ICCEPM 2022
The 9th International Conference on Construction Engineering and Project Management
Jun. 20-23, 2022, Las Vegas, NV, USA

Automation technology for analyzing 3D point cloud data of construction sites

Suyeul Park[1], Younggun Kim[2], Yungjun Choi[3], Seok Kim[4]*

[1] *Department of Railroad Convergence System, Korea National University of Transportation, 157 Cheoldobangmulgwan-ro, Uiwang-si, Kyeonggi-do, 437-763, Republic of Korea, E-mail address: sypark@ut.ac.kr*
[2] *Department of Railroad Infrastructure System Engineering, Korea National University of Transportation, 157 Cheoldobangmulgwan-ro, Uiwang-si, Kyeonggi-do, 437-763, Republic of Korea, E-mail address: xpdlvm090100@ut.ac.kr*
[3] *Department of Railroad Infrastructure System Engineering, Korea National University of Transportation, 157 Cheoldobangmulgwan-ro, Uiwang-si, Kyeonggi-do, 437-763, Republic of Korea, E-mail address: cyj62601@ut.ac.kr*
[4] *Department of Railroad Infrastructure System Engineering, Korea National University of Transportation, 157 Cheoldobangmulgwan-ro, Uiwang-si, Kyeonggi-do, 437-763, Republic of Korea, E-mail address: kimseok@ut.ac.kr*

Abstract: Denoising, registering, and detecting changes of 3D digital map are generally conducted by skilled technicians, which leads to inefficiency and the intervention of individual judgment. The manual post-processing for analyzing 3D point cloud data of construction sites requires a long time and sufficient resources. This study develops automation technology for analyzing 3D point cloud data for construction sites. Scanned data are automatically denoised, and the denoised data are stored in a specific storage. The stored data set is automatically registrated when the data set to be registrated is prepared. In addition, regions with non-homogeneous densities will be converted into homogeneous data. The change detection function is developed to automatically analyze the degree of terrain change occurred between time series data.

Key words: 3D digital map, Point cloud date, Automation technology, Construction management

1. INTRODUCTION

Recently, various studies have been conducted to apply the latest digital technologies, such as drones, 3D scanners, GNSS, and 3D digital maps, to construction sites. [1,2,3]. In order to apply these technologies to construction sites in South Korea, related research project is being actively conducted focusing on smart construction technologies. This study develops an integrated module that automatically executes denoising, registration, and terrain change detection algorithms when building digital maps using 3D point clouds collected from UAV(Unmanned Aerial Vehicle) and UGV(Unmanned Ground Vehicle) in construction sites.

In this study, considering huge area of construction site, it was assumed that UAV and UGV measure the site every 3 to 4 times per day. And the measured data can be used for scheduling and planning by checking the progress of the earthwork and road pavement work. This study aims to develop an analysis module of digital map that have functions preprocessing and analyzing for collected terrain information of UAV and UGV by automatically denoising, registration, and terrain change detection. In general, there are many difficulties in building digital maps by measuring construction sites and road pavement sites using UAVs and UGVs at a certain time period per day. Because point cloud data acquired at construction sites have high density and volume due to scanning huge construction sites.

It takes much time and effort to build 3D digital maps by manually handling 3D point clouds for noise removal, registration, and terrain change detection analysis. Therefore, in this study, we focused on automating the data preprocess. Comparing to other studies, this study focuses on integration and automation of the noise removal algorithm, registration algorithm, and terrain change detection algorithm for earthworks and pavement works.

This study develops 'Digital Map Autonomous Analysis Module(DMA2M)' integrating three functions, such as denoising, registering, and detecting changes. In order to develop DMA2M, this study conducts in the following way: (1) A literature review was conducted on point cloud-based noise removal algorithms, registration algorithms, and change detection algorithms. (2) Algorithms suitable for construction sites were selected based on the the literature review. (3) An integrated framework of algorithms was established. (4) The DMA2M was suggested. (5) 3D point clouds were collected by measuring construction sites using UAVs and UGVs. (6) The performance test of DMA2M was conducted.

2. SMART CONSTRUCTION TECHNOLOGY DEVELOPMENT PROJECT

The second division among twelve divisions in Smart Construction Technology Development Project study develops on-site information collection technology and analysis technology to apply the latest digital technology to earthwork and road pavement construction sites, and this study aims to improve productivity and safety of construction sites. The main research contents of the second division consist of (1) development of autonomous information collection technology using UAV and UGV, (2) development of digital map-based field information analysis technology, (3) development of CPS(Cyber Physical System) simulation and visualization technology, and (4) integrated field data management platform technology. Various institutions such as universities, companies, and government-funded research institutes are participating in the second division. The research in this paper is being conducted by taking charge of the second research topic((2) development of digital map-based field information analysis technology).

