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Developing a 3D BIM for Earthwork Construction

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Abstract: ***The Building Information Model (BIM) is gaining wide popularity in the construction industry. This attempt is, however, limited to a predefined operation of structural facilities. The application of BIM can be extended to include undefined operations in earthwork construction. The objective of this paper is to introduce the concept of an earthwork BIM environment that is currently under development in the Construction System Laboratory at Pusan National University. First, this paper defines the concept of earthwork BIM. Second, it discusses the key aspects of earthwork BIM, including 1) geographical information, 2) equipment configuration, and 3) equipment position. In the future, the 3D BIM environment will be tested at an actual construction site to determine its applicability, and it will be extended to include construction equipment such as bull dozers and pay loaders.***

Keywords: construction vehicle, 3D BIM, earthwork construction, earthwork BIM

I. Introduction

The Building Information Model (BIM) attempts to apply construction design in a 3D model and control construction data. The technology provides a digitally constructed environment that can be used for planning, design, construction, and operation [1]. The 3D building components can be assembled in a sequence of construction processes. The simulation of actual construction can provide valuable information prior to the actual construction [2]. The contractor can use the BIM environment as a communication tool with the owner, helping to prevent possible disputes.

BIM is widely accepted in the construction industry because the technique brings up an environment in which the life cycle of a construction project can be conveniently saved and reused [3]. The 3D components contain attributes on dimension, volume, material type, duration, etc. that are saved in a database. Using this information, the application of BIM can be extended to include cost control and time management. Due to these benefits, the modeling technique is used for managing construction information in office buildings, industry facilities, bridges, and other infrastructures.

Although BIM offers many benefits, as mentioned, the technique is mostly used in a predefined operation with structural facilities. The ease of modeling a predefined structure limited the application of BIM in the structural facilities. However, the BIM can be extended to include undefined earthwork operations.

The objective of this study is to extend the BIM technique to an earthwork operation at a construction site. Contrary to the predefined environment of buildings and bridges, earthwork operation is undefined and is influenced by the varying site conditions and dynamic changes at the construction site. Therefore, when the BIM technique is applied to an earthwork operation, the technique should be able to use the information on the dynamic changes that occur during the course of excavation.

This paper introduces the concept of an earthwork BIM and the technical components that should be investigated in developing the undefined environment of earthwork BIM.

II. Definition of Earthwork Bim

The earthwork BIM is an attempt to model an earthwork operation in a 3D environment. Since the earthwork operation is executed on an undefined path, the earthwork BIM should be able to estimate the changes in the geographical terrain during digging as well as the configuration of the construction equipment, such as excavators and dump trucks (FIGURE I).

Since the earthwork BIM is applied to an undefined environment, this study is a challenging endeavor. The earthwork BIM should be built with an interface that includes sensory devices attached to the construction equipment. The location can be identified using Global Positioning System (GPS) data. This information can show in real time the changes during the earthwork operation.

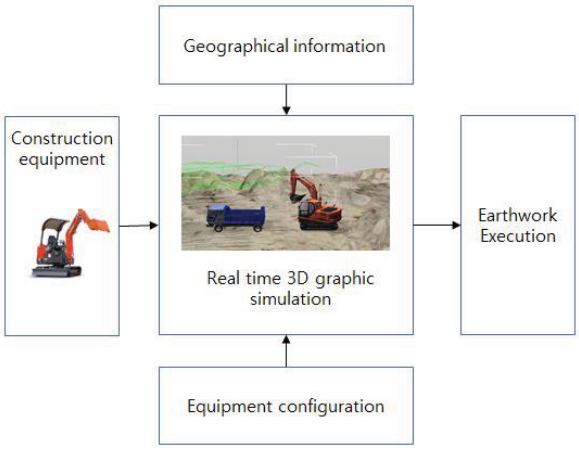

FIGURE I.
OVERVIEW OF THE EARTHWORK BIM

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III. KEY TECHNICAL COMPONENTS IN EARTHWORK BIM

Earthwork usually has a high cost impact on the overall construction budget. Utilizing the earthwork BIM, the earthwork operation can be planned ahead in the early design stage to prevent the unnecessary waste of resources. The earthwork BIM tries to simulate the actual earthwork operation at the construction site. To attain this goal, the modeling technique has three key technical aspects: 1) geographical information, 2) equipment configuration, and 3) equipment position.

