DEVELOPMENT OF AN INTEGRATED MODEL OF 3D CAD OBJECT AND AUTOMATIC SCHEDULING PROCESS

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ABSTRACT: Efficient communication of construction information has been critical for successful project performance. Building Information Modeling (BIM) has appeared as a tool for efficient communication. Through 3D CAD objects, it is possible to check interception and collisions of each object in advance. In addition, 4D simulation based on 3D objects integrated with time information makes it realize to go over scheduling and to perceive potential errors in scheduling. However, current scheduling simulation is still at a stage of animation due to manual integration of 3D objects and scheduling data. Accordingly, this study aims to develop an integrated model of 3D CAD objects that automatically creates scheduling information.

Keywords: BIM; 3D Model; Automatic Scheduling; Simulation

1. INTRODUCTION

As the scale of construction projects continues to become larger and more complicated, efficient data flow is required for successful project implementation. Building Information Modeling (BIM) has appeared as a tool for efficient communication. BIM improves interoperability for project phases, minimizing unnecessary consumption of human, material and time resources. In projects where BIM has been implemented, drawings are not just design plans, but also contain detailed data of each sub-component within the model. BIM is also useful for improving the efficient flow of data within the life cycle of the entire project. 3D CAD model can be used to check the interference and conflict between construction objects in advance, and the 4D simulation which is an extended application of 3D CAD model, allows for review of the entire construction plan to inspect potential errors in advance, simplifying the overall construction management[1].

However, 4D simulations through the use of computer systems currently in use are possible only after drawing up the 3D CAD model and planning the construction schedule separately, and manually matching the sub-components in the 3D CAD model with the corresponding activity in the construction schedule. This task requires considerable input of time and human resources, and the increased scale of projects makes it extremely difficult to manage the vast amount of data[2]. In addition, the current 4D simulation available is a visually-oriented representation that is more of a one-time picture of the project useful only in the beginning stages of construction. This representation is unable to reflect the design modifications and environmental changes that frequently occur in the middle of the construction phase, resulting in considerable burden of regenerating the 4D simulation through the manual matching process[3]. In order to overcome this problem, this study is to develop a prototype system that automatically generates construction schedules based on the 3D CAD model.

2. MSIS-RP3

The 4D simulation systems that are currently available for use include Bentley Schedule Simulator, Vico software Constructor 5D Presenter, NavisWorks JetStream, and so on. These systems contain construction planning features and can be linked to construction scheduling systems[3]. However, the matching features are limited to simple opening of files and editing feature is only available for start time and end time. Features for construction scheduling are not supported, resulting in a wasteful input of time and human resource when linking 3D model with the construction schedule.

This study attempts to overcome abovementioned shortcomings by proposing the development of a prototype of MSIS-RP3(Model-Schedule Integration System of Revit and Primavera Project Planner). MSIS-RP3 will generate a construction schedule for each individual sub-component through utilizing the object data in the 3D CAD model and make the generation of a construction schedule through exchanging data of current compatible systems.

