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3D Ground Terrain Processing Platform for Automated Excavation System

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Abstract: Efficient management of the construction heavy equipment is required to reduce the rate of carbon emissions and on-site accidents. The intelligent excavation system (IES) will improve the construction quality and productivity through information technologies and efficient equipment operation, especially in large earthwork projects. Three-dimensional digitized ground data should be required for identifying the path of heavy equipment and work-site environment. Rapid development of terrain laser scanners (TLS) is more readily to acquire the digital data. This study suggests the '3D ground terrain processing platform (3D-GTPP)' including data manipulating module and analyzing module of the scanned data for intelligent earthmoving equipment operation. The processing platform consists of six modules, including scanning, registering, manipulating, analyzing, transmitting, and storing. 3D ground terrain processing platform presented in this study will provide fundamental information for intelligent excavation system (IES), which will increase the efficiency of earthworks and safety of workers in significant.

Keywords: Terrain Laser Scanner, Processing Platform, Intelligent Excavation, Construction Heavy Equipment

I. INTRODUCTION

Heavy equipment vehicles in work-sites, such as bulldozers, excavators, and backhoes, has been considered as one of the major causes of carbon dioxide generation and on-site accidents [1]. Efficient management of the construction heavy equipment is required to reduce the rate of carbon emissions and on-site accidents [2]. The intelligent excavation system will improve the construction quality and productivity through information technologies and efficient equipment operation, especially in large earthwork projects [3].

Three-dimensional digitized ground data should be required for identifying the path of heavy equipment and work-site environment [4]. Rapid development of terrain laser scanners (TLS) is more readily to acquire the digital data. Recently, 3D scanners can collect approximately one million points per one second, and analysis software can automatically register multiple scan segments into one 3D model. Current 3D scanning and registering technologies is able to transfer a real ground shape to digitized landscape, but is insufficient to be applied to the intelligent earthmoving equipment operation.

The earthworks activities also have direct effects in the sequencing of the rest of the other activities since earthwork contributes high percentage in project [5]. The scheduling of earthwork operations are of major importance in obtaining an efficiently operated construction project [6]. The schedule of earthwork operation is determined based on the amount of earthwork movement. Excavated material is easily considered to occupy exactly the same space, but it is not due to soil properties. However, The accurate cut-fill balance and total amount of earthwork movement can be determined considering soil properties, including soil type, density, and moisture content [7,8].

This study suggests the '3D Ground Terrain Processing Platform (3D-GTPP)' that manipulates scan data to add some soil properties and compares scanned ground level and planned ground level to calculate cut-and fill volumes.

II. 3D GROUND TERRAIN POCESSING PLATFORM

A. *Architecture of 3D-GTPP*

Intelligent excavation system is built upon three major components, 'work environment sensing and task planning system', 'intelligent robot control', and 'hardware development and system integration' [9]. 3D-GTPP produces and supplies fundamental data for intelligent excavation system, especially for division of 'work environment sensing and task planning system'. 3D-GTPP consists of six modules, such as registering, controlling, manipulating, analyzing, storing, and transferring data. Fig. 1 shows the flow chart that on-site scanned data are transferred to 'Task planning system' through 3D-GTPP.

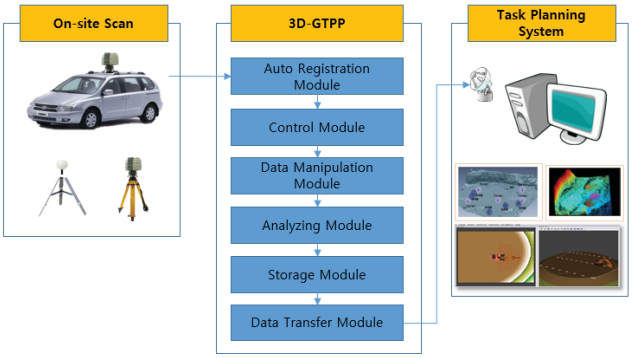

Fig. 1 Flow Chart of 3D Ground Terrain Processing Platform

Point cloud is obtained from on-site scanning system, including spear targets, single TLS, and TLS mounted on vehicles. The scan points are registered by auto registration module and updated by data manipulation module. Based

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on the updated point data, the work amount is calculated by analyzing module.