3. DIGITAL MAP AUTOMATIC ANALYSIS MODULE

In this study DMA2M was consists of an integrated framework as shown in Figure 1. 3D point clouds are acquired by UAVs and UGVs and are stored in the storage of the server. DMA2M always monitors the storage of server, and when 3D point clouds acquired from UAVs and UGVs are stored in the storage, DMA2M immediately operates to remove noise from the acquired point clouds and sequentially executes the registration algorithm. The registrated digital maps are stored in a storage, and then the digital maps of UAVs and UGVs are integrated into one to make an integrated digital map. The integrated digital map is accumulated in a storage. The time series data accumulated in a storage match the size of the integrated digital map equally by the change detection algorithm. Through comparison between integrated digital maps, the construction progress of the earthwork is shown in various colors and values of vertical distance.

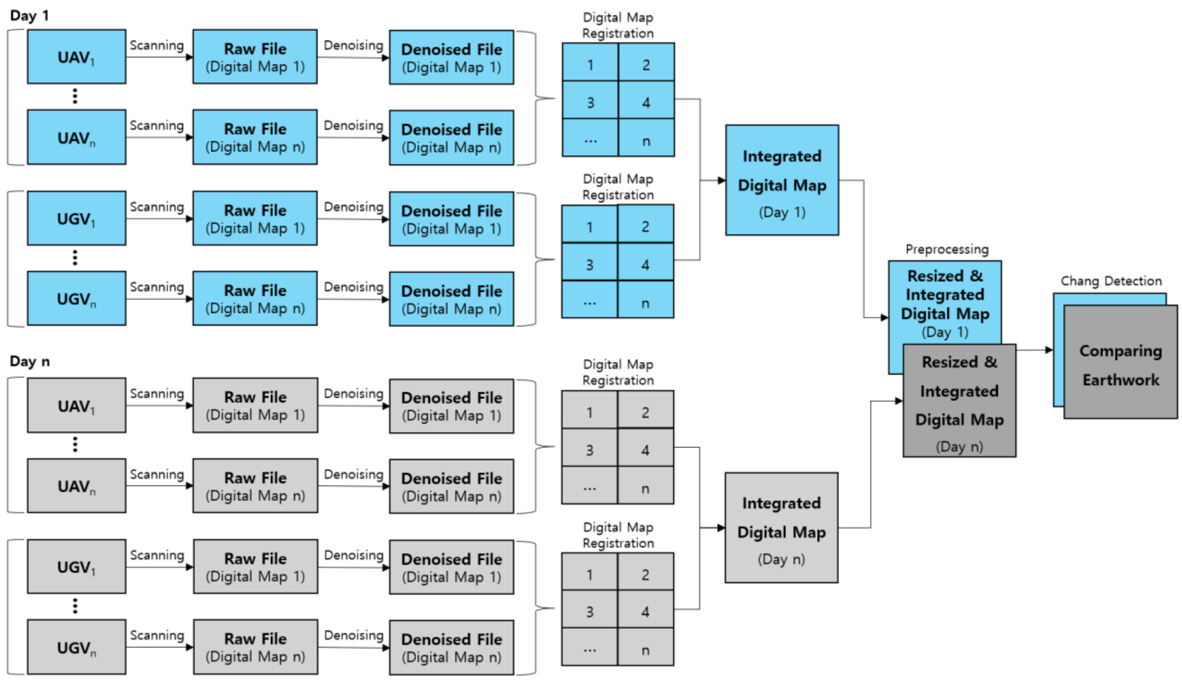

Figure 1. Data process of DMA2M flowchart

3.1. Noise removal algorithm

Noise removal algorithm of DMA2M is selected focusing on denoising execution time and performance, because point cloud data (PCD) are acquired from huge construction sites. The PCD are very noisy and highly dense. This study conducted a literature review on a noise removal algorithm based on execution time and performance. Performance tests for some denoising algorithms are conducted. According to the performance test results, the Voxel grid algorithm is selected for the noise removal algorithm of DMA2M, because of relatively less execution time than other algorithms and excellent performance in noise removal [4].

