DIGITAL TWIN TRIAL OF SNOW REMOVAL WORK OPERATION UTILIZING IN-VEHICLE PHOTOGRAMMETRY TECHNOLOGY

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1. ABSTRACT

The digital twin world reflects not only the current situation in real time, but also reproduce the accumulated digital information (data) acquired in the past. Furthermore, AI prediction technology utilizing such data is expected to predict and express snow removal dispatch decisions.

The purpose of this trial is to verify the practicality of digital twin. The superimposition of summer and winter road conditions as a 3D model allows heavy equipment operators to confirm the situation of composting structures during snow removal operations, thereby enabling efficient snow removal operations.

Reconstruction of the road 3D model is done by utilizing in-vehicle photogrammetry system that consists of low-cost action cameras and open-source technology. This makes the technology easily accessible for small and medium-sized construction industry applications.

2. INTRODUCTION

This trial of snow removal work digital twinning using videos and 3D data was conducted as part of the PRISM project from Ministry of Land, Infrastructure, Transport and Tourism to utilize data in improving quality management in civil engineering works. The trial took place in Rumoi city, Hokkaido, located in northern part of Japan which is commonly known for heavy snowfall.

The objective of this trial is to propose method of digital twinning through point clouds and 3D reconstruction reproduced by in-vehicle photogrammetry system. 3D models of the snow removal routes were created using frames extracted from videos taken from a driving vehicle with GPS information collected by the camera.

3. METHODOLOGY

Four action cameras (GoPro Hero 10) are mounted on top of the car to capture (Fig. 1) road surface in high-resolution 4K videos with continuous shooting speed of 120 frames per second. The data collected from two of these cameras are used for analysis, while the remaining two cameras serve as backup in case of any contingencies.

Fig. 1 In-vehicle photogrammetry shooting method

Videos are extracted to still frames using FFmpeg and linked to GPS data with ExifTool which are both open-source software to be used to create 3D model with Agisoft Metashape Professional software. Reconstructed 3D models are then overlayed in QGIS software to view and navigate the summer and winter model of the same area at the same time.

Point cloud reconstruction from video shot by in-vehicle cameras require large amount of calculation due to extensive set of frames, thus a method to extract necessary key frames for point cloud formation is developed.

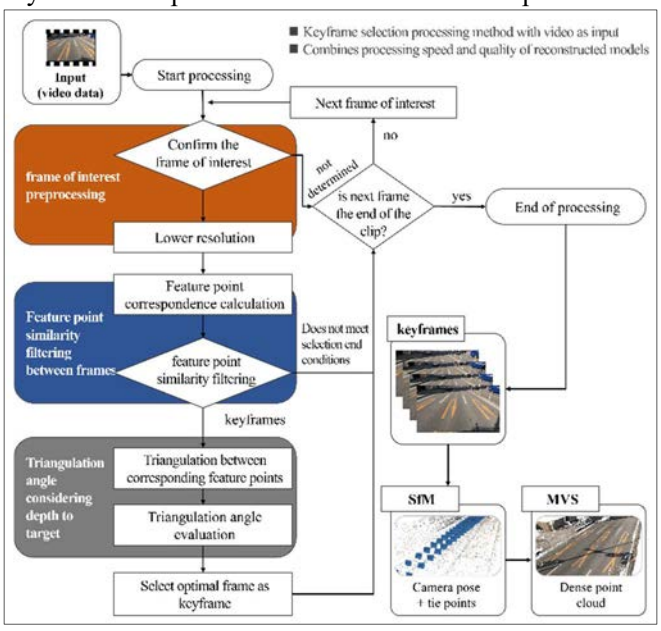

Fig. 2 Method for automatic removal of redundant frames in video

4. RESULTS

Trials were conducted at snow removal routes around Rumoi City, Hokkaido.

Fig. 3 3D model of the same area during summer and winter

First set of data were collected in November 2022 before the winter season started which are used to represent the summer condition model. The figures below show examples of 1 km length road model, where models of the same area when covered by snow during winter were also created.

Keywords: digital twin, snow removal, 3D model, photogrammetry, efficiency
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Fig. 4 Sample of summer model shot in November 2022 (1 km)

Winter data were collected twice in January and February 2023 where the piled snow volume is higher.

Fig. 5 Sample of winter model shot in January 2023 (1 km)

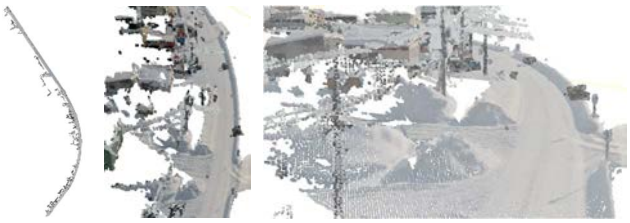

Fig. 6 Sample of winter model shot in February 2023 (1 km)

Each of the models contain GPS location information collected by the camera, enabling it to be overlayed to the exact location on the maps by superimposing these models in QGIS software. Thus, summer and winter condition of the road can be confirmed through the plan view and also by navigating the model in 3D from the heavy machine operator point of view/ eye level.

Fig. 7 Summer model (11/2022) overlayed with maps on QGIS

Fig. 8 Winter model (1/2023) overlayed with maps on QGIS

Fig. 9 Winter model (2/2023) overlayed with maps on QGIS

5. DISCUSSIONS

Fig. 7, Fig. 8, and Fig. 9 shows 3D reconstructed model of a part of snow removal route road superimposed on google maps of its exact location. Consequently, operators can grasp the area surrounding before starting the snow removal operation, reducing the probability of work errors or mistakes such as damaging public facilities including fences, road signs, or electricity poles.

In the future, synchronization between the models and heavy machine's real time location can be useful for machine guidance monitor installed inside the vehicle, which will enable the operator to confirm the condition under the snow during the work operations.

In this trial, 3D reconstruction of the snow removal routes had been conducted for a total length of approximately 20 km intra-city and 45 km at the suburb area outside of the city. (Fig. 10)

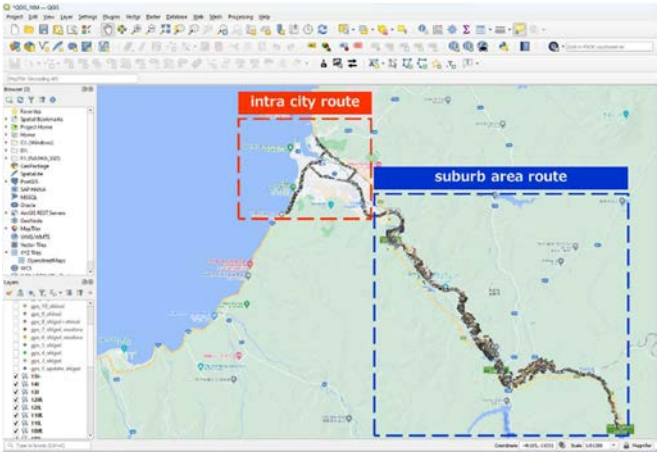

Fig. 10 Overall reconstructed 3D model overlayed on QGIS maps

6. CONCLUSION

A simple digital twin approach for snow removal route can be carried out with in-vehicle photogrammetry system and create a virtual space that projects physical state of snow-covered areas and summer condition by fusing various dynamic information.

Furthermore, this method is a feasible technology that can be implemented by only combining action cameras with necessary software and this environment is expected to enable a simulated experience (simulation) of snow removal operations on the digital twin, which will lead to increased efficiency and knowledge (know-how) transfer in the field.