Automation and Robotics in Construction XVI © 1999 by UC3M

A CONSTRUCTION SCHEDULE CONTROLLING SYSTEM USING WEB-BASED KNOWLEDGE TECHNOLOGY

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Abstract: Schedule controlling is a critical task in managing construction projects. However, in practice most contractors do not control and update schedule frequently due to the lack of proper controlling method. In the real construction world, most decision-making rules are not based on the mathematical method, but on the contractor's assumptions, limitations and management style. Thus, expert's experience somehow is a significant factor for performing a well scheduling. This paper will propose a construction scheduling system using both Internet technology and knowledge-based system to improve the traditional project scheduling. An object-oriented activity model is developed based on schedule controlling, progress measurements, and data exchanges.

Keywords: Scheduling; Expert System; Web-based; Internet; Object-oriented

1. INTRODUCTION

Project controlling is a significant approach to complete construction projects on schedule and on budget. Due to the limitation of current controlling technology, the project managers can not use this approach efficiently. Project control requires three elements: (1) a baseline, (2) measurement methods of progress, and (3) effective and corrective action [1]. An initial schedule is the baseline to proceed a project. Generally, only few special or small projects will follow the initial schedule from the beginning to the end. During the construction phase, most circumstances need to update the planned schedule, especially when a change order is necessary. Although project managers even realize the importance of updating and controlling schedules, they still do not update the schedule frequently. There are three major reasons for the above situation: (1)the lack of an effective approach that superintendents or foremen measure the progress of project and update the schedule more easily, (2)the lack of an efficient method to collect information needed and provide decisions to reschedule project, and (3)distance problem: the distance between job-site and office will influence the communication between project manager and experts.

This paper is focused to solve the problems mentioned above using Internet technology, expert system, and object-oriented modeling. Domain knowledge of the expert system for scheduling control is described. Then an object-oriented activity model based on integration of schedule control, progress measurements, and data exchange will be developed. By using this activity model, the proposed system can assist schedulers developing the initial schedule network used for schedule controlling. Job-site managers or superintendents can use a web browser at job site to input the actual schedule information into the project schedule database via Internet. Consequently, expert system associated with the adequate knowledge engineering experience acquiring from project scheduling experts can update project networks, and provide proper decisions for schedule controlling through the web that makes the real-time updating and controlling of a project schedule possible. Finally, the framework of the proposed system will be described as well as an overall schedule controlling system will be implemented.

2.LITERATURE REVIEW

The application of expert system in civil engineering has been evolved for the past decades. Since 1980's, much research reported that the knowledge-based expert systems applied for construction planning, engineering and management was developed rapidly [2]. Many expert systems related to construction management were developed to solve problems including of construction site layout, construction risk identification, time and cost estimation, and other construction-related issues [2]. As for those related to scheduling, William presented a knowledge-based approach to selecting a scheduling system [3] and a knowledge-based prototype for construction planning and scheduling productivity was developed by Benjamin [2]. Rasdorf and Abudayyeh proposed the work-packaging model to integrate cost- and schedule- control function and a conceptual design of data model for control based on relation concepts was built [4]. Most research presented about project scheduling was discussing about how to prepare an optimal schedule considering time or cost constraint using different kinds of approaches; however, less is related to the methods to control [4,5,6,7].

More research that improves traditional job-site data collecting and processing using information technologies were evolving. Most of them are related to automated data-acquisition technologies, such as bar coding, magnetic strips, optical character recognition and voice recognition. In 1991, Russell presented a computerized approach for collecting and processing site information that builds on the traditional superintendent's daily report [8]. Recently, while Internet prevails, the research that combines Internet and database technologies to help with job-site data collecting and processing also reveals its importance [9,10,11,12].

Several researchers proposed information models for schedule controlling, but did not mention the detailed approach to apply in practice. Those research using database, Internet, or other computer technologies to improve the processing of construction information still made a lot of efforts on data collecting, but did not focus on developing a systematic approach to schedule controlling.

3. PROBLEM STATEMENTS AND RESEARCH OBJECTIVES

As mentioned above, so far, there aren't any effective approaches to control the schedule; actually, it about depends on the engineers' experience. The condition of job site, however, is rather complicate and still contains many uncertain factors. The critical path changes frequently, but network can not be updated timely. Once engineers have any carelessness and are not aware of the change, they will not found the situation until a severe delay occurs and lose the best opportunity to control the schedule. On the other hand, the approach accessing to job-site information is limited and there is still not an effective mechanism for schedule controlling; therefore, the value and effectiveness of the information is low.

The objectives of this research are as follows: (1)Developing a new schedule analysising module to asssit the engingneers controlling project schedule and renewing the network; (2)Establishing an expert system based on the expertise to provide better strategies on scheduling; (3)Building an integrated framework to improve the effectiveness of the creation, transmission and proceeding of construction information; and (4)Providing an automatic real-time alarm system to avoid risks as well as relieve the loading of management. The entire architecture of the overall schedule control system is shown in Figure 1.