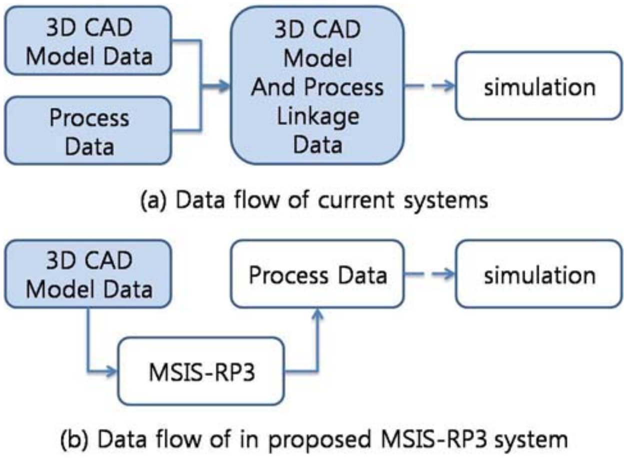

Fig. 1. Comparison data flow between MSIS-RP3 and current system

Figure 1 compares the data flow of current systems in use and the proposed MSIS-RP3 system. The shaded box represents the generation of new data. In the case of Fig. 1(a), the data of the 3D CAD model and the construction process, and the related unification process must be individually inserted as well as the relation between the data. However, for MSIS-RP3, required data at each stage is generated and re-used based on the 3D CAD model developed from the data input in the construction designing phase. This allows for the smooth data flow and elimination of the unnecessary information waste. The particular data utilization allows for the automatic unification between model and schedule, and results in effective simulation.

The simulated construction project for this study is a six-story building, as shown in Fig. 2, with one concrete core and 706 steel frames of columns and beams. Although this study is limited to steel frame structures, the building component in 3D CAD modeling can easily extended to other types of buildings. The model consists of a column with three-story height and beam construction will progress on each floor.

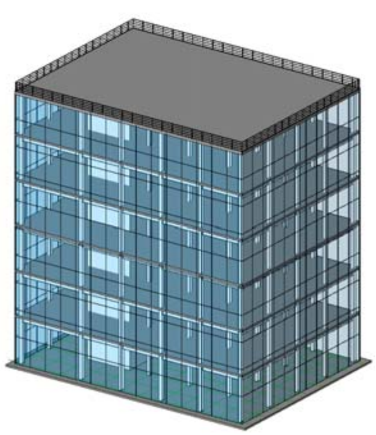

Fig. 2. 3D CAD model for six-story project

Two main systems used to achieve the ultimate goal of developing an integrated model-schedule prototype are Revit Architecture, a 3D CAD system from Autodesk, and Primavera Project Planner (P3), a construction scheduling system. Also, C#, Visual Basic.Net was used in order to develop MSIS-RP3.

3. APPROACH FOR INTEGRATING 3D CAD MODEL AND PROJECT MANAGEMENT PROGRAM

Figure 3 depicts three main steps of data flow originating from the 3D CAD model, passing through the MSIS-RP3, and ending in the construction scheduling system. A process of additional input of required data and removal of unnecessary data takes place at each step. The followings describe detailed processes of each step.

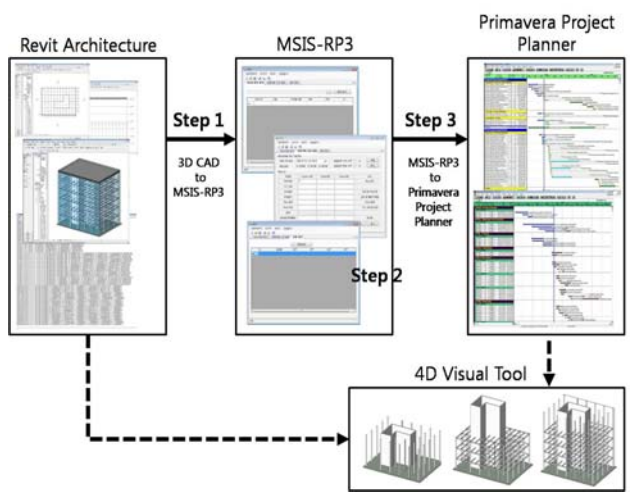

Fig. 3. Data flow between Revit and MSIS-RP3 and Primavera Project Planner

3.1 Step 1: CAD to MSIS-RP3

The first step involves the extraction and input of CAD Data. This step covers the extraction of data for each sub-component of the 3D CAD model as designed by the architect, and the input into the MSIS-RP3. The extracted data for sub-component includes the unique ID, class, type, level, coordinates, and other relevant data. The unique sub-component ID which results from matching the corresponding data of each sub-component related from the 3D CAD model to the construction scheduling system is transferred as a fixed value in order to realize 4D visualization. This value is essential for the automation of the integrating process of the 3D model and construction schedule that must be manually linked in the current 4D simulation systems.

