Examination of reconstruction 3D models from photogrammetry

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1. Abstract

There is a growing need for 3D (three-dimensional) reconstruction from photogrammetry in the civil engineering field for various purposes such as CIM (Construction Information Modelling), progress tracking, ICT (Information and Communication Technology) etc. This report summarizes the results of a case study and a verification of 3D reconstruction using photogrammetry for construction management of Hokkaido earthwork construction site for the purpose of efficiency and productivity improvement of construction work under the visual-construction approach. The results show that 3D models from photogrammetry is an effective tool for progress tracking in the construction of earthwork and is much more effective than the 3D model from CAD data. Additionally, Reducing the number of pictures processed for 3D reconstruction reduces the processing time significantly however it affects the output quality, but it can be enhanced again by adding a few extra pictures.

2. Construction outline

This project which is proposed by the Ministry of Land, Infrastructure, and Transport is a series of construction work of the countermeasure construction for the landslide from the slope on the up-line side in General National Highway No. 239 Kiritati in Hokkaido area that occurred in April 2012.

The geological condition of this area is characterized by mudstone that is susceptible to slaking due to slight stress release and a tuffaceous clay layer that exists as a sandwich layer, which is prone to collapse.

The 3D reconstruction by the photographed image targeted the tunnel wellhead excavation part in this work.

Photo.1 Side and Top Images from the construction site

3. Method of 3D reconstruction

Point cloud data can be generated through the usage of laser scanners or from photogrammetry either by digital camera or UAV (Unmanned Aerial Vehicle). Laser scanners generate higher accuracy 3D models however due to its high cost and the limited project time, we used the photogrammetry method. Since the excavated part of the construction site is approximately 30X50 m and the entire area can be viewed from the ground there was no need to use UAV. Hence, the images were taken for this project by a digital camera.

4. Procedures of photo measurement

There are many studies on how to create point cloud data from images and many software programs have been released as an open source. Here, 3D reconstruction was performed using Meshroom, Regard3D, COLMAP, and AGISOFT METASHAPE which can create 3D Delaunay meshes; Cloud Compare and ParaView were utilized for visualization purposes. Photographs were taken every 1 to 3 weeks during the drilling construction. A general-purpose mirrorless single-lens camera (12MP) and an action movie camera (12MP) were used for photographing. The shooting points were taken from the outer circumference of the target area, and it was photographed from equally spaced points as much as possible. Since the action movie camera uses an ultra-wide-angle lens, one image is taken at one point, but with the mirrorless single-lens camera, three or four images were taken at one point to cover the entire target area. The number of shots taken per one time was from 150 to 600 (see Photo 2). The time taken for one shooting was about 30 minutes, and the calculation time for 3D reconstruction was about 1 day (PC specifications: Core i7-7700K, Nvidia GeForce GTX 1050)。

Photo.2 Construction yard foreground (left), excavation slope (right)

5. Utilization of 3D model

1) Terrain shape reproduction

Figures 1 and 2 show reconstructed 3D models. Fig.1 3D model from a mirrorless single-lens camera and Fig.2 shows a 3D model from an action movie camera. Also, the texture is rendered on the mesh, and it is possible to recognize not only the shape but also the difference in soil quality. In addition, the machinery arm in operation is not reproduced since the shooting was carried out during excavation work.

Fig. 1 shows a mirrorless single-lens camera（2018/10/23）

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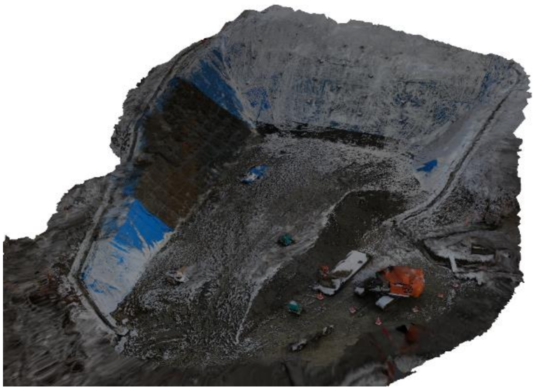


Fig. 2 shows an action movie camera（2018/11/14）

2) Shape difference

Fig. 3 shows differences between the models of Fig.1 and Fig.2 and shows the topography change in the 3-week construction with color contours. There is a gap in the heavy machinery area as the photos were shot during construction work however, it is also possible to manage the amount of soil by shooting after removing the heavy machinery.