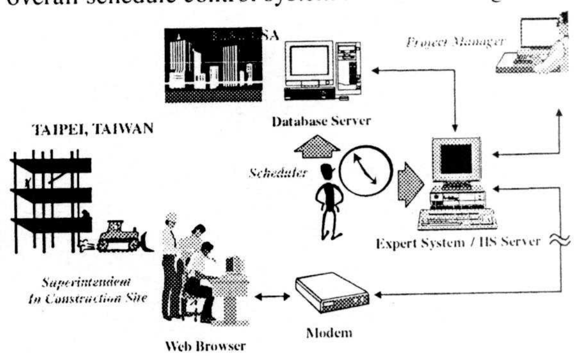

Figure1. Entire architecture of the overall schedule control system.

4. DOMAIN KNOWLEDGE

Schedule controlling refers to controlling the activities on the critical path but it ignores other non-critical activities. However, once the construction begins, critical path changes frequently due to the human and environmental uncertainties. If not updating the network immediately, engineers are unable to be aware of the change and that will result in ineffective control. Because of the frequent change of the critical path, it will waste lots of time and labor on updating the schedule network.

There are two methods to improve it: (1) Eliminating the frequency of the critical path changing to prevent the activities that have less float from being the critical ones; and (2) Updating the schedule network automatically and immediately by means of the techniques and mechanism of computers. Therefore, the right concepts of schedule control is that, whether the activity is critical or not, we need to control it with different efforts instead of controlling the critical activities only. Real-time updating the schedule is also necessary. However, it's obviously complicated and inefficient to control the non-critical activities at the same time. On the other hand, for activities behind schedule, it relies on the experience of engineers to provide corresponding strategies. Thus, the two parts involving with complicated and decisive work are what the expert system developed in our research works.

4.1 Requirements for schedule controlling

In general, the schedule control system need the following three basic functions:

(1) Provide strategies: For instance, if a critical activity is behind the planned schedule, the actual schedule may cause the project delay that would issue a delay penalty. The decision of crashing the project or paying penalty would be made at this point. In such situation, the schedule controlling system can provide the decision-makers with sufficient information to make adequate decisions.

(2) Provide precaution: Duration the construction phase, the schedule control system should predict the probable activities behind schedule according to the actual progress to provide precaution.

(3) Distribute resources rationally: The system must real-time update the network and automatically adjust the use of labor, materials and equipment according to the latest progress which can distribute resources more rationally to decrease the cost and risk.

4.2 Determine methods of progress measurement

When it comes to schedule control, first of all we need to obtain the difference between the actual progress and the planned progress, respectively for individual activities and the whole project. Then we can judge if the schedule is behind or not. On the other hand, according to the index of progress and the other relevant information, we can propose the corresponding strategies for the activities behind schedule and implement the schedule control. Because the project includes various activities, there is no single approach to measure the progress. According to the characteristics of the activities, there are five methods to measure the progress: (1)Unit completed: The progress is determined by dividing the number of units completed by the total unit of units, (2)Incremental milestone: The approach applies to activities that have multiple unit work with several sequential tasks. Each task is assigned a percentage of completion as a milestone. The progress is calculated by summing the product of milestone percentage and the completed percent of each task for each unit, (3)Start/finish: The progress is determined as the incremental milestone method that the start is assigned a percentage from 0 to 100. Typically a percentage of 20 to 30 percent is used for milestone of start, (4)Cost ratio: As for the complicated process, i.e., inspection, safety, the activity can be measured by cost ratio. The cost ratio is the accumulated cost divided by the total cost of the activity, and (5)Opinion: The other measurement methods can base on the subjective evaluation of the experienced engineer [1]. As for the total project completed, it can be obtained by earned value method [1,4,5].

4.3 Factors affecting schedule

There are many factors affecting the planned progress of individual activity. Generally, the factors include weather, work, work force, and site condition, etc. [8]

(1)Weather: temperature, wind, humidity, precipitation and snow;

(2)Work: re-work, insufficient material, insufficient equipment, improper coordinating between interfaces, inadequate estimated duration and delay of the predecessors;

(3)Work force: low productivity, surplus labor, insufficient labor, low motivation, improper instruction and accidents; and

(4)Site condition: insufficient working space and poor ground condition.

