Analysis of 3D reconstruction by photogrammetry measurements for Pavement crack analysis

Ikee Co., Ltd. Nishiyama Shu, Kurokawa Yosuke, ○ Macome Jaime
Kankyo Fudo Tekuno Co., Ltd. Suda Kiyotaka, Honda Yoichi.

1. Abstract

The development of Information and Communication Technology (ICT) in the construction field is expected since the announcement of i-construction by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Many technologies are effective in big companies, and it is difficult for small and medium-sized construction company to adopt it. The purpose of the trial work was to analyze pavement crack by 3D model reconstruction built from photographic measurements and laser scan. The pavement crack analysis was meant to establish an analytical method of photographic measurements with less burdensome cost, in order to lead to the quality evaluation of road maintenance work. The report was adopted by the MLIT project which aimed for introducing and utilizing innovative techniques to dramatically improve the productivity of construction sites. The Matsuni maintenance work reported about the trial work of the technology to improve the quality etc. in the construction site.

2. Construction outline

The trial work took place from 2018 to 2019, in the Matsuni maintenance construction site of the MLIT in Ehime prefecture. Two construction sites where evaluated, one located in Iyo city on the National road R56 and the other one in Matsuyama city on the Bypass National road R196 as Shown in the Fig. 1.

Fig. 1 Nakayama (left) and Oura (right) Pavement construction sites

3. Methodology

To evaluate and analyze the pavement cracks from 3D reconstruction model we took the following steps:

1. Take pictures of the construction site with hand camera and scan the target area with a Leica P40 laser Scan;
2. Reconstruct the 3D model from photos and laser scan;
3. Visualize, analyze and evaluate the pavement cracks from the reconstructed 3D model as shown on the diagram 1.

The 3D models were reconstructed by COLMAP software for photogrammetry and Leica Cyclone software for the Leica P40 laser scan. For R56 construction site with (25mx5.9m) 147m^2 of area we set one station for the laser scan in the sidewalk of the road and measured, and for photogrammetry we took about 620 pictures from sidewalk. For the R196 construction site with (300mx7.6m) 2280m^2 of area we set 9 stations in the sidewalk for the laser scan and measured, and for the photogrammetry we took about 3350 pictures from sidewalk.

1: Take pictures and scanning (Construction site)
↓
2: 3D reconstruction（In office by software）
↓
3: Results analysis (In office by software)

Diagram 1. Work flow for 3D reconstruction and crack analysis

Usually, UAV (Unmanned Aerial Vehicle) are used for surveying the construction site, however, inside cities due to the risk of accidents in busy roads we used hand digital camera with single-lens which allowed us to take more clear and sharp pictures which gave us more details to our 3D model reconstruction, and we took the pictures from sidewalk, of the road.

3.1 Procedure for 3D reconstruction and crack analysis

The 3D model was reconstructed with COLMAP software, and it was visualized, analyzed and evaluated with Cloud compare software. The 3D model from Leica laser scan was reconstructed by Leica Cyclone software and it was visualized, analyzed and evaluated with cloud compare.

The pictures of the construction site were taken using a Sony α7III (single-lens 28mm 24MP) before, during and after construction, and scan with Leica P40 laser scan shown on fig. 2. The 3D model was reconstructed in a (Core i-7 8th generation CPU @2.2 GHz, 32GB of RAM and NVIDIA GeForce GTX 1070 8 GB graphic card) gaming PC.

The cracks were analyzed from the reconstructed 3D model and evaluated according to the area in which it was observed. It was possible to observe the cracks during construction, after milling 10cm of the pavement.

Fig. 2. Leica P40 Laser scan on the left, Sony α 7III on the right.

The 3D model reconstruction from the feature point's extraction to the point cloud took from 5hours on R56

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Contact: 791-3131 愛媛県伊予郡松前町北川原 79－1 株式会社愛亀 道路事業本部 工務部 089-984-3387

construction site to more than 24hour on R196 construction site. The 3D model reconstruction time was directly related to the number of pictures processed per model (see fig. 3). The pictures were reconstructed into 3D model by SfM (Structure from motion) and MVS (Multi view stereo) technology as shown on fig. 3.

