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Development of a 3D earthwork model based on reverse engineering

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Abstract: Unlike for other building processes, BIM for earthwork does not need a large variety of 3D model shapes; however, it requires a 3D model that can efficiently reflect the changing features of the ground shape and provide soil type-dependent workload calculation and information on equipment for optimal management. Objects for earthwork have not yet been defined because the current BIM system does not provide them. The BIM technology commonly applied in the manufacturing center uses real-object data obtained through 3D scanning to generate 3D parametric solid models. 3D scanning, which is used when there are no existing 3D models, has the advantage of being able to rapidly generate parametric solid models. In this study, A method to generate 3D models for earthwork operations using reverse engineering is suggested. 3D scanning is used to create a point cloud of a construction site and the point cloud data are used to generate a surface model, which was then converted into a parametric model with 3D objects for earthwork

Keywords: 3D model, BIM, Reverse engineering, Earthwork, Planning

I. INTRODUCTION

Around the world, the introduction of BIM is being expanded, and the construction sector is playing a pivotal role. South Korea introduced it with a government-driven pilot project, and the Public Procurement Service is setting up a BIM application and expansion project. In private sectors, however, the terrain for BIM introduction has not yet been prepared in terms of professional agencies and personnel as well as related systems, and pilot projects are being attempted. BIM features are being applied in a limited manner to tasks such as quantity surveying, checking for interference, and drawing blueprints. In particular, BIM has been applied to civil infrastructures to a very limited extent. The main obstacles to the practical application of BIM in the infrastructure sector are the irregular structures compared to buildings, a lack of standard information models for soils of various sites, and a lack of 3D objects necessary for design. In 2015, the Ministry of Land, Infrastructure and Transport [1] plans to set up an action plan for applying BIM to 20% of infrastructure projects by 2020 and a pilot project.

Research on earthwork-related BIM has been conducted within a very limited scope. Kim et al. [2] probed a format for earthwork data model in their study on the expanding the structure of Industry Foundation Classes (IFC) and presented shape elements and design parameters for road construction earthwork. They divided the earthwork into cutting, filling, and cut-embankment areas. To schematize the extended IFC concepts, Kim et al. [3] presented earthwork object schemas representing objects for original and planned terrains, filling, void space after cutting, pre-earthwork original terrain, and parts joined to the structure.

Unlike for other building processes, BIM for earthwork does not need a large variety of 3D model shapes; however, it requires a 3D model that can efficiently reflect the changing features of the ground shape and provide soil type-dependent workload calculation and information on equipment for optimal management.

II. BUILDING INFORMATION MODELING FOR EARTHWORK PROCESS

Objects for earthwork have not yet been defined because the current BIM system does not provide them. The BIM technology commonly applied in the manufacturing center uses real-object data obtained through 3D scanning to generate 3D parametric solid models. 3D scanning, which is used when there are no existing 3D models, has the advantage of being able to rapidly generate parametric solid models. In this study, 3D scanning was also used to create a point cloud of a construction site. The point cloud data were used to generate a surface model, which was then converted into a parametric model with 3D objects for earthwork.

A. 3D scanning and surface model creation

A 3D scanner can create a point cloud, which can be converted into a non-uniform rational B-spline (NURBS) surface model. However, a commercialized 3D scanner cannot cover a space as wide as an earthwork site. To solve this problem, Chae et al. [4] suggested a data fusion algorithm that integrates the data obtained from multiple reference points into one coordinate system, where the reference points are spherical targets installed at a sufficient number of points partitioning the site. Topographic data are obtained by scanning each partial area. After the integrated point cloud is obtained, a triangular mesh is generated. Many researchers have proposed algorithms for generating a triangular mesh from a point cloud. In this study, the Delaunay triangulation method was applied to enhance the rendering speed and generate a relatively smooth polygon mesh. The generated

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polygon mesh, then undergoes a Texturing process to form a colored surface model

B. Input of design data and equipment specifications

Once the surface model is completed, information begins to be input for the earthwork process. The input information includes the earthwork, site boundaries, planned contours, the positions of the formation level, soil survey (boring) data, and construction equipment specifications. A soil transport plan is set up based on the input information. In the case of cutting, the overall volume of earthwork is divided into the free haul volume, volume removed by a dozer, and volume removed by the excavator and truck combination. The input data are also used to determine the efficient excavation diameter and depth. The ground to be removed in earthwork is divided into general soil, weathered soil, weathered rock, soft rock, and hard rock in increasing order of depth. The soil parts are removed by excavation. The soil and rock layer distribution is estimated on the basis of the boring data, and the estimated distribution is used as basic data for providing the geophysical information necessary to set up the parametric model.

C. Basic objects for data structure and earthwork

An octree data structure is used in order to store all of the information necessary for converting the surface model obtained through 3D scanning into the parametric model. An octree recursively decomposes the entire target earthwork area by subdividing it into increasingly smaller subareas using cubes that represent the entire area. Thus, it serves as a data structure holding detailed information of the work area represented by the corresponding cube. The root node of an octree is the center of the cube, where the z-axis value (altitude) of the 3D coordinates (x, y, z) of the root node is positioned along the formation level. The degree of decomposition from the root node to lower-level nodes is determined by considering the effective diameter and depth of excavation. Based on the set standards, the octree is decomposed from the root node to lower-level nodes until terminal nodes with physical dimensions of 7 m × 7 m × 2 m to 12 m × 12 m × 23 m are reached. When the terminal nodes consist of various soil types, additional decomposition can be performed to calculate the excavation mass for each soil type.

Eight types of primitive objects that enable octree-based information storage are suggested. The primitive objects perform the rapid 3D implementation of the shape of the detailed work area represented by each node and the efficient calculation of the workload.

D. 3D parametric solid modeling

Parametric models hold other information besides the 3D morphology to enable efficient work. They are characterized by synchronized changes in all interlinked nodes when information in a given node is changed. Once the octree decomposition is completed, the information of each node is stored by being dichotomized into shape information and attribute information. Nodes are basically divided into cutting nodes, filling node, and completed or void nodes. Shape information is provided by using primitive and applied objects, and attribute information provides data on the given node itself, edge point coordinates of the primitive objects, soil type, workload, and equipment required for the corresponding work. In particular, the soil type is identified by using the soil composition map generated with the boring data in order to calculate the workload for a given node. The workload for each soil type can be calculated on the basis of the boundary line between two different soil types.

III. Conclusion

In recent years, research on introducing BIM to earthwork has been ongoing. However, there is a lack of 3D object data that can be applied to earthwork. The manufacturing industry has been successful at generating novel 3D solid models using the reverse engineering technique and applying them to design. In this study, A method to generate 3D models for earthwork operations using reverse engineering is suggested. 3D scanning is used to create a point cloud of a construction site and the point cloud data are used to generate a surface model, which was then converted into a parametric model with 3D objects for earthwork.

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