B. Data Manipulating Module

Data manipulating module transforms registered data into the form of TIN (Triangulated Irregular Network), mesh, and solid, and update additional properties like soil type, density, and moisture content. Fig. 2 is the example of data manipulation for selected area. Users are able to specify the area in various form, rectangles, circles, and freestyles, and update data properties.

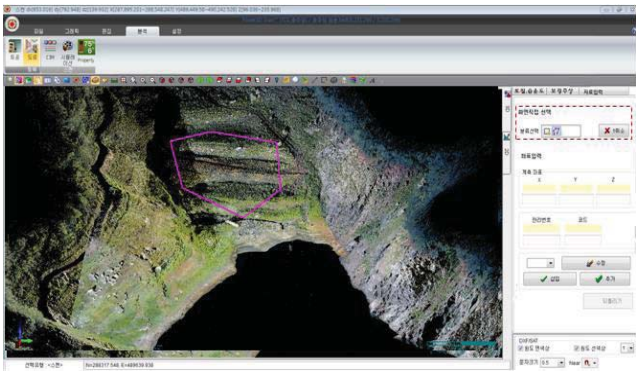

Fig. 2 Data Manipulation for Selected Area

The manipulation module allows users to input boring information by the boring depth and visualizes the same soil properties using the Voronoi diagram. Fig. 3 shows updating scanned points with boring results.

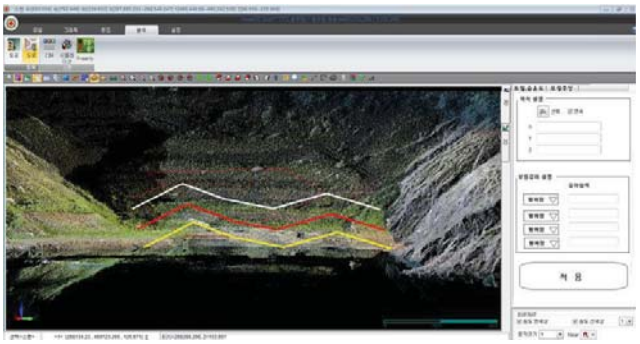

Fig. 3 Data Manipulation using Boring Report

C. Analyzing Module

The analyzing module provides functions of calculating cut-and-fill volumes and predicting work amount for the future. Analyzing module imports plan drawings, such as CAD files, for the selected areas, compares planed area and scanned ground surface, and calculates the soil volume to be excavated and filled. The volume is computed based on the soil properties that is updated from data manipulation module. Project manager can predict the work amount based on the analyzing results and set up action plans for subsequent works. Fig. 4 presents the comparison between planned and scanned areas.

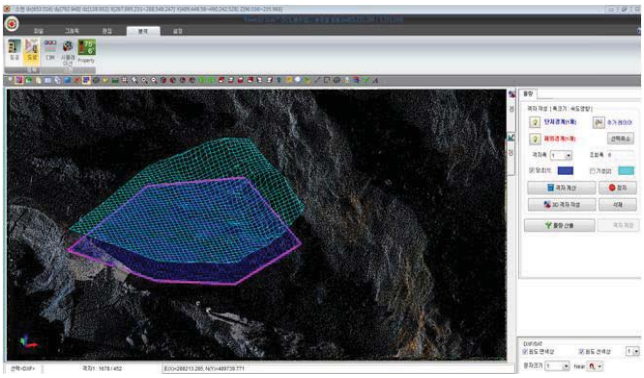

Fig. 4 Analyzing cut-and fill Volume

III. CONCLUSION

3D ground terrain processing platform (3D-GTPP) presented in this study will provide fundamental information for intelligent earthmoving equipment operating system. 3D-GTPP includes two core functions: data manipulation and analyzing modules. Work quantity, type, and work path of heavy equipment vehicles would be identified based on the data from 3D-GTPP, which will increase the efficiency of earthworks and safety of workers in significant.

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