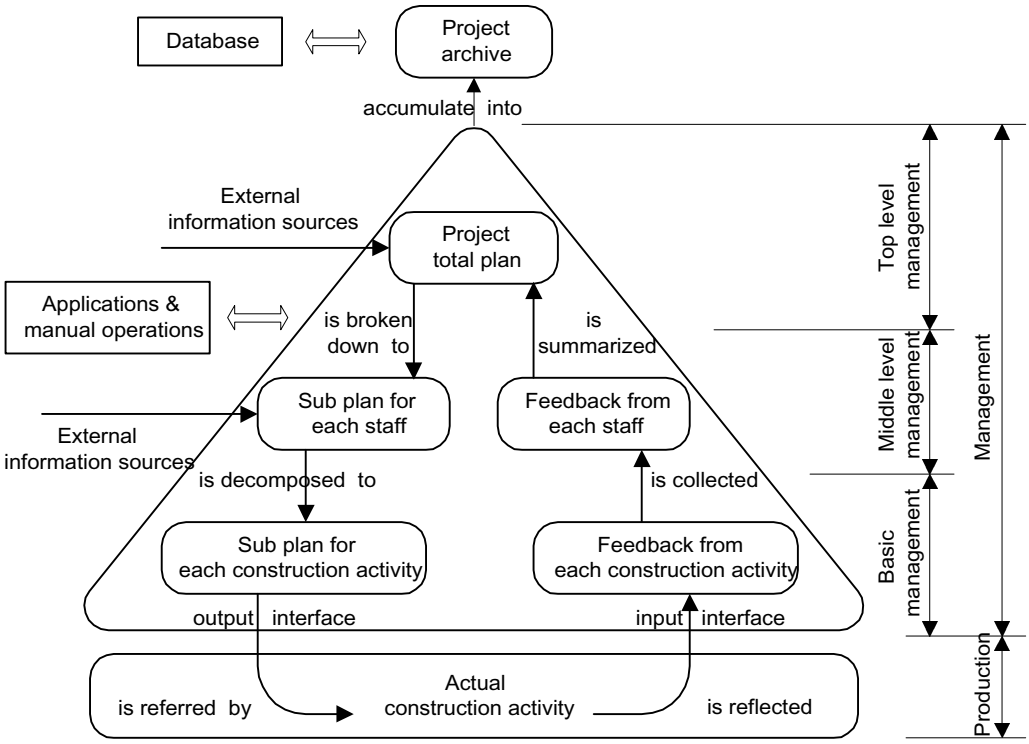

Fig. 4: General system behavior model

3.2.4 Example of system behavior models: for steel bar binding

Many models have been built corresponding to the system behaviors, here a model for steel bar binding will be illustrated. As shown in Fig. 5, when the process of steel bar binding starts, the collaborative environment should notify the technical staff to extract the steel bars from the design drawings for steel bar transforming, and to prepare the documents used for depicting the technical requirement. At the same time, the collaborative environment also notifies the material staff to make the plan of material provision. Further description for this figure is omitted because of limitation of space on paper. One may follow the figure to understand the whole workflow for this particular process. Obviously, this kind of model provides the rules for the

collaborative environment to organize the workflow of the staffs for the project management of building construction.