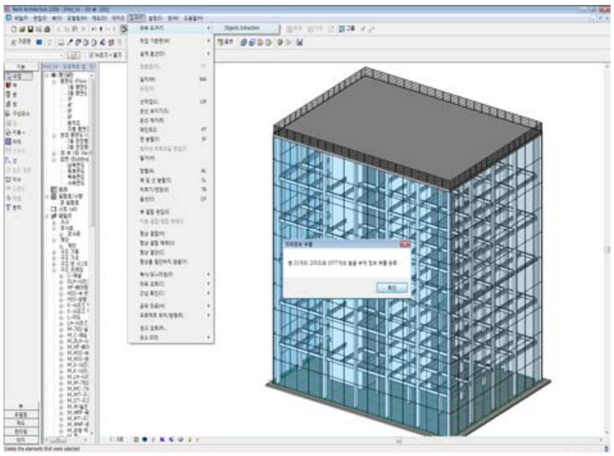

Fig. 4. Extraction of steel sub-components using the external command in the Revit system

The sub-component data acquired from the 3D CAD model is saved/printed in text form and transferred to the next stage of MSIS-RP3. Fig. 4 is a view of an extraction of steel sub-components using the external command in the Revit system. Revit offers an external command function that makes it possible for the user to create and use an additional system based on available API.

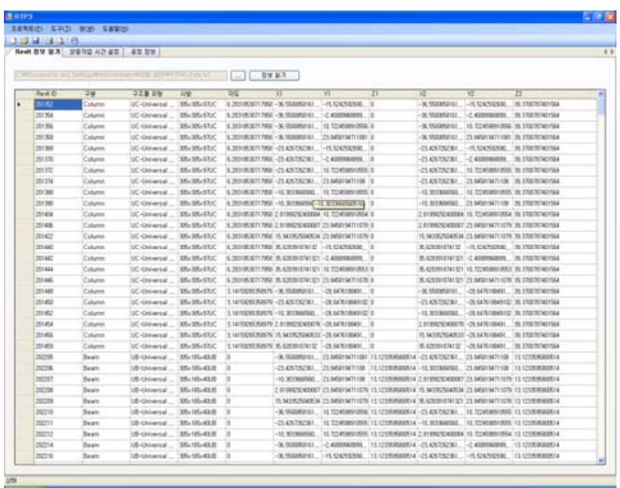

Fig. 5. Steel sub-components data in MSIS-RP3

The extracted data of steel sub-components from the 3D CAD model is inserted to MSIS-RP3 as shown in the data mining process (Fig. 5). During this process, MSIS-RP3 acquires the Revit ID, class, type, coordinates, and other required data for the construction plan.

3.2 Step 2: Process in MSIS-RP3

The sub-component data of steel frame structures extracted from the 3D CAD model undergo a series of processes aimed for construction planning. Generally steel frame construction has many forms and is initiated through each node, taking on a different form depending on the characteristics of the structure, site, construction method, and other factors.

The increasing number of high-rise buildings has called for rational and effective construction methods such as the N method, Automatic Climbing System (ACS) method, and others to be applied in the area of structural construction. Column installation in N method allows for effective following operations through labor diversification resulting from completing steel crossbeams and deck plates on each floor. In the ACS method, the walls made from reinforced concrete are built first and the steel frame construction follows in successive steps[4]. The following study applies the ACS method and appointed steel frame construction as the subject of this study.

The generation of steel frame construction is comprised of the following six stages.

(1) A point of origin is designated for the efficient analysis of location data from the acquired data of the steel frame structure. The origination point is not fixed and is designated based on the characteristics of the construction. For the purpose of this case study, the origination point is located in the far bottom southwest corner of the 3D CAD model.