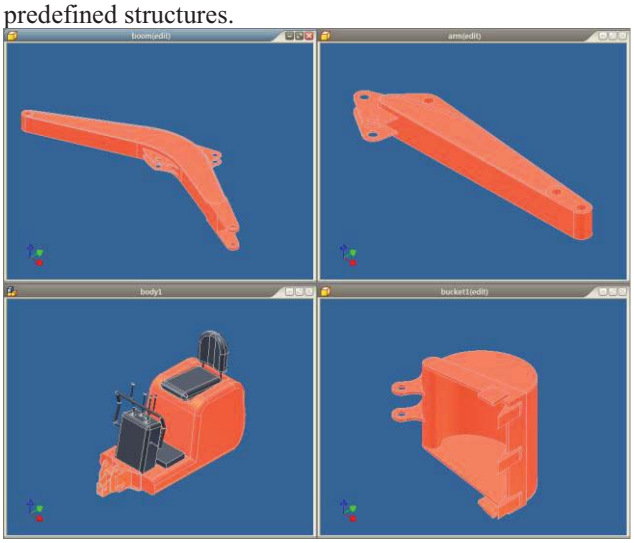
1) Geographical Information

The 3D geographical information is important in planning the earthwork operation. A digital map shows the characteristics of the terrain in a specific area, and it should be prepared to model the area where the excavation is to be executed.

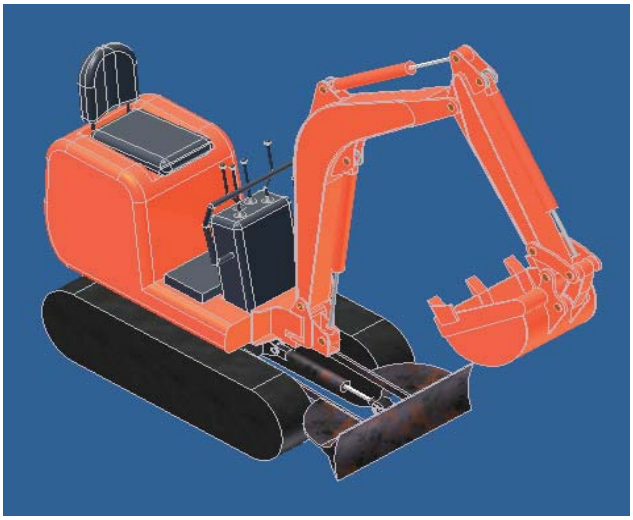
The digital map can be converted as a CAD file to indicate the x, y, and z positions and then put into a BIM viewer, where it can be used to indicate the changes in the terrain as the excavation progresses. The 3D earthwork BIM is designed to show the changes in the geographical terrain in a real-time fashion. The digital map is also used to estimate the approximate amount of excavation.

2) Equipment Configuration

The equipment configuration models the activity of the construction equipment during the earthwork operation. For example, the excavator is made up of a boom, arm, and bucket (FIGURE I(a)). The boom is attached to the body of the excavator. The components of the excavators should be modelled individually and then put together to show the excavation movement. Then, the angles of each component are measured to calculate the final position of the bucket tip (FIGURE I(b)). The information on the angles come from the sensors attached to the components. Therefore, the 3D earthwork BIM requires an integration of hardware and software, which differentiates the task from the general BIM for predefined structures.



(a) Components of an excavator



(b) 3D modeling
FIGURE II
SIMULATION OF EXCAVATORS IN A 3D ENVIRONMENT

3) Equipment Position

Equipment position refers to where the equipment is located within the excavation area. The position data is used to simulate the actual position of the construction equipment. The earthwork BIM simulates the movement of the excavator at the location where the actual excavator is located. Also, the BIM simulates the movement of the dump trucks in conjunction with the excavator.

The position data is coming from a GPS. In the Global Navigation Satellite System (GNSS), at least four satellites transmit encoded signals. Then, the receiver on the ground calculates the x, y, and z positions [4]. The global position is converted into a local position to indicate the location of the equipment at the construction site.

IV. CONCLUSION

Currently, the Construction System Laboratory at the Pusan National University is studying the application of BIM technology to earthwork operation. This approach is unique in that the BIM technology is implemented in an undefined earthwork environment. The final output of this research will provide a machine guidance system that can assist equipment operators in earthwork operations. Relying on the guidance system, the operators can increase productivity in executing the earthwork operation.

The study is expected to provide benefits in that 1) the equipment operator can acquire information on the status of the excavation, 2) the progress of the excavation can be summarized, and 3) communication can be facilitated by relying on the 3D display. In the future, the 3D BIM environment will be tested at an actual construction site for its applicability, and it will be further extended to include construction equipment such as bull dozers and pay loaders.

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