Photogrammetric approach for 3D modeling in dynamic sites.

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1. Abstract

3D Modeling from photogrammetry has been used widely in the construction industry for various purposes such as visualization, measurements, progress tracking, and productivity analysis. Photogrammetry is a challenging task especially for existing structures such as tunnels, roads, and bridges. It can be difficult to model dynamic sites such as tunnels which may be risky if photos have to be taken manually. Hence, this paper aims to investigate an approach for photogrammetry of dynamic sites. The investigated method is time-efficient, safer and provides an acceptable level of quality for 3D modeling.

2. Construction outline

The construction site as shown in Figure.1 is Obetsukari Tunnel which is located in Rumoi, Hokkaido. This project is a series of works to repair the damage caused by the aging of the tunnel structure which has been used for more than 40 years. The maintenance work includes cracks repair work, salt damage repair work, and waterproofing work.

Figure 1 Tunnel site.

3. Methodology

As the tunnel site is operating and cars are driving in both directions, the proposed approach is to use action cameras mounted on a car (as shown in Figure 2) driving through the tunnel so there is no disruption caused in the tunnel traffic.

The camera used in this study is 4K action camera with Continuous Shooting Speed 30 frames per second, Camcorder Sensor Resolution 12.0 MP, Max Video Resolution 3840 x 2160 and Frame Rate (Max Resolution) 60 fps.

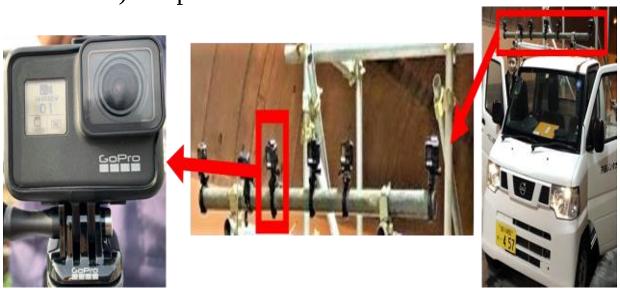

Figure 2 action camera mounted on a car.

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, etc.

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.

4. Procedures

This study used 6 cameras mounted on the top front of a car (Figure.3). The process was performed at several speeds to check the quality of the photos. At a high speed and low lighting conditions, this can cause blurry images that are not suitable for 3D modeling.

In this study, we performed three trials: driving at 10km/hr speed, 30 km/hr speed and a trial of walking and taking pictures manually for quality comparison.

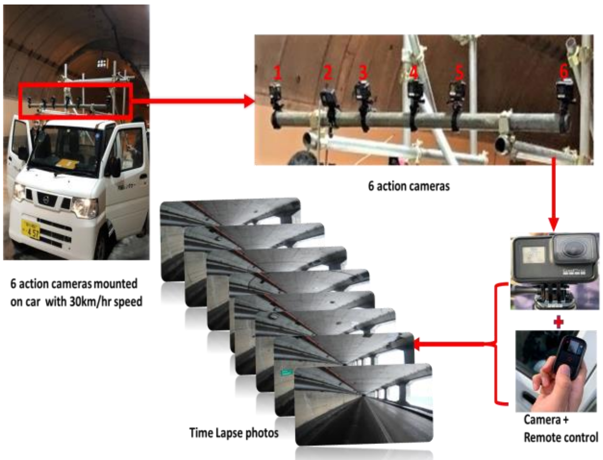

Figure 3 six go-pro cameras mounted on a car; remote device; and time-lapse sample.

The car drives five cycles (one cycle is counted as going and coming back to a specified point) with cameras mounted and different orientation: facing forward, facing upper front to capture the ceiling of the tunnel, facing downwards to capture the asphalt surface, facing the left side, and finally facing right side to capture the tunnel both sides areas.

After capturing the whole tunnel, the photos are uploaded to the PC to eliminate the blurry, out of focus, and over/under exposed photos that are unable to be fixed. Selected photos are uploaded to Agisoft Metashape Software and aligned to produce the tie points, dense point cloud creation, mesh, and texture.

Lastly, the model is checked and evaluated. If the model is in low quality (there are holes/ missing areas in the model or too much noise) then other trials are needed to achieve the highest possible quality, as shown in Figure 4.

