Application of Information Technology for Visualizing and Optimizing Construction Project Schedule

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Abstract: Recently, various information technologies such as VR (Virtual Reality) and AR (Augmented Reality) are being used for visualizing construction information. Specially, BIM (Building Information Modelling) is a representative tool for IT application in construction industry. Generally, BIM uses VR and nD CAD system to visualize construction schedule data. This study develops a methodology and system to apply BIM functions using 4D CAD simulation technique for risk analysis and schedule progress monitoring in the construction industry.

1 INTRODUCTION

As construction projects grow in scale and complexity, and new construction methods and techniques are adopted, the quantity of data generated at each of the construction phases is becoming greater. As such, practicality of using VR (Virtual Reality) and BIM (Building Information Modelling) based on three-dimensional design is expanding in the construction industry. Most recently in particular, use of information technology (IT) such as VR and BIM in the construction industry is being an essential item for successful project management in the construction industry.

4D CAD system is a representative function in the BIM tool. 4D CAD means that construction schedule as an another dimension is added in 3D object. Project manager can visually check the construction status using 4D CAD system because 3D object for the appearance of finished work is continually simulated by construction date. Recently, 4D CAD system is being a useful tool for visualizing construction schedule data. However, use of CAD in civil engineering projects is relatively low compared to building projects, which has led to insufficient application of VR and BIM in real projects (Kang, 2010a, 2010b). Because civil engineering projects consist of horizontal work area and non-repetitive activities, it is difficult to make 3D objects of each activity. Fischer et al. (2005) had suggested 4D simulation examples and advantages of many large projects by dividing design phase and construction phase. Dawood et al. (2002) had developed PECASO (Patterns Execution and Critical Assessment of Spatial Organization) model that can manage space crash and interference between activities within 4D environment. PECASO model realizes 4D object through four modules of space crash process between activities generated in project execution. This research develops a method and functions for 4D CAD system using VR tool for civil engineering projects.

2 VR FUNCTION FOR CONSTRUCTION PHASE

2.1 IT Application in Construction Industry

The goal during the construction phase is to reduce schedule, minimize cost and ensure construction quality through improved constructability and mitigation of abortive work. To achieve this, integrated management of construction information is required. However, there are further challenges

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against collection and sharing of construction data as projects have become larger and more complex, with greater work scope and increased need for collaboration between stakeholders including clients, designers, builders and subcontractors.

As such, this research aims to propose an operating process for construction VR for collection and sharing of construction data during the construction phase. This process first reviews the project information and designs, and on that basis establishes a construction plan that can enhance work efficiency through identification of information such as work sequencing errors, planned vs. actual progress and construction risks using 3D visual simulation applied to existing business workflows. In particular, this process allows for data extraction by sequence for expedited identification of and response to issues analyzed.

The work sequence review simulation can demonstrate hundreds of activities and their predecessor/successor relationships to visually identify errors in work sequencing. The module first generates a WBS (Work Breakdown Structure), 3D model and schedule based on the project design, and integrates them around the WBS.

In this research, we have developed an automated module of our own for generation and combined simulation of the WBS, 3D model and schedule in order to increase usability and efficiency. 3D and 4D objects can be simulated by WBS level in this module. It would be helpful for project managers to visualize project schedule by work unit. Predecessor and successor relationships by process can be determined using mouse controls and the relationship entry module. Then the activities were executed as simulations that not only represented each process but also integrated the overall schedule. By identifying the sequencing errors in advance and re-adjusting the predecessor and successor activities for each process accordingly, the process can prevent abortive works.

The VR functions for current BIM systems are focused on the simple simulation of finished appearance by construction schedule. This study suggests a VR function for visualizing construction risk by construction schedule. Construction risk means the risk in constructability of each activity. VR function in the system represents different colors of 3D object of each activity by risk level.

2.2 Application of Fuzzy Theory for Quantifying Construction Risk

Construction risk information of each activity can be visualized using Fuzzy analysis in the 4D CAD system. Each activity has a risk degree that is represented by different color. This study classifies risk degree with 5 groups and each group has a color from red color to blue color. Fig 1 shows 4D objects that simulate the finished work by each risk degree.