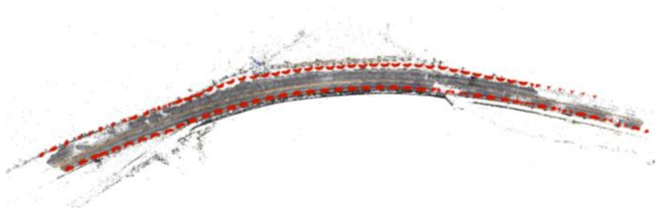

Fig. 3 Camera (red marks) and reconstructed point cloud linkage.

4. Results and discussion

1). 3D reconstruction by photogrammetry measurements

The reconstructed 3D model by photogrammetry measurements provided a very high detailed point cloud for the pavement cracks analysis compared to the laser scan model as shown on fig. 4. It had very clear and realistic color of the pavement, high details of the cracks and clear details on the edges of objects (ex. Manhole).

Fig. 4. R56 construction site 3D model reconstruction by Photographic measurements (top) and by Leica laser scan (bottom)

On the other hand, the 3D scan provide very high accuracy of the point cloud coordinates, high accuracy on the elevation and curves of the construction site (ex. Pavement lines) but a relatively poor details of pavement cracks and the edges of objects (ex. Manhole) which are subject of our trial as shown in fig. 4.

2). Crack analysis results from 3D reconstruction

The results of our trial shows that for the pavement crack analysis, the photogrammetry measurements were efficient in providing more details for our evaluation compared to the laser scan results. However, the 3D scan provided more accurate point clouds for the purpose of area and volume calculation due to its very small error (5mm to 10mm) on point cloud coordinates when measurements were conducted in 50m to 100m distance from the scan station. The point cloud of the R56 construction site had clear crack details compared to the R196 construction site. It may be due to the total area of the construction site (see Fig. 4 and Fig. 5).

Fig. 5. Total area (top) and visible crack section (bottom) of Oura construction site 3D model by photogrammetry measurements.

With photogrammetry measurements we could visualize from the reconstructed 3D model, cracks on the roadbed (10cm bellow the pavement surface) after milling the pavement surface for road maintenance as shown of Fig. 6.

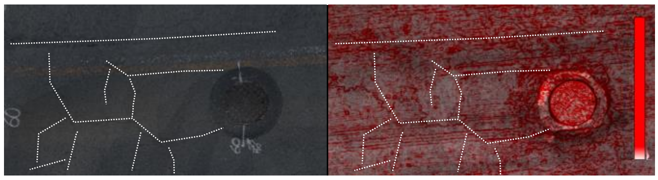

Fig. 6. Pavement cracks before (left) and after (right) milling 10cm of the pavement surface (white lines highlights the cracks visibility).

The elevation and surface inclination mapping of the 3D model reconstruction, illustrate very clearly the occurrence of pavement cracks as shown in figure 7. The pavement cracks were much visible in the tires pathway compared to the center of the lane.

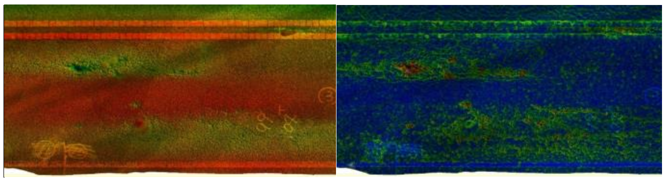

Fig. 7. Elevation (left) and inclination mapping (right) of pavement from 3D reconstruction model.

5. Conclusions and recommendations

The 3D model reconstruction by photogrammetric measurements provided more details for the purpose of pavement crack analysis especially on R56 construction site due to its small area, while the laser scan provided highly accurate point cloud coordinates for the purpose of area and volume calculations. Moreover, the pavement cracks reached more than 10cm going bellow the pavement and reaching the roadbed, in cases of the sites with a cement mixed roadbed, while in a simple crashed-stones roadbed, the assessment was not clear due to a non-rigid roadbed.

We recommend more investigations of the pavement cracks using photogrammetry measurements due to its easy, simple, robust and cheap application and above all, in order to make high quality infrastructures, durable and with zero risk of accidents during the survey.

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Contact: 791-3131 愛媛県伊予郡松前町北川原 79－1 株式会社愛亀 道路事業本部 工務部 089-984-3387