Keywords: 3D Modeling, Photogrammetry, construction.
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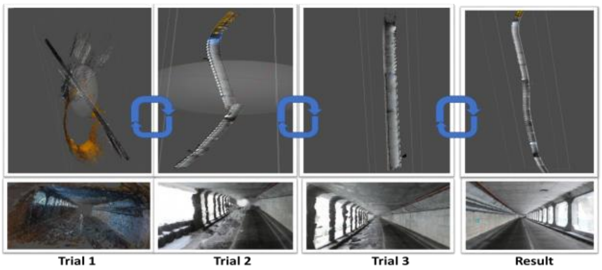

Figure 4 Trials with the same set of Photos for quality improvement

4. Results

In the walking trial (Figure 5), 1,100 photos were taken with a mirrorless camera in single capture mode. The quality and color of the model are very good as shown in Figure 5. The model accuracy is around 9 centimeters. The quality and accuracy can be enhanced if more photos are taken but the processing time and the capturing time will increase significantly.

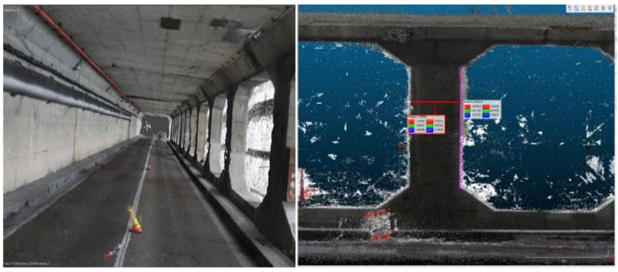

Figure 5 3D model in walking trial with manual single-shot.

In a 10 km speed driving trial (Figure 6), only 300 photos taken in the time-lapse mode were aligned in the model because the photos did not overlap enough and did not align well. The model quality is average but the accuracy is bad because of a low number of photos.

Figure 6 3D model in 10 km driving trial

In a 30 km speed driving trial (Figure 7), approximately 950 photos captured in the time-lapse mode were aligned and used to create a 3D model. The model overall quality is good and the accuracy of the model is around 2 cm which is considered very efficient.

Figure 7 3D model in 30km driving mode.

5. Discussion

In the walking trial, the model overall quality and clarity are better than the 10km/hr and 30 km/hr driving trial, as each photo was taken steadily and the camera had the time for auto-focusing. However, the accuracy of the model in 30km/hr is the highest which is an important factor in 3D modeling (Table 1). The time needed for capturing the pictures in the walking trail is around four hours which is considered a very long time and unsuitable for dynamic sites like this tunnel. On the contrary, the 30 km/hr driving trial took only around 7 minutes to capture photos of the specific area which is very sufficient for the tunnel as there will be no need to alternate the traffic and cause any disruptions.

Mode	**Walking**	**Driving 10km/hr**	**Driving 30km/hr**
Required time	≈4 hours	≈20minutes	≈7minutes
Accuracy	≈9 cm	Bad	≈2 cm

Table 1 Required time for different photogrammetry modes.

The 10km/hr driving mode model quality and accuracy are inadequate as the photos did not overlap well because of the camera positions thus it did not align which caused the model's problem.

7. Conclusion

The results show that the quality of the 3D model in a 30 km/hr driving trial is adequate and acceptable for visualization, progress tracking, and measurement purposes which is the most suitable method for public construction sites like tunnel and asphalt repair sites.

In tunnel and asphalt repair sites that are still operating, photogrammetry with drones and manual photo capture method is unsuitable yet risky, and sometimes drones are not possible to be used due to the law of that city.

It can be concluded that photogrammetry by using action cameras mounted on a car driving through the construction site is an efficient, fast and safe method for creating a 3D model. Moreover, this method can be used in dynamic sites such as tunnels, bridges, and roads for creating 3D models without disrupting traffic.

8. Future studies

More trials are needed to improve the 3D model quality and accuracy, especially in the driving modes. Additionally, to increase the measurement accuracy and the model quality, RTK GPS can be used to create markers to produce a more accurate 3D model.

9. References

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