4D CIM and Construction inspection by Photogrammetry

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1. Abstract

3D Modeling from photogrammetry has been used widely for promoting ICT in the construction industry for various purposes such as visualization, measurements, progress tracking, and productivity analysis. 4D CIM is About adding the time dimension to 3D models of the construction site for progress tracking purposes. 3D models of the construction site were created weekly and high accuracy RTK-GNSS GPS data was collected to accurately reference the 3D models. This study aims to investigate the effectiveness of 4D CIM by photogrammetry for site inspection, Progress tracking, and design to as-built verification. The investigated method is efficient, cheap, and provides a high level of accuracy for inspection purposes.

2. Construction outline

The construction site as shown in Figure.1 is at shonaigawa river in Aichi Prefecture. This project is a series of works for disaster prevention by supporting the soil slope stability for the riverbanks.

Figure.1 construction site top view on the right and construction site real view on the left.

The work includes soil compaction work, sheet piling, waterproof sheets installation, and concrete blocks installation.

3. Methodology

As the construction site size is big, using a drone for photogrammetry would be the best choice. However, the construction site is very close to Nagoya airport, hence it is not allowed by the government to fly a drone in this area. We developed a method that is like the drone way of shooting from the top view which is by using a 5.5 meters pole and attaching the action camera to the end of the pole (as shown in Fig.2) to get the same view as the drone. By dividing the construction site into three parts, and a person carries the pole and walk-in every part back and forth while shooting a 4K video and a time-lapse of photos.

The camera used in this study is a 4K action camera with Camcorder Sensor Resolution 23.6 MP, which can record 5K 30fps, 4K 60fp.

Figure.2 5.5 Meters pole and GoPro Hero9 attached to the end

The software used for 3D modeling is Agisoft Metashape Professional which is used for dense point cloud generation and editing, 3D modeling, digital elevation model generation. The software used for referencing the 3D models with RTK-GNSS GPS data is Cloudcompare software which is an open-source software used mainly for post-processing purposes.

The specifications of the computer used for processing are CPU intel Core i9-9th generation, ram 64GB, GPU NVIDIA GeForce RTX 2070 Super 8 GB.

Figure.3 RTK-GNSS system on the right picture with a Wi-Fi router and battery, antenna connected to the system in the right picture.

We used a low-cost RTK-GNSS system as shown in fig.3 for collecting GPS data with an average accuracy of 1-2 centimeters at different points at the construction site to be used later for the 3D models referencing process.

4. Procedures

4k videos and time-lapse photos are captured almost every week at the construction site to keep up with the construction work progress. Frames were extracted from each video, then the pictures are filtered to remove blurry and out-of-focus images. Then pictures are uploaded to Metashape software for processing to

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create 3D point cloud data. The Point cloud data were checked and cleaned from noise then imported to cloud compare for post-processing such as GPS referencing and accuracy check.

5. Results

12 3D models representing 12 construction steps of the concrete blocks' installation work were created in the period between 12.5.2020 to 2.21.2021 and referenced with GPS data as shown in fig.4

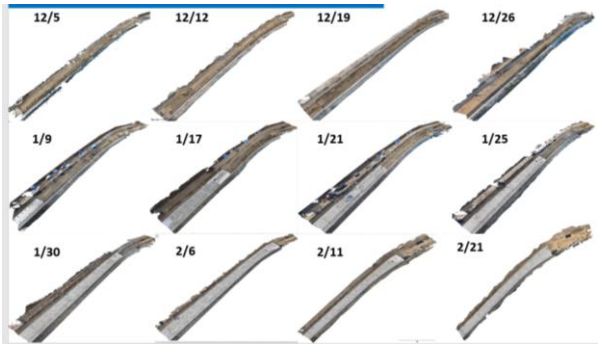

Figure.4 12 3D models for construction steps from 12.5-2.21

The 3D model's average accuracy was 3 centimeters which were within the acceptable accuracy limit. Each 3D model can be further analyzed and a height display, surface slope display, accurate measurements of the model, and sections can be done.

3D design cad data were created for design verification with the as-built data as shown in fig.5. the average accuracy of the block locations in the z-direction is around 2 centimeters.

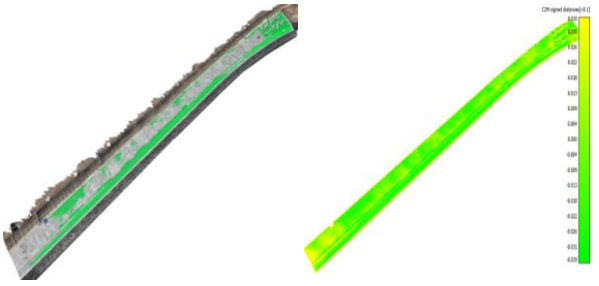

Figure 5. on the left 3D model is superimposed with 3D CAD, on the right the vertical distance between the 3D CAD and the 3D model.

Additionally, the produced 12 3D models can be viewed in VR. A site inspection can be done more realistically in VR with many interactive features such as scaling the model, walkthrough, viewing more than one model aligned in the same place, and measuring the dimension of the blocks in the model.

	pictures	processing time		pictures	processing time
step 1	2548	4.4 hrs	step 7	1221	1.16hrs
step 2	3493	6.45hrs	step 8	2527	2.6hrs
step 3	2095	2.4hrs	step 9	1335	1.3hrs
step 4	1217	1.5hrs	step 10	1329	1hr
step 5	2510	4.22hrs	step 11	1296	1.21hrs
step 6	1560	2hrs	step 12	1590	1.6hrs

Table.1

Additionally, the Calculation time and the numbers of pictures reduced significantly from the beginning of the trial the pictures range from 2000- 3493 pictures and calculation time 4.4-6.4 hrs. to 1296-1590 pictures, and calculation time 1.2-1.6 hrs. the reduction of time and picture number was the result of many trials and the finding that videos when extracted in 1FPS gives a smaller number of pictures, better alignment results, and shorter processing time.

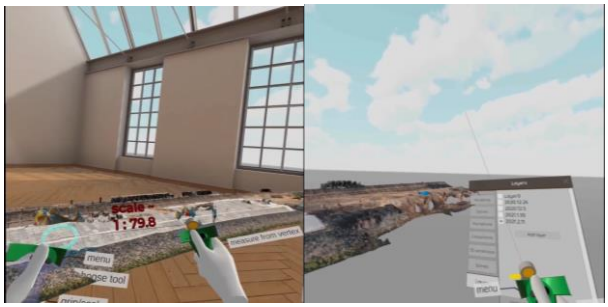

Figure.6 On the left VR view while scaling the model. On the right the layers of different models according to the data of each model

The 3D models can also be viewed interactively in a VR environment for inspection, progress tracking, and viewing various models on different dates as shown in fig.6, scaling, and dimensions measurements.

6. Conclusion

4D CIM by photogrammetry showed great potential in site inspection, progress tracking, and design verification. The RTK-GNSS system provided a low-cost system with high accuracy of GPS readings which was essential for the referencing of the 3D models. The 3D models' accuracy was generally around 2-3 centimeters which are very good and acceptable for this study.

The developed Pole method for photogrammetry when the use of drones is prohibited showed high efficiency and the alignment of photos went smoothly in most of the trials.

Visualizing the 3D models in VR has great potential as the models are very interactive and realistic, it provided an easy tool for inspection and measurements of the concrete blocks. Also, VR models can be shared on the cloud and viewed anywhere remotely and easily which is helpful in the case of remote sites.

7. References

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