ABSTRACT

The practical application and research activities of 4D CAD system for visualizing construction schedule information are being increased by the practical use of IT tools in construction management (CM) field. The IT tools in CM can be used for real time management and visualized information management. 4D CAD system is a representative tool for visualizing schedule information management. This study suggests an improved methodology to organize 4D object for construction schedule management and progress control. And a new management technology to control schedule information by each work breakdown structure (WBS) level is included in the study and the suggested method is verified by the developed 4D CAD system. And this research introduces some methodologies for visualizing 4D objects that consist of horizontal work area. It may be expected that those functions can raise the applicability of 4D CAD system by verifying the interfering activities and identifying the priority of each activity.

Keywords: 4D CAD, Construction Schedule, WBS, 3D object

1. INTRODUCTION

1.1 Advance IN VISUALIZING Construction Schedule Data

Recently various kinds of information technology (IT) tool are being introduced for construction management (CM). A systematic information management is one of prerequisite processes for developing a computerized CM system by using IT tools. In case of construction
schedule management, the numerical data from traditional tools needs to be changed by visualized data using 3D drawings and computerized schedule data. 4D CAD system is a representative tool for visualizing construction schedule data. In this study 4D object means that 3D object of drawings is linked with time schedule. Figure 1.1 shows a change in scheduling tool from traditional technology to 4D CAD system.

**Figure 1.1** A change of construction scheduling tool from 2D to nD expression

Recently, the meaning of CAD application in construction management expands over visualized information management for cost and resource. It can be called by 5D and 6D CAD system. nD PMIS (Project Management Information System) means a visualized CAD system that cost and resource information adds to existing 4D object. The all of numerical construction information from existing PMIS can be visualized in nD PMIS by construction schedule.

### 1.2 NEW APPROACH FOR DEVELOPING 4D CAD SYSTEM

Because 4D CAD system includes schedule and drawings information, database of the system consists of schedule data, 3D and 4D objects. Accordingly, the successful information management in 4D CAD system is an important factor to serve user’s convenience and to simplify link process between construction schedule and 3D object. So, how easy it is to map schedule data to drawings data is a key factor for practical usability of 4D CAD system (Kang 2004, Kang 2006).

It is also possible to manage work space conflict in a construction project by 4D CAD system. For example, (Mallasi and Dawood, 2003) suggested...
space strategies that affect the development of realistic 4D space visualizations to minimize space-time conflicts in a project. The authors of the paper introduced a simple generic algorithm to reduce space-time conflicts by analysis of construction activity execution patterns. An approach to link information classification system with 4D object was also attempted in 4D/VR construction processes simulation research (Dawood, 2002).

Current 4D CAD systems, such as Project 4D (2005), Virtualstep (2001), VTT (2003) and Stanford (2004), have many helpful functions to simulate 4D object. However, because each 3D object needs to be linked with each activity, the link process to make 4D object is complicated for project managers. Though the link process between schedule and 3D object is essential process and important function that control practical application of the system, it is uncommon to find a research for describing detail methodology of link process. Most researches about 4D CAD are focused on representation of advantages of 4D CAD and case studies of practical application.

The improved methodologies need in link process between schedule and 3D object. And it also needs simulation of 4D object by each element or work zone. This study proposes a new approach to use work breakdown structure (WBS) code as a common information in 4D CAD system including link process. So, the study uses WBS as information centre for managing all of data in 4D CAD system. Accordingly it is possible to simulate 4D object by each code level in WBS. And this study develops a new 4D CAD engine by using WBS code and the system includes a function to simulate progress status of each activity visually.

2. INTEGRATED INFORMATION MANAGEMENT IN 4D CAD system BY USING WBS

2.1 MAPPING SCHEDULE AND 3D DRAWINGS USING WBS CODE

If there is a common code system that can be used in both schedule and drawings data in 4D CAD system, the link process can be simplified because all data in the system is generated by a common code. This study proposes a standard WBS code to be stored as a library file within 4D CAD system and the all functionalities of 4D CAD system can be operated in reference to the common code in the library. To configure schedule information in schedule management module, schedule data is created directly in reference to the pre-defined WBS code and activity list.

In terms of drawings configuration, too, drawings object corresponding to system-provided WBS code is stored in advance. As both schedule and drawings data are stored in reference to common WBS codes, they are mapped to each other automatically in 4D simulation. Figure 2.1 shows data interface scheme using common WBS code.
The basic function of 4D CAD system is to simulate planned vs actual progress of construction facilities in 3D by interfacing construction schedule and drawings. A proper code structure that can be used to manage such data is necessary for systematic information management and it could be an information centre in 4D database. Utilizing WBS as an information centre can improve usability of 4D CAD functions for practical application.

For example, 4D simulation can be performed at various levels from element level consisting of operations to space level consisting of elements or structures, according to code level hierarchy of WBS. Namely, as described in Figure 2.1, schedule data can be mapped to individual WBS code and corresponding 3D objects are mapped to the same code as well. As this enables 4D simulation aligned to a specific user needs by classifying work size per management level, construction schedule management function of 4D CAD system can be greatly enhanced.