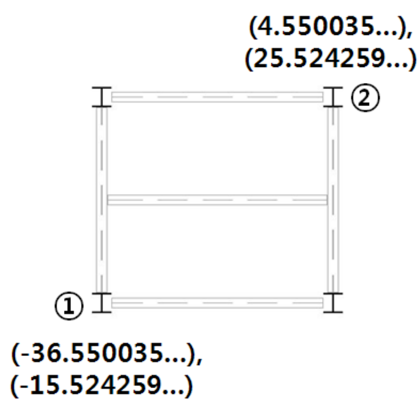

Fig. 6. Alteration of Global-Coordinate-System

(2) Starting from the point of origin, the coordinates (Global-Coordinate-System) of all existing steel structures should be accounted for and a new grid (New-Coordinate-System) based on the location of the column needs to be drawn. A zone is established based on each column or the supporting foundations of the column. The coordinates inputted from the 3D CAD model will be named the global-coordinate-system and each location of the sub-components will be expressed in decimal form. Some errors may result from the conjugated expressions of very small differences in decimal points. When four column exist, such as in Fig. 6, column ① and the adjacent girder has an X, Y coordinate of (0, 0), while the coordinates for column ② are converted to (1, 1). The converted coordinates are called New-Coordinate-System and the coordinate values are designated by the order a sub-component is located from the point of origin without regard for its actual length.

The value for the Z coordinate does not change in the new coordinate system. Modification of the Z value is not necessary due to the fact that although Z is expressed in decimal form in Revit, it is classified based on a uniform 'Level'. A zone is established upon application of the New-Coordinate-System based on each column or the supporting foundations of the columns, Fig. 7 shows the different zone types that may exist, while Fig. 8 is a classification of the zone types by different forms.

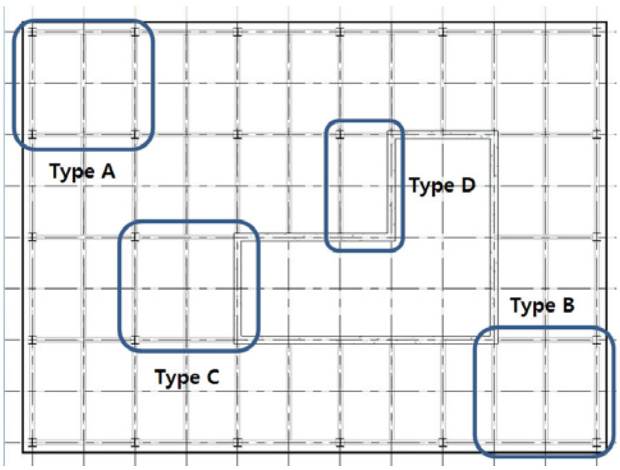

Fig. 7. Zone types in case study

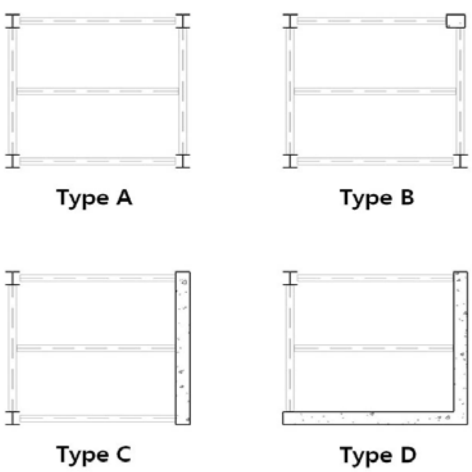

Fig. 8. Classification of the zone types by different forms

(3) Once the zone has been established, all the sub-components need to be accounted for and plotted according to the new coordinates. Sometimes a sub-component (column, girder) that is plotted twice on two or more separate zones may exist. However, construction follows a set order the zones and the sub-component that is plotted first is omitted in the following construction so that it will not be a problem. The order of installation of sub-components within a zone is dependent on the characteristics of the site, while the standard order by type is column-crossbeam-beam. For this study, the order of installation for the same sub-components follows a clock-wise direction starting with the sub-component located nearest to the point of origin.