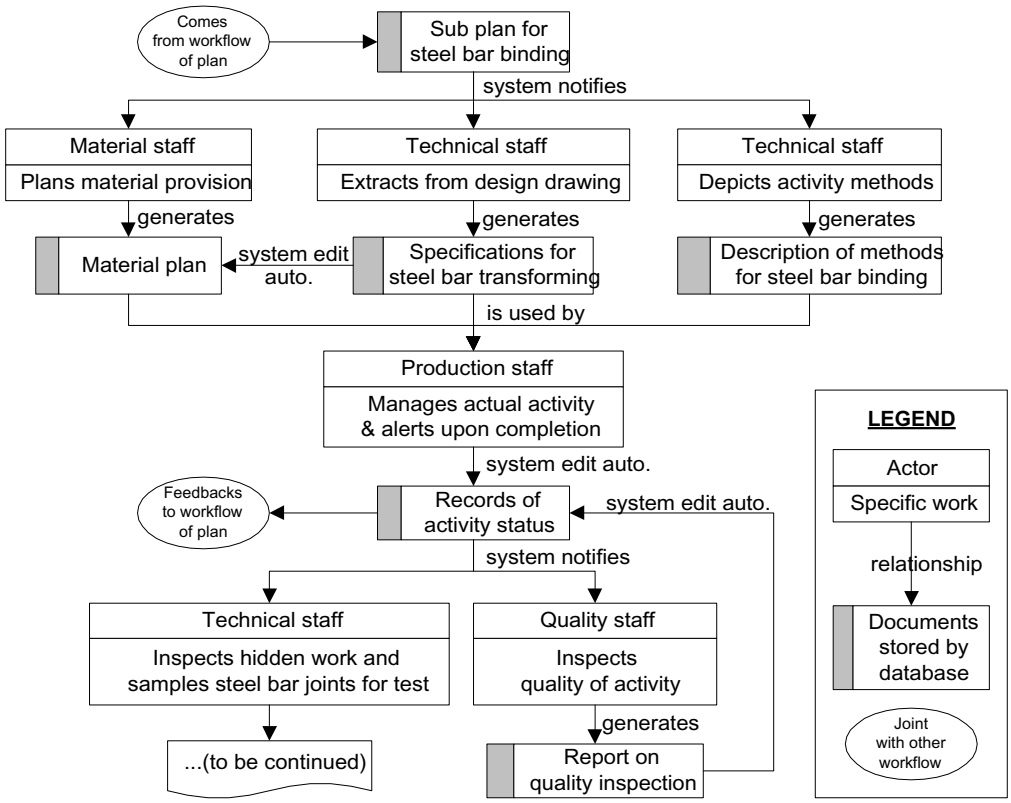

Fig. 5: Workflow of steel bar binding

4 Functions of the collaborative environment

The functions that the collaborative environment should provide can be clarified based on three views. First, in view of an individual staff, the collaborative environment should provide a series of functions for each staff to fulfill his works. Some of the functions are in common, for example, the function of browsing the project information. While others are different, because different staffs are required to record different information and make different decisions.

Second, in view of collaboration of staffs, the function of communication, as well as the automatic organization of workflow, should be provided, so that not only can the staffs work according to the notification from the collaborative environment, but also they can take their initiative to work actively. Besides, the collaborative environment should provide the function of showing the results of collaboration. That is, if more than one staff is taking part in a certain activity, each staff should be able not only to see the progress of his work, but also to see the progress of work of other staffs who are taking part in the same activity.

Third, in view of making full use of the computer's ability, utility functions

should be provided to help the user work more efficiently. For example, once the number of floor and the number of parts in each floor are entered, the collaborative environment should generate the activities of construction process automatically. The staff is allowed to edit the item of the activities and he does not have to input the items from scratch. In addition, various construction codes and specifications should be provided in the collaborative environment for users to look up efficiently.

The functions, which were determined based on the above considerations, are shown in Table 1.

Table 1: Functions of the collaborative environment

Menu item	Sub menu items	Menu item	Sub menu items
System	Project information Authority of information access Current information of processes Historical information of processes General information of project Codes and specifications E-mail	Confirm	Confirming of work state Confirming of work preparedness
		Technical	Construction diary Technical depiction Test application Evaluation of test result Technical support Technical inspection
Planning	Breaking down of process Construction planning	Quality	Quality inspection Quality analysis Handling of quality accidents
Material	Warehouse entry and exit registration Warehouse information Summary of material usage Analysis of material usage Material planning Material provision information	Test	Material test Construction test
		Archive	Project completion documentation Output of summaries

5 Implementation of the prototypical collaborative environment

The prototypical collaborative environment runs on a LAN. It consists of two parts, the server-side application and the client-side application. The former runs on MS SQL Server 6.5 on MS Windows NT Server 4.0 operating system, and the latter runs on MS Windows NT Workstation 4.0 or Windows 95/98 operating system.

The prototypical collaborative environment was developed using MS Visual C++ 5.0, and the central database was accessed by using ODBC 2.0. Most of the functions in Table 1 have been implemented, among them, many of the functions have been implemented ourselves, while some functions have been provided by integrating existing softwares. For example, MS Project 95 has been integrated in the collaborative environment for carrying out construction planning, and MS Excel 97 has been integrated to generate the summaries of project information. It deserves a mention that the existence of a central database system makes it easy to integrate other applications as well as to add new functions by using ODBC.

6 Conclusions

This paper focuses on the computerization of project management of building construction and has proposed a new pattern of total project information management based on the usage of LAN and a collaborative environment system.

Domain models have been established, and a prototypical collaborative environment, which is used to manage the total project information with the proposed pattern and works on a client/server database management system on LAN, has been developed. This work indicates that the pattern is feasible, and it seems that the methods used in the research are applicable to the computerization of similar fields.

7 References

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