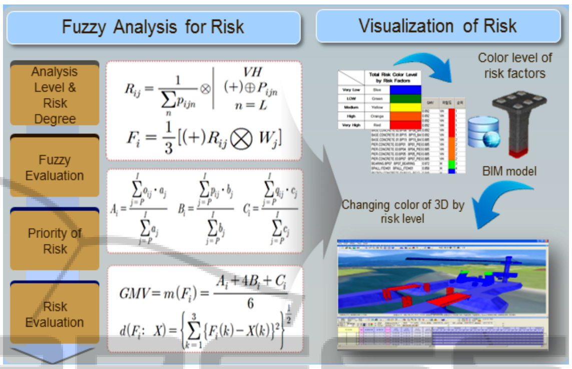

Figure 1: Risk identification by Fuzzy analysis.

The fuzzy theory is used to obtain an objective data from substantial and experienced data of risk degree of each activity by field engineers. If a finished activity simulates with red color in 4D simulation system, project manager should monitor the activity carefully because the activity has high risk degree. In this 4D CAD system, all activities are simulated with each color of 5 colors by each risk degree that was analyzed using Fuzzy theory. Fuzzy theory is used for verifying the subjective risk degree with quantitative data.

The risk of each activity is analyzed by multiplying risk probability to risk intensity. Project manager should input those data for analyzing risk. The developed 4D system in the study has a risk analysis function using Fuzzy theory.

If project managers use this system, they can take an intensive management plan for the activities with risk degree of high level. And they can easily identify those activities because the activities are simulated in 4D CAD system with different color such as red color or green color.

2.3 Visualization of Risk Information for Construction Project

Fig. 2 shows a VR function for visualizing construction risk analysis developed in this study.

The construction risk analysis module reviews various internal and external risks on construction in order to mitigate them in advance. To achieve this, the module measured risk levels through Fuzzy and risk analysis techniques, and simulated those risks

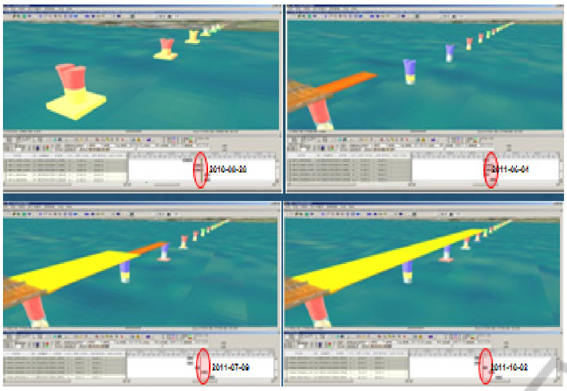

Figure 2: VR function for visualizing construction risk.

visually. Risk evaluation measured risks on factors of cost, time and work condition in order to identify activity sequences that had high probability of schedule delays, cost overruns or accident occurrence. The evaluation rated each activity on a scale of five grades and displayed them in different colors by risk level. This provides for an understanding of risk management priority by sequence, while also serving as an effective communication using a 3D visual simulation displaying risk levels by color.

3 4D FUNCTION FOR SIMULATING CONSTRUCTION PROGRESS

The other VR function in the study is for visualizing construction progress. Construction schedule, specially progress situation between planned schedule and actual schedule, needs to be visualized for easy understanding of schedule delay. This study uses to classify some colors by grouping delay activities, normal activities and earlier activities comparing with planned schedule. The each activities are using red color, green color and blue color in simulation function.

Fig. 3 shows processes of realizing telepresence to visually compare the simulation realized in the previous stage based on the planned schedule with progress status of the construction at the site. 4D CAD screen module, which is divided to show two images simultaneously, is generated. These images make it possible to visually check schedule progress status in the construction site compared to the planned schedule as of today.