(4) Once the order of installation for the sub-components is finalized, the order can be determined by the direction of the crane, the characteristics of the site, or even by the new rules set by the site manager. As shown in Fig. 9, the order of installation can take on many different forms and the logic for each different form can be easily generated. In such cases, the decision is made or can be revised based on the method required for the particular site or location of the crane. We will follow form ① in this study.

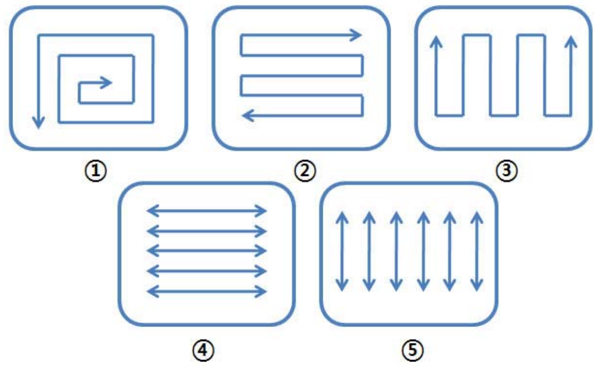

Fig. 9. Order of installation

(5) The time required for the construction and installation of columns, girder, and beam is calculated and inputted in the system. For the subject of this study, steel frame object, the required time for construction and installation can be estimated to the minute making effective construction planning possible.

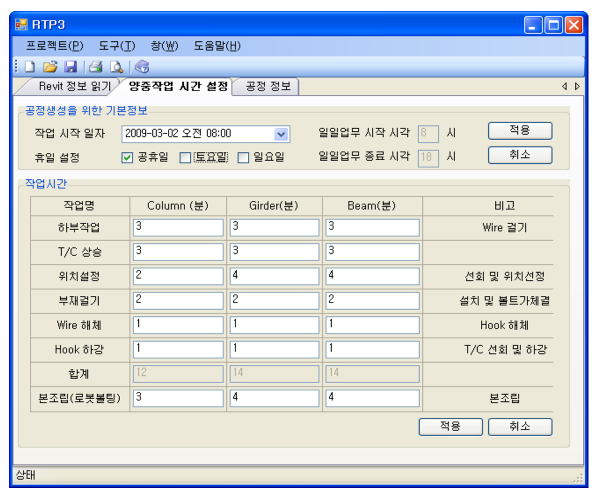

Fig. 10. Establishment of time for construction and installation

(6) With the inputted time as the standard, the construction plans are drawn up accordingly. For steel objects the time required for installation can be estimated to the minute, however, since the lowest standard of measure for the P3 used in this study is one hour, the plans are based on hourly labor. The

construction plans use hourly labor of sub-components as one unit. Although plan-by-the-minute installation plan is possible, the present study is conducted using hourly labor and also requires for the Revit ID data for every installed sub-component involved in each activity.

3.3 Step 3: MSIS-RP3 to Primavera Project Planner

The construction data generated from MSIS-RP3 in Step 2 is inputted into Primavera Project Planner. Like the Revit system, P3 utilizes API and can be modified depending on the user's purpose. Fig. 11 is the construction plan inputted using MSIS-RP3.