3.2. Registration algorithm

When measuring construction sites using UAVs and UGVs, it needs to divide survey areas due to hardware performances such as drone weight limit, battery usage time, lidar sensor measurement range, etc. For these reasons, multiple digital maps by UAV and UGV are generated. The multiple digital maps need to be merged to conduct terrain change detection algorithms with the merged digital maps. This study includes a registration algorithm for merging multiple digital maps of UAVs and UGVs. Through this step, one digital map of UAVs and one digital map of UGVs are created. For the registration, DMA2M utilizes ICP(Iterative closest point) registration algorithm [5]. The ICP registration algorithm performs fine registration using rotation matrix and translation vector, and has the characteristic of highly accurately and efficiently for registering digital maps of irregular construction sites [6].

3.3. Changes detection algorithm of 3D digital map

Pre-processing algorithms and change detection algorithms are developed to calculate the progress of construction work and the amount of earthworks. Preprocessing algorithm identifies the same size of two digital maps compared to each other before executing a change detection algorithm. Time series point cloud data can be obtained in different ranges depending on construction progress and field conditions. If two digital maps do not have the same size, the accuracy and speed of change detection algorithm may decrease, so preprocessing algorithm is required to equalize the analysis range[7]. Therefore, in this study, preprocessing algorithm using the pixel method was applied to match the analysis size. Through the preprocessing algorithm, change detection algorithm is performed with two digital maps of the same size. The change detection algorithm shows the progress of construction and the amount of earthwork as visual and numerical results (Figure. 2).

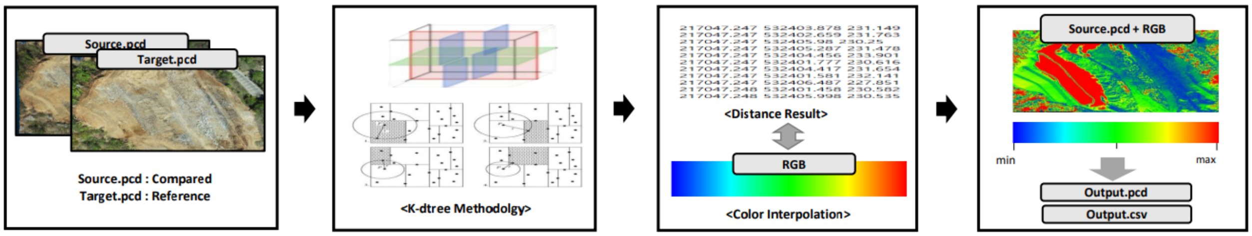

Figure 2. Change detection process

The change detection algorithm is applied with C2C(Direct cloud-to-cloud comparison algorithm) that has advantages in terms of speed and accuracy. The comparative operation is developed using Kd-tree(K-Dimension Tree)[7]. As shown in Figure 2, the results of the analysis through the terrain change algorithm can be compared with numerical data in the *.csv format and RGB data in the *.pcd format.

4. PERFORMANCE TEST

Performance test was conducted with PCD from UAVs taken on different days of the same site with DMA2M. Four digital maps were measured from earthwork sites of highway construction.

