2024 IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM)
July 15-19, 2024. Boston, MA, USA

Investigation of the Influence of the Magnitude of Camera Vibration on 3D Reconstruction Results by Photogrammetry Based on Simulation

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***Abstract*—Photogrammetry is a technique for 3D reconstruction of target objects from multiple images shot of the object. In the case of actual photography, the object may not be reconstructed due to the inability to shoot images suitable for photogrammetry because of vibration in the camera's angle of view of the object. Therefore, we simulate this vibration by using random numbers and verify the influence of the magnitude of the vibration on the reconstruction result obtained by photogrammetry. The verification results show the relationship between the magnitude of the vibration and the success rate of 3D reconstruction.**

***Index Terms*—3D reconstruction, Photogrammetry, Structure from motion, Multi-view stereo, Decommissioning**

I. Introduction

It is desirable to be able to present information on the decommissioning workspace in three dimensions for planning strategies for removing fuel debris in the decommissioning of the Fukushima Daiichi Nuclear Power Station. Therefore, our research group has researched 3D reconstruction from images by using SfM (Structure from Motion) [1] and MVS (Multi-View Stereo) [2] because the reconstruction using SfM-MVS is inexpensive and easy to understand the internal conditions [3] [4]. In other words, it is very important to investigate in advance how the shooting conditions affect the 3D reconstruction by SfM-MVS and to predict the 3D reconstruction results in decommissioning activities, where there are few opportunities to shoot movies. For example, when a camera is installed on a robot or rail to shoot images of the building inside, the camera may vibrate. In this study, we perform shooting simulations considering the vibration of the camera and investigate the influence of the magnitude of vibration on photogrammetry.

II. Images generation by simulation

To investigate the shooting conditions that affect SfM-MVS, setting up and adjusting the mock-up requires high costs for the preparation of the environment and the arrangement of various cameras, lighting, and other equipment. Therefore, using the 3DCG software Blender [5], we generate images for verification of 3D reconstruction from the virtual environment constructed by simulation and verify the shooting conditions that are effective for 3D reconstruction. Figure 1 shows the virtual environment constructed by Blender, with a 5.5 m diameter, 1.5 m high cylinder, and 0.3 m cubes equally spaced inside the cylinder. The surface of the cylinder is covered with a rust texture, and each cube is covered with a wood grain texture. Furthermore, considering the application to the modularized rail structure developed for the Fukushima Daiichi Nuclear Power Station decommissioning project [6], a virtual camera is installed at a height of 0.75 m from the floor, as shown in Figure 2, and the camera angle θ is set to be changeable. In this study, θ is set at 45 degrees as a basic angle. Then, by moving the camera on the virtual rail, a simulation is performed to capture images of the reconstructed object on the floor surface. The track of the shooting simulation is shown in Figure 3. The viewing angle is set to 121 degrees

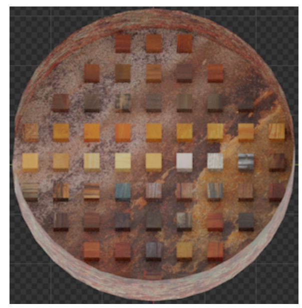


Fig. 1: Virtual environment constructed by Blender

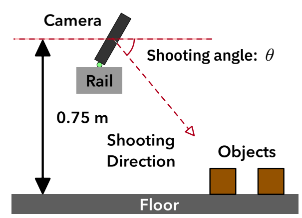


Fig. 2: Camera angle settings

This work was supported by the Nuclear Energy Science & Technology and Human Resource Development Project (through concentrating wisdom) from the Japan Atomic Energy Agency/Collaborative Laboratories for Advanced Decommissioning Science.

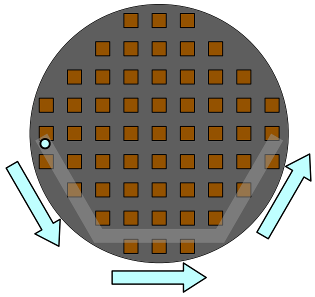


Fig. 3: Camera shooting track

with reference to an action camera, and the depth of field is set so that the floor surface would be in focus. However, since the camera shooting angle vibrates during shooting, it is necessary to simulate this vibration using random numbers and to investigate the effect of the magnitude of the vibration on the reconstruction results obtained by photogrammetry. Therefore, artificial vibration is implemented by adding a uniform random number to the shooting angle when generating images. In this study, the following four patterns of random numbers are used to investigate the effect on the magnitude of the vibration.

1) ± 5 degrees (i.e., θ goes from 40 to 50 degrees)
2) ± 15 degrees (i.e., θ goes from 30 to 60 degrees)
3) ± 25 degrees (i.e., θ goes from 20 to 70 degrees)
4) ± 35 degrees (i.e., θ goes from 10 to 80 degrees)

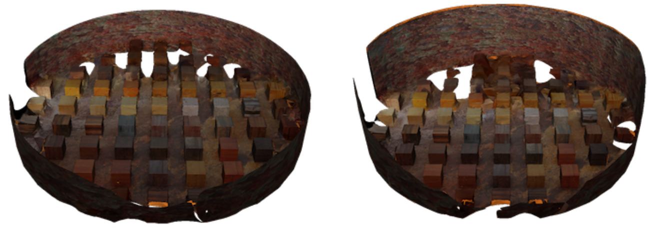
Images for verification are generated for these four patterns. A total of 41 images are generated at equal intervals from the shooting simulation and applied to SfM-MVS. The resolution of the generated images is set to 1920px $\times$ 1080px, referring to an action camera. For each pattern, 10 simulations are performed to generate 10 pairs of image data.

III. Verification results

We perform 3D reconstruction by applying the set of images generated in Chapter 2 to SfM-MVS. In this verification, a combination of COLMAP [7] and OpenMVS [8] is adopted.

Table I shows the relationship between the magnitude of vibration and the success rate of 3D reconstruction for the 10 data sets. For comparison, the table also shows the success rate of 3D reconstruction from images generated without vibration and at a constant angle in 10 trials. From this table, it can be seen that the success rate of 3D reconstruction decreases as the larger vibration. This is because camera vibrations increase the probability that they prevent feature matching between images.

Next, Figure 4 shows an example of the successful reconstruction results when the magnitude of the vibration is ± 5 degrees and ± 35 degrees. From this figure, it can be confirmed that a larger space is reconstructed even if the magnitude of the vibration is large. This is because the larger vibration causes the camera to shoot a larger space.



(a) ± 5 degrees (b) ± 35 degrees

Fig. 4: Example of 3D successful reconstruction result

TABLE I: Relationship between the shooting angle θ and the success rate of 3D reconstruction

Shooting angle θ	Success rate of 3D reconstruction
45	100%
[40, 50]	100%
[30, 60]	50%
[20, 70]	60%
[10, 80]	40%

IV. Conclusion

In this study, we verified the effect of the magnitude of camera vibration on the 3D reconstruction obtained from photogrammetry by simulation. The verification results showed that the larger the vibration magnitude, the lower the success rate of the reconstruction. On the other hand, when 3D reconstructions were obtained even with larger vibration magnitudes, it was confirmed that a larger space was reconstructed.

These results indicated that if the features between the images can be obtained, the reconstruction can be performed even if the vibration magnitude is larger. In other words, if the camera vibration is a periodic oscillation like a sinusoidal wave, it is possible to reconstruct a larger space than with fixed-angle shooting. We would like to test this hypothesis in the future.

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