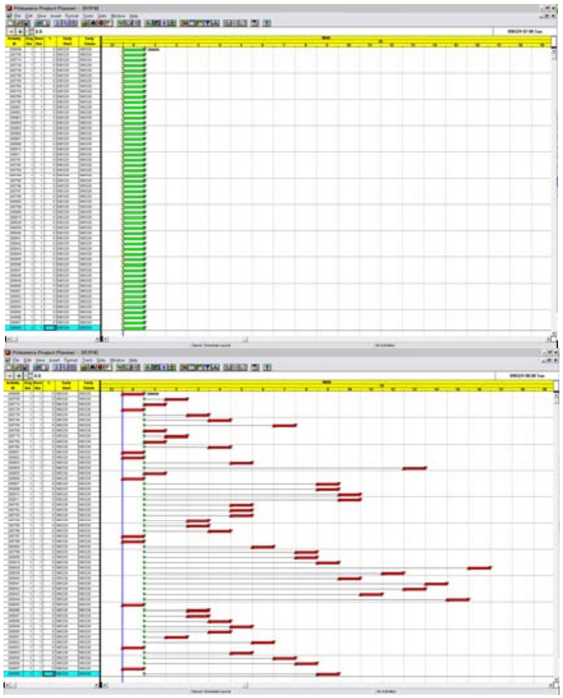

Fig. 11. Input schedule and scheduled schedule in Primavera Project Planner

Through this series of applications automatic construction generation is made possible from the 3D CAD model and leads to the next step of 4D simulation. In the simulation result from the P3 system, due to the limitation in the smallest unit of measure for operating time, the simulation is expressed in the pre-specified unit. However, once a minute-by-minute construction plan is completed and each sub-activity is generated, a more detailed simulation is possible.

4. EVALUATION

Through the development of MSIS-RP3, a model-schedule integrated system prototype, further study of the relationship between construction plan generation and modeling has been explored. The followings explain the benefits and limitations involved in the development of the integrated model-construction prototype that have surfaced from the case study.

4.1 Benefits

The 3D CAD systems currently in use, utilizes the parametric method in expressing and managing 3D object data. However, this data is used in limited roles such as 4D simulation and cross-check applications within construction processes and cannot be applied in the overall construction scheduling process. Also, unnecessary waste of resources results from the 4D simulation because it requires for manually match up of the 3D CAD model and construction activities from the user. MSIS-RP3, the resulting product of this study, solves the problem of inefficiency by organizing not only the characteristics of the 3D-CAD sub-component, but the necessary data needed in construction scheduling and utilizing particular data in scheduling. The main feature of the parametric method based 3D CAD, is that it utilizes the unique properties of the sub-component and eliminating the unnecessary repetitive data generation processes involved in 4D simulation. Also, future integration of applications utilizing MSIS-RP3 and 3D sub-component data will lead to the development of various management systems for the overall construction scheduling and not limited to the planning process.

4.2 Limitations

The two key limitations of this study are as follows. First, even though other construction object can be applied in the 3D CAD model, the study was limited to steel construction object only. Automatic schedule generation logic development and application to the system is needed not only for steel objects but for all others. Second, the plan-by-the-minute feature of the MSIS-RP3 system was not applicable due to the limitations of the planning & scheduling process system. Intricate and detailed construction scheduling is needed for overall simulated construction scheduling required for analyzing the conditions of the construction and identifying the issues resulting from changes in construction plans. As a result, a construction scheduling system that supports time management to the minute is needed, and MS Project that supports the smallest unit of measure for time is to be re-applied.

5. CONCLUSIONS

The purpose of this study is to address and overcome the shortcomings of the current 4D simulation systems currently in use through developing a model-schedule integration system prototype. The need for an effective connection of construction data and the manually input process in the current 3D CAD model was realized, and the MSIS-RP3 system, a system that recognizes the 3D CAD object as unique data making automatic schedule generation possible, was proposed as a solution. Through the case study, it was possible to observe that the resulting data flow was supportive. Application of this system can minimize the unnecessary input process of irrelevant data resulting in better, more efficient 4D simulation. The key benefit of MSIS-RP3 is that through utilizing the unique data of 3D sub-components based on 3D CAD model, leads to efficient data flow and prevents the waste of resources. The findings of this study will be applied to future studies aimed at realizing an integrated total construction scheduling system that is not limited to just the planning process that supports compatibility with all construction materials and other related applications.

6. ACKNOWLEDGMENT

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