4.4 Provide control strategy

The main objective of providing strategies for schedule control is to provide engineers with corresponding strategies rather than the Fast Track crashing the project. Once master progress or some critical activities are supposed to be behind schedule. Schedule control strategies, mainly are to prevent the condition that parts of critical activities are behind schedule severely and extra resource for crashing the project will be paid. Because the critical path changes frequently, engineers are unable to be aware of it. Besides, it's difficult for them to monitor the progress, and therefore the condition is not noticed until the schedule is obviously far behind. From the view of management, it's very inefficient. As a result, a perfect schedule control system can monitor the phenomenon that may affects the progress in advance during the construction and provide precaution and corresponding strategies to prevent the condition mentioned above from happening.

As soon as any factor described in section 4.3 is to affect the master progress of the project, the superintendent should take some actions corresponding to the factor. For example, insufficient working space results in inefficiency that affects the progress, it is necessary to promote the job-site layout instead of increasing the labor, Table 1 is some examples of the affecting factors and corresponding strategies that job-site supervisors need.

As for how to decide the moment to take actions using individual activity progress, an index of delay, S, is introduced.

$$S=\frac{(planned\ schedule-actual\ schedule)\ (\%)}{(100-planned schedule)\ (\%)} \qquad (1)$$

The definition of the index of delay is shown as the above equation. It's calculated by dividing the difference of planned progress and accumulated actual progress by planned progress left. The value of zero means that the activity calculated is just on schedule. The positive value represents being over schedule while the negative value means being behind schedule. The more the positive value is, the more the schedule is behind. It's important for this definition to prevent the risk in advance.

If the index of delay is between the total float and free float, shown in equation (2), the system only warn the superintendent. When it is higher than total float, shown in equation (3), it's time to take action. As for the strategies' contents and levels, it is depends on the factors and other indexes, such as total project completed.

$$f\cdot\frac{Total\ Float}{Duration} > S \geq \frac{Free\ Float}{Duration} \Rightarrow warning \qquad (2)$$

$$S \geq f\cdot\frac{Total\ Float}{Duration} \Rightarrow may\ take\ action \qquad (3)$$

Table1: Examples of affecting factors and corresponding strategies

Factor	Action
Much precipitation	Crashing the project
Narrow space	Rearrange the site layout
Low productivity	Depends on the reason of low productivity
Under-manning	Hiring more workmen
Predecessor postpone	May crash the project
Insufficient Material	Contact the supplier or change to other activities
Insufficient Equipment	Search alternative supplier
Rework	Crashing the project

5. ACTIVITY MODEL FOR SCHEDULE CONTROL

There are two sub-models in the activity model developed in this paper: (1)relational data model which stores the basic information of initial schedule network and a series of attributes to measure activity progress and provide strategies for schedule controlling, and (2)object-oriented model which contains objects whose attributes and methods are used for calculating the progress of each activity and master progress, inferring strategies for schedule controlling in reference engine, and generating web interfaces. The relationships of relational data model and architecture of the system objects are shown in Figure 2 and 3, respectively.

The major objects are described as below:

(1)Project: it calculates and stores the master progress of the project;

(2)Schedule: it stores the planned and actual schedule information, such as the start, the finish, quantity and progress for each working day;

(3)Resource: it stores the planned and actual quantity of all the resources used for the activity including of labor, material and equipment;

(4)Progress: it calculates the actual and planned progress for each activity using different progress measurement approaches associated with the attributes of the activity;

(5)Strategy: it contains a series of attributes that provide the inference engine to decide the schedule controlling strategies corresponding to the problem sources; and

(6)Web Interface Generator: it generates the web interfaces corresponding to the activities of different attributes of progress measurement approaches.

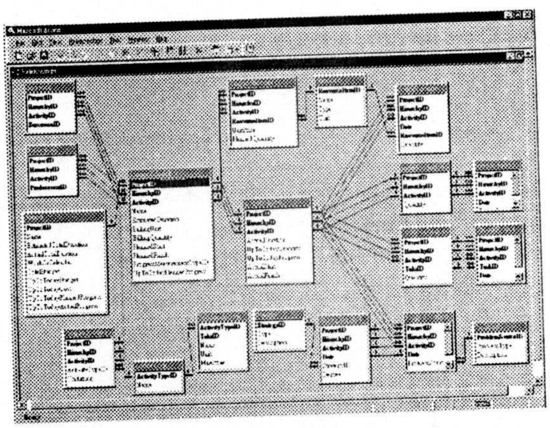

Figure 2. Relationships of relation data model

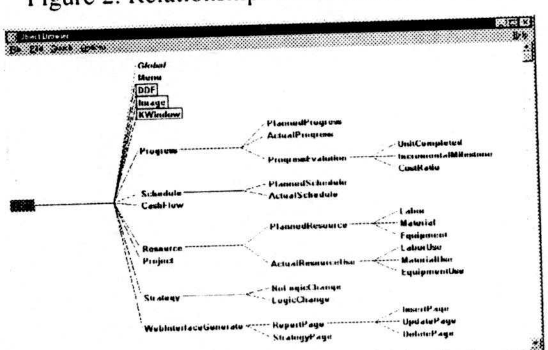

Figure 3. Architecture of system objects

6. SYSTEM IMPLEMENTATION

6.1 General description

The entire architecture of the overall schedule control system is shown in Figure 3. The descriptions of the company side and construction site of the system are as follows.