2.2 4D SIMULATION BY WBS CODE LEVEL

In this research, a technique that can realize 4D object selectively of structures user wants per work level or element item is composed by applying WBS-centred link system for 4D realization. If 4D CAD system uses a simple code system that has not code level as in WBS, project manager can visualize just one work item for the only selected code as in Figure 2.2. Figure 2.2 represents excavating work for a tunnel. Project manager can confirm the work process of excavating work by its schedule, but he cannot confirm whole work process of the tunnel by code selection in upper level.
Figure 2.2 Simulation of 4D object by a specified code

However, if 4D CAD system uses a WBS with code level, it is possible to simulate 4D object by selected work level as in Figure 2.3. The level of WBS consists of facility, space and element levels. Element item means detail parts to construct a dependent structure and space item means dependent structures to construct a facility and facility item means final whole products by several space items in a project. For example, a highway facility consists of spaces such as bridge1, bridge2, tunnel1 and tunnel2. And a bridge space consists of elements such as abutments, piers and decks.

Figure 2.3 shows the process of composing 4D object by WBS level which project manager wants to simulate. He can check the detail 4D object for excavating work of tunnel and simulate the 4D object for whole tunnel construction in upper level by simple selection of WBS code. The left part in Figure 2.3 shows whole WBS code of the project and right part shows 4D simulation process by selected WBS code level in left side. This partial 4D realization by code selection per WBS level is useful function to be utilized under the situation of the necessity of partial 4D realization for intensive management in case the whole project scale is enormous.
Partial 4D realization by the selection of WBS code is possible for one work item or specified element. And in case if construction manager selects the upper level WBS code, it is possible to go bringing with all lower level construction items together. Like the left side of Figure 2.3, 4D objects of certain spaces (for example, earthwork section, bridge, tunnel, and etc.) can be realized by this function. If user drags schedule of the parts user wants selectively in WBS code, schedule information also expresses only schedule of the lower activities in the selected schedule and realizes 4D object for them. Therefore, it is possible for project manager to control visualized schedule data intensively per element or work zone.

3. 4D REALIZATION FUNCTION IN HORIZONTAL ACTIVITY SPACE

Taking highway project as an example, this study has introduced technique for users to realize 4D of the section they want in the horizontal work items after spreading main construction items of the whole sections of the highway on 4D realization screen. That is, it has a methodology of composing 4D realization horizontally if the relevant section is selected with mouse after classifying the whole sections from the starting to the ending
point into the concept of earthwork, open cut tunnel and bridge sections according to the actual status of activities.

**Figure 3.1 4D object visualization process in horizontal activity space**

Figure 3.1 shows the loading process of 4D object of the relevant section by selecting the section of horizontal activity space in 4D CAD system. As in the Figure 3.1, the section of horizontal activity space is selected from the whole section loaded on the right upper side of window by dragging with a mouse. Next, the command of horizontal activity space in the spread sheet window is executed to load WBS code that is relevant of 3D object within the selected horizontal activity space. And then 4D object generation for horizontal activity space is being completed. Figure 3.1 is the section of horizontal activity space and is the result of the completion of object composition by selecting earthwork section for the completion of case project. In the lower part of the figure, project schedule table of the selected horizontal activity space is shown.

In the developed system in this research, like this, it is possible to generate 4D object of the relevant section by simple operation of a mouse.
along the direction of construction route that is being progressed horizontally.

4. EXPRESSION METHOD OF THE STATUS OF SCHEDULE PROGRESS CONTROL

In order for 4D CAD system to have replacement effect of the existing construction schedule management tool, technique that visualizes the current progress status compared to planned schedule in three dimensional objectification is required. That is, it is possible to visualize the current progress status by distinguishing exceeding progress or delayed progress parts in separate shape. To make this function, separate management of 3D object database for the relevant parts is required.

Progress information is calculated with activity quantity at the construction site daily. This research introduces a method of automatic calculation of progress rate within the system only with entry of activity quantity. These progress control functions are compulsory functions for the visualization of construction schedule management and shall be introduced in 4D CAD system.

4D planner of developed system is composing 4D progress control function that can analyze progress status at each time point together with general 4D realization function. Figure 4.1 shows progress control method visualized by classifying with the colours identified in 4D CAD system of this research.
In this research, the progress status compared to planned schedule is classified into the status of exceeding, delay, and normal activities and the method of expressing in blue, red, and yellow colour respectively as in the Figure 4.1 is being tried. That is, the current progress status is visualized by classifying the relevant elements in three dimensional colours by dividing the activity of exceeding or delaying parts in actual implementation in comparison with planned schedule. These visualized progress parts can also express detail information of exceeding or delay in numerical data.

5. CONCLUSIONS

Usability and applicability of 4D CAD system is greatly influenced by 4D engine configuration and efficiency of internal data management. While improved system configuration approaches to address such issues are in great demand, this research proposed an approach to enhancing 4D data management.

Concept of common information centre was incorporated into the 4D data management scheme to integrate all data management of 4D engine with reference to common information code. WBS code was used for common information centre and all discrete functions of 4D CAD system were referenced to WBS code as their key fields so that all data stored in 4D CAD system could be managed per activity level, which was validated in actual system implementation and capable of improving performance of as-is 4D CAD system significantly.

And this study developed a 4D simulation system by using a new approach for simulating horizontal work area. Because it is still difficult to apply 4D CAD system for civil engineering project that each activity is progressed by horizontal pattern with geometric triangulate network, this new approach is worth continuing research for improving performance of current 4D CAD systems significantly.

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6. REFERENCES


