USING BIM MODEL AND GENETIC ALGORITHMS TO OPTIMIZE THE CREW ASSIGNMENT FOR CONSTRUCTION PROJECT PLANNING

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ABSTRACT
Project planning is among the most critical factors to the success of a construction project. In project planning, cost and schedule are closely interrelated, because they share a lot of common data in their planning processes. Therefore, the integration of cost and schedule functions has been an attractive issue in construction project planning. Many researchers have emphasized the benefits of this integration and several different methodologies combining cost and schedule data have been provided. However, the results of the previous studies are not comprehensive enough to fulfill the requirements of project planning. This paper presents a model-based planning system that employs Building Information Model (BIM), Object Sequencing Matrix (OSM), and Genetic Algorithms (GAs) to obtain an optimal crew assignment under resource and workspace constraints. The purposes are to evaluate the project costs and optimize the temporal distribution of resources in project planning. A computer implementation called Cost/Schedule Integrated Planning System (CSIPS) is also developed to verify the feasibility of the proposed approach.

Keywords: BIM model; Crew assignment; Genetic Algorithms; Project planning

1. INTRODUCTION
Project planning is among the most critical factors to the success of a construction project. In project planning, cost and schedule are closely interrelated, because they share a lot of common data in their planning processes. Therefore, the integration of cost and schedule functions has been an attractive issue in construction project planning. Many researchers have emphasized the benefits of this integration and several different methodologies combining cost and schedule data have been provided (Jung & Woo, 2004; Chen, 2008). However, the overhead efforts of collecting and maintaining detailed data have been highlighted by previous research as the major barrier to utilizing this concept in real-world implementation (Lee & Yi, 1999). Advance information technology has been recognized as a definite solution in the integration of project cost and schedule (Kang & Paulson, 1998). Besides utilizing information technology, optimizing planning methods can be another solution that can result in reducing the amount of required efforts.

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This paper presents a model-based planning system that employs building information model (BIM) (NBIMS, 2008), object sequencing matrix (OSM), and genetic algorithms (GAs) to generate a cost-schedule integrated plan for construction management. The proposed BIM model incorporates multi-aspects of construction information required for project planning and management. In order to present the information of construction activities and specifications in the model, this research starts with analyzing the discrete processes within the building construction. The essential characteristics of building components are then defined in the property sets of the BIM CAD objects (Feng & Chen, 2008). These graphic objects are then further developed as schedulable objects and utilized to create the BIM model.

To schedule the construction project, BIM model and the object sequencing matrix (OSM) are adopted to determine the construction sequence of building components based on the physical relationships between BIM CAD objects. Since a building generally consisted of thousands of building components, this research applies GAs to optimize the construction sequence because of its capability of handling the large-scale optimization problem. This optimized sequence servers as a basis for project scheduling. In addition, the GA-based crew assignment includes the evaluation and optimization of the temporal distribution of resources and costs is applied in the project scheduling. Since the resulting schedule is integrated with project cost, it becomes possible for project planners to easily examine relevant resources and costs of a specified time period. The meaningful information generated from the cost-schedule integrated plan will be useful for management to execute the project requirements.

This article is organized in the following manner. First, the procedures for developing a BIM model are discussed in further detail. Next, the proposed project planning method is described. Finally, a computer implementation called Cost/Schedule Integrated Planning System (CSIPS) is presented to verify the feasibility of the proposed approach.

2. BUILDING INFORMATION MODELING
The proposed model is an extension of a BIM model, which consists of BIM CAD objects and incorporates multiple types of construction information required for construction planning and management. In order to present the information on construction activities and specifications in the BIM model, this paper analyzes the discrete processes undertaken within facility construction. Several facets, such as dimensions (e.g., width, area), spaces (e.g., office, classroom), elements (e.g., column, beam), materials (e.g., steel bars, concrete), work sections (e.g., cast-in-place concrete, painting), management (e.g., regulations, cost) are used to classify the construction information. The standard classifications organize the attributes’ structure of a BIM object. These attributes are divided in three aspects include geometric data, containment hierarchy, and construction contents, and are used to present the essential properties of building components as depicted in Figure 1.