At the company side, both the web server (Internet Information Server, IIS) and the expert system are installed on a Windows NT server. The database system can be located on the same host or on another computer with network connection as shown in Figure 2 to alleviate the load of the IIS server. Schedulers can input the initial schedule network into the database through an interface enclosing the database. The expert system then decides the method to measuring the progress for each activity and builds the corresponding web interfaces.

At a construction site, the daily report fillers, site engineers and superintendents can access the database directly to updating the schedule through the web interfaces using a fixed network connection or modem. When any activity is to be behind schedule, the expert system will remind and warn the superintendents and provide the corresponding strategies of schedule control. The manually done traditional paper reports can now be written into the company database directly in electrical forms through web interfaces.

6.2 Four major components

There are four components in the system architecture: Expert system, database, scheduling software and web interfaces.

(1)Expert system: The main functions are that deciding the approach of progress measurement for each activity, generating the corresponding web interface for each activity and providing strategies for controlling schedule.

(2)Database: it is used for storing all kinds of schedule control information, such as the planned progress, actual progress, planned resource and actual resource use. In which, the interface enclosing the database is designed to enter the initial schedule information. As for the updating the schedule, one can use the web interfaces. The database also store the strategies applied for problems inferring from the expert system in order to provide engineers accessing the information they need.

(3)Scheduling software: Because of the limits of active web interface writing skills, the image representation of logic relationship in the network is done by the scheduling software. It also can provide other functions, such as resource leveling, to enhance the system.

(4)Web interfaces: There are two main functions of web pages— one is for inputting the actual progress and resource use; the other is for showing the calculated progress and for filling the "Schedule Control Page" as the progress is behind and retrieving the strategies inferring from the expert system.

7. SYSTEM OPERATION

Figure 4 is the flow chart of the system operation that can be divided into the following phases:

7.1 Phase 1: entering the initial schedule

Through the interface enclosing the database system, schedulers can create the initial schedule information including of the basic information such as activity name, estimated duration, logic relationship, plan of the resource use, budget and so on. Besides, a series of extra information used for controlling the schedule also need to be entered. After that, the database system or scheduling software can calculate the construction dates and floats. Figure 4 shows the interface provided by database system to input the initial scheduling information.

7.2 Phase 2: updating the schedule

After the construction starts, engineers fill the daily reports through the web interfaces everyday according to the observation of the actual progress. Once the progress information is calculated by the expert system and entered into the database, the system will update the schedule network automatically. The web interfaces also have different forms to input for activities whose progress is measured by different approaches.

On the other hand, the form that general daily report needs also included in the web interfaces. Figure 5 shows one of the web interfaces.

7.3 Phase 3: controlling the schedule

Engineer can obtain the on-going progress by performing a query for progress. If the system find the probability that some activities may influence the master progress, engineers can use the "Schedule Control Page" to fill the "Progress Evaluation Forms" for problem sources and pass the data to the database. The expert system performs the inference according to the data to work out the corresponding strategies and return the strategies to the database. The results will be shown in "Strategy Page" by perform another query to be the reference of the reaction.

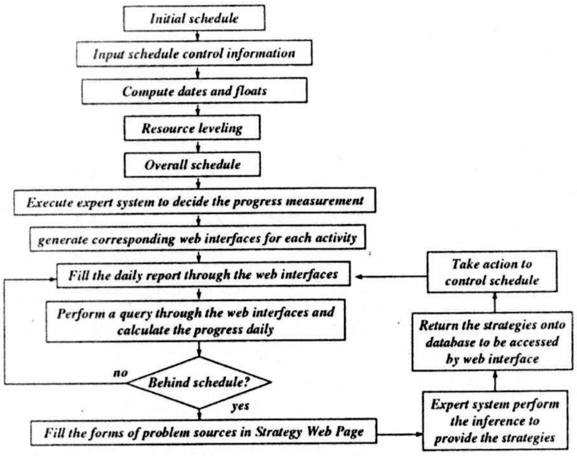

Figure 4. Flow chart of system operation

8. CONCLUSIONS

The project schedule control system developed in this paper utilizes two mature computer technologies of expert system and Internet to provide mechanism that job-site engineers can real-time update the schedule and providing strategies for them to control schedules. The web-based daily report system allows data to be entered and examined at both the construction sites and management offices, which achieves timely information distribution. The expert system approach relieves the loading of massive controlling tasks. The system architecture presented in this paper is a pilot study to integrate several information techniques in the field of project schedule controlling.

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