The progress simulation module in Fig. 3 allows effective progress management by visually

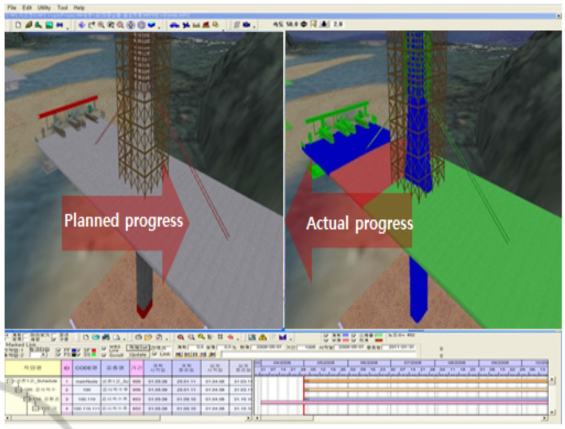

Figure 3: VR function for visualizing planned schedule and actual schedule.

simulating the difference between planned and actual completion over a large site area. Progress of each activity was calculated using the start date, end date and the required resource quantities. First, actual progress was calculated with the schedule module using the planned dates and actual resources spent. The calculated progress was categorized into normal, delayed and ahead vs. planned, and these results were linked to 3D models and displayed in blue, red and green to represent the progress status visually.

4 4D FUNCTION FOR OPTIMIZING CONSTRUCTION SCHEDULE

To improve the constructability, the overlapping between activity schedules should be reduced in whole construction period. In order to minimize the number of overlapping activities, a corresponding analysis should be executed based on specific constraints. First of all, overlapping duration for a corresponding activity should be minimized changing in 'day' units within a particular total float. During this process, the relationships with predecessor activities should be maintained. In general, a project has diverse overlapping activities, and solving the overlapping of individual activities is meaningless. Therefore, all the overlapping activities should be moved back and forth in 'day' units within the total float to search for an optimal schedule that minimizes the overlapping level.

Because a series of these types of procedures are repeated based the number of overlapping activities, a methodology detects the optimization solutions of a schedule as per the change days of the total float is required. This study suggests a genetic algorithm methodology to resolve the optimized construction schedule. That is, the number of a project's activities becomes a chromosome for each generation while movable days for each overlapping activity within the total float are regarded a gene. After an initial solution is created, a project's overall overlapping level is repeatedly analyzed and an optimal solution with the minimum overlapping level can be derived. Thus, an optimal schedule that minimizes overlapping activities can be created without any change in the initial project duration. The VR function for minimizing overlapping schedule using genetic algorithm needs to be developed in improved BIM systems.

5 CONCLUSIONS

This research presented a VR system for the construction phase that can raise the usefulness of BIM on the construction projects. The proposed VR process enables integrated management of construction data through analysis of progress, sequencing errors and risks. A Fuzzy analysis and a simple optimization concept that are linked with BIM functions were suggested in the paper. Considering that the existing studies for BIM are focused on the visualization of work condition, this approach can be a useful function for project manager. Also as the system uses visual representation of complex and numerical information for a construction project, it can be expected that the system will be actively used as an effective decision making tool.

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REFERENCES

Dawood Nashwan, etc., 2002. Registering space requirements of construction operations using Site-PECASO model. *Proceedings of CIB W78 Conference*

Kang, L. S., Park, S. Y., Moon, H. S., and Kim, C. H., 2007. Improvement of basic functions for visualizing schedule and 3D object in 4D CAD system. *Conference Proceedings of CIB 2007*, South Africa.

Kang, L. S., Moon, H. S., Park, S. Y., Kim, C. H., and Lee, T. S., 2010a. Improved link system between schedule data and 3D object in 4D CAD system by using WBS code. *KSCE Journal of Civil Engineering, 14(6), 803-814.* Seoul Korea

Kang, L. S., Moon, H. S., Dawood, N., and Kang, M. S., 2010b. Development of methodology and virtual system for optimized simulation of road design data. *Automation in Construction*, *19, 1000-1015.*

Martin Fischer et al., 2005. Experiences with 3D and 4D CAD on building construction projects: benefits for project success and controllable implementation factors. *Construction Information Digital Library* (http:://itc.scix.net)

Dawood Nashwan and Mallasi Z., 2006. Construction Workspace Planning: Assignment and Analysis Utilizing 4D Visualization Technologies. *Computer-Aided Civil and Infrastructure Engineering*, 121, 498 – 513

Kamat V. R., 2003. *VITASCOPE: Extensible and Scalable 3D Visualization of Simulated Construction Operations.* PhD dissertation, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.