In the geometric aspect, the attributes include the coordinates and dimensions of the building component, and the physical relationships with the adjacent components. In the containment hierarchy, the BIM model is structured per the IFC BIM standard (NBIMS, 2008; IFC Model, 2008). The building components are further classified into physical, spatial, and logical CAD objects in this paper. This containment hierarchy defines the structure of the BIM model and is useful for integrating and processing project information. In construction contents, the work necessary to construct the building components is described by the specifications of the required work sections. Typically, each design component in the planned facility will have one or more associated work items. The work items employed in this study are classified and coded according to the hierarchical standard codes established by the Public Construction Commission (PCC) in Taiwan (PCC, 2009).
The PCC coding system was developed with reference to the CSI MasterFormat system (MasterFormat, 1996). As a result, the information of construction contents is organized into the project-required work presented graphically by the BIM objects. The BIM objects are utilized to create a BIM model in an IFC-based CAD system. After the creation of the BIM model, all project-required work can be identified based on the collected work items in the BIM objects. The large amount of information described in the BIM objects will be exported as a relational database for project planning. The use of standard classifications enhances the integration of construction information and also improves the viability of integrated cost and schedule planning systems by reducing the overhead efforts and by reusing historical databases.

![Figure 1 Structure of the attributes of a PIM object](image)

3. GA-BASED SCHEDULING

3.1. Object sequencing matrix

In the proposed scheduling method, the physical relationship between building components, which is defined by the geometric attributes retrieved from the BIM objects, is utilized to formulate the construction sequence of the components and is presented in the Object Sequencing Matrix (OSM). As shown in Figure 2(b), the circled “S-D” indicates that object C1 (column) is “supported directly by” object B1 (beam), the circled “S-I” indicates that object W1 (wall) is “supported indirectly by” object B3 (beam), and the circled “D” indicates that object W3 (wall) “depends on” object C1 (column).

The sequence of objects in OSM is the construction order of building components. As shown in Figure 2(b), the circled “S-I” in the upper-right zone indicates that object C1 is supported indirectly by object B4, i.e. object B4 must be installed before object C1. Therefore, object B4 should be scheduled before object C1. In other words, the object relationships in the upper-right zone of the matrix should be all moved to the lower-left zone, which is the rational sequence of the building components. Based on these precedence relationships between building components and regardless of the construction continuity, a number of possible construction sequences will be developed. In order to generate a more practical construction sequence for
the construction work. The information includes the completion of work items, resource consumption, and cost. In project evaluation, the data obtained from “Construction Plan” and construction records, such as budgeted cost, actual cost, scheduled completion, and actual completion will be used in the earned value analysis. The cost and schedule variances assist in evaluating and controlling project risk by measuring progress in monetary terms.

5. CONCLUSION
This paper presents a model-based scheduling method that employs BIM objects to generate information required for project planning. As a core information repository, the BIM model consists of the BIM objects ensures the consistency and reliability of project information processing. From the findings of the case study, this consistent project information model, with associated data regarding functional, material and product information, has the potential to significantly reduce overhead efforts, reduce errors, and improve project performance. Furthermore, the application of the Genetic Algorithms (GAs) helps to optimize the construction sequence and to assist in crew assignment, which takes into consideration the constraints on resource, workspace, and productivity. Results show that by applying the OSM and the GAs to the proposed scheduling method, the project planner can quickly generate an efficient and flexible schedule from the vast amount of BIM objects. Since the BIM objects associate each work item with the resources it requires and its associated costs. The resulting schedule is integrated with project costs, which makes it possible for planners to easily examine relevant resources and costs of a specified time period and provides information concerning the detailed operations throughout the construction process. The proposed CSIPS system has demonstrated the efficiency and feasibility of the proposed approach in project planning and control. The proposed solution is more adequate for general contractors. Since the general contractors have to manage their own subcontractors, laborers, materials, and equipments, many different types of data from many different participants should be managed in an integrated way. In our future research, the MEP (Mechanical, Electrical, and Plumbing) systems will be demonstrated in the BIM model to develop a comprehensive project information system.

6. ACKNOWLEDGEMENT
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7. REFERENCES