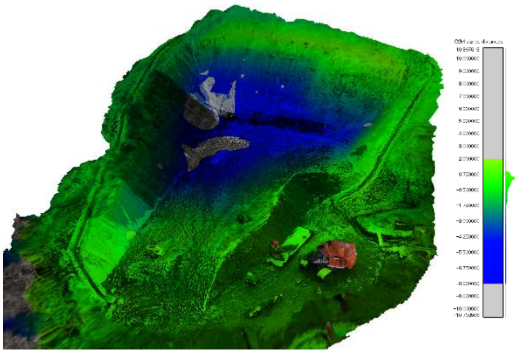


Fig. 3 Difference between October 23 and November 14

3) Comparison with CAD data

Fig. 4 is an elevation distribution view of a 3D model created from CAD data. 3D reconstruction enables more detailed shape reproduction than CAD data.

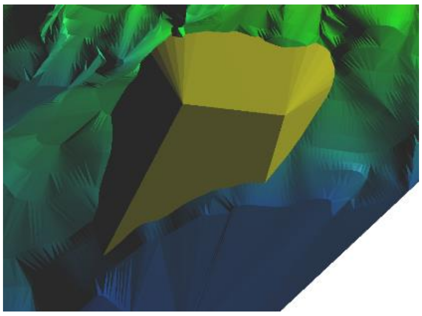
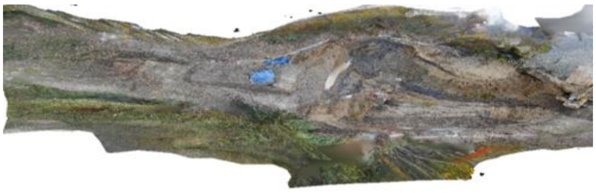


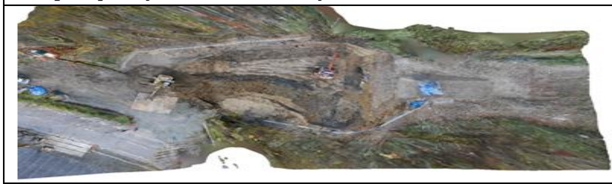
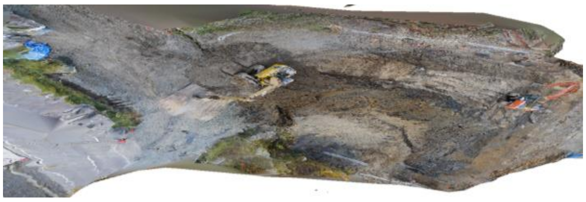
Fig. 4 3D model constructed from CAD data

6. Model optimization study

Different trials with different pictures set and calculation time were examined, and the output quality was evaluated to optimize the generated model.

The number of pictures for each trial is 500, 300, 200 and 150 respectively. By reducing the number of images from trial 1 around 200 pictures in trial 3, we noticed that the calculation time of trial 2 was reduced by more than 8 times than trial 1. However, the model quality difference between the two cases is not big. In addition, case 3 processing time took around 5 times longer than case 2 due to the inconsistency in model creation and reprocessing the model itself to improve its quality. In the 4th case, the 150-picture model was generated smoothly but with relatively much lower quality.


Case 1: 500 Picture processed (481 after alignment). Calculation time: 19 hours and 51 minutes. Output quality: Good quality and level of details.

Case 2: 300 Pictures Processed (264 After alignment). Calculation time: 2 Hours and 35 minutes. Output quality: Medium Quality and Level of details.

Case 3: 200 Pictures Processed (199 after alignment). Calculation time: 13 hours and 44 minutes. Output quality: medium quality & low level of details.

Case 4: 150 Pictures Processed. Calculation time: 2 hours and 8 minutes. Output quality: low quality& very low level of details.

7. Conclusion

It can be concluded that 3D reconstruction from photogrammetry can be efficiently used for progress tracking of earthwork, CIM etc. For model optimization, in Case 2 compared to Case 1, reducing the number of pictures significantly reduces the computation time and the output quality is still acceptable. The quality of Case 4 with 150 photos is problematic however, adding some extra photos can improve the overall quality of the model. In the future, we believe we need to create more efficient procedures to make the 3D Reconstruction process more practical.