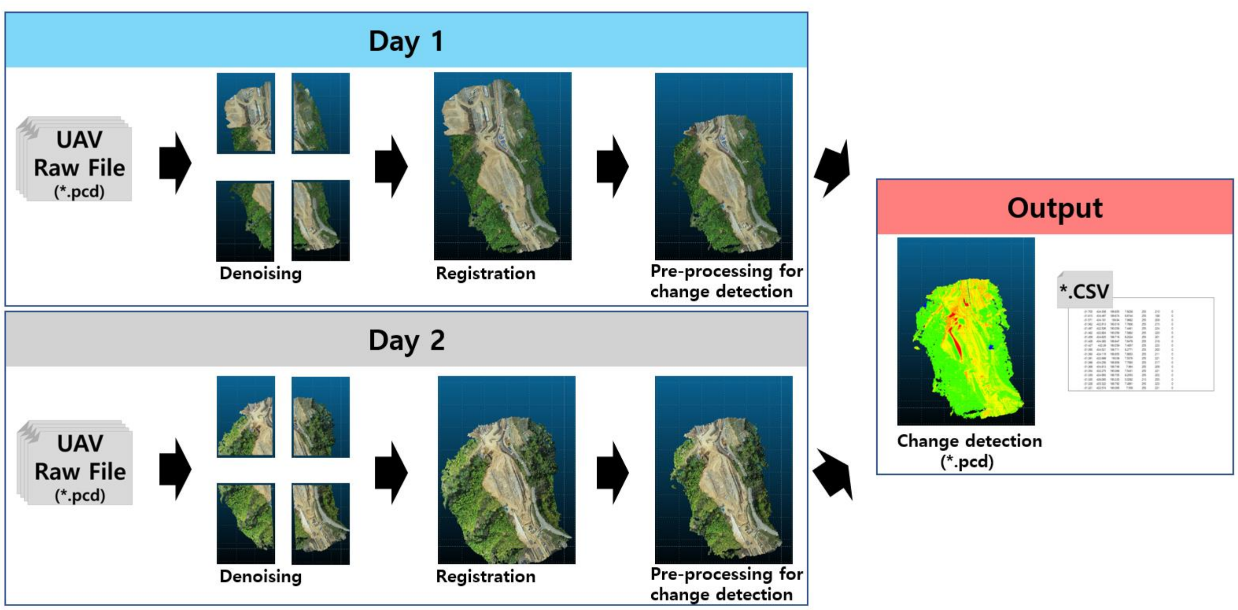

Figure 3. Performance test result of DMA2M

First, the four digital maps of the UAV surveyed on Day1 were stored in a folder (Figure. 3). Noise in each digital map was sequentially removed and the denoised digital maps are stored in a folder. The four digital maps were registrated to one digital map on Day1. In addition, the four digital maps surveyed on Day2 also processed through noise removal and registrating steps, the same as data on Day1. With the accumulated time series data of Day1 and Day2, the preprocessing algorithm operated, making the digital maps of Day1 and Day2 the same size as shown in Figure 3. The change detection algorithm operated to analysis the distance of point clouds showed as color and numerical data. The color data was stored as .pcd file format, and data on the change distance was stored as .csv file format. In this performance test, it was confirmed that a number of time series UAV measurement data were automatically analyzed. The analysis results can confirm the construction progress of Day 1 and Day 2.

5. CONCLUSION

In general, point clouds acquired at construction sites have high density and volume data. It takes much time and effort to preprocess and postprocess these data in manual. To solve the problem, this study presents DMA2M that automatically deal with point clouds at construction sites and analyze the construction progress. This could improve the efficiency of building 3D digital maps for construction sites. To this end, this study developed DMA2M including noise removal algorithms, registration algorithms, preprocessing algorithms, and change detection algorithms. with the developed DMA2M, performance test was conducted with data measured on different days using UAV at the construction site. The performance test showed that all algorithms are worked successfully, and the analysis results were shown in color and numerical data, making it easy to review the progress of the construction. DMA2M could be useful in increasing the efficiency of the construction of digital maps by automating tasks. In order to apply DMA2M to the field, verification of accuracy is necessary. In the future, we will continue to improve the performance and function of DMA2M and apply it to the field.

ACKNOWLEGEMENTS

This research was conducted with the support of the "National R&D Project for Smart Construction Technology (No.22SMIP-A158708-03)" funded by the Korea Agency for Infrastructure Technology Advancement under the Ministry of Land, Infrastructure and Transport.

REFERENCES

[1] D. Girardeau-Montauta, M. Rouxa, R. Marcb, G. Thibaultb, “Change detection on point cloud data acquired with a groud laser scanner”, Proceedings of the ISPRS Workshop Laser scanning 2005, Enschede, the Netherlands, pp. 30-35, 2005.

[2] J. Chen, Y. Fang, Y. Cho, C. Kim, “Principal axes descriptor for automated construction-equipment classification from point clouds”, Journal of Computing in Civil Engineering, vol. 31, no. 2, 2016.

[3] C. Hugenholtz, J. Walker, Owen Brown, S. Myshak, “Earthwork volumetrics with an unmanned aerial vehicle and softcopy photogrammetry”, Journal of Surveying Engineering, vol. 141, no. 1, pp. 1-5, 2015.

[4] S. Park, S. Kim, “A performance evaluation of denoising algorithms for the 3d construction digital map”, Journal of KIBIM, vol. 10, no. 4, 2020.

[5] L. Cheng, S. Chen, X. Liu, H. Xu, Y. Wu, M. Li, Y. Chen, “Registration of laser scanning point clouds: a review”, Sensors, vol. 18, no. 5, 2018.

[6] Y. He, B. Liang, J. Yang, S. Li,J. He, "An iterative closest points algorithm for registration of 3d laser scanner point clouds with geometric features", Sensors, vol. 17, no. 8, 2017.
[7] R. Qin, J. Tian, P. Reinartz, "3Dchange detection approaches and applications" ISPRS Journal of Photogrammetry and Remote Sensing, vol. 122, pp. 41–56, 2016.