AN INTRODUCTION OF HIGH-PRECISE 3D MEASUREMENT SYSTEM AND ITS APPLICATIONS

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Abstract:

We have been studying the high-precision three-dimensional measurement system using cameras. In this paper, our system is verified, and its application is reported.

The principle of our measurement system is based on the stereo measurement. In our system, reducing the quantization error by numerical processing can realize the high-precision 3D measurement at the long distance. This measurement system has many applications, such as industrial use, ITS, robotics, and many others.

Our system has been applied on the observation of the glacier. The Perito Moreno glacier, which is our target, moves very fast and the moving speed is reported as about 2 m/day. Then, it is thought that the important information about the global warming can be obtained by observing this glacier. But, as the width of the glacier is several km, there were no reports of continuously observing the movement of the glacier in high accuracy. As a result, the unique observation results about the daily movement of the glacier were measured. The observation of the glacier flow was carried out for the third straight year. In this paper, the valuable results of the glacier observation and experimental results to verify the precision are discussed.

Keywords: *Image measurement, 3D measurement, Glacier observation*

1. Introduction

We have been developing the high precision measurement system using multi-cameras. The accuracy of our developed system was verified at the several circumstances. We applied our system on the measuring Perito Moreno glacier. In this paper, our system is verified in the imitation environment of glacier measurement and the glacier observation results are reported.

1.1. Stereo vision

The stereo vision is the basic method to measure the target by using two cameras in principle. After the target image is taken with two cameras, the each line of sight from camera to the target can be calculated using the camera calibration. The intersection of two lines of sight shows the target position.

1.2. Improving measurement accuracy

The stereo vision using two cameras contains the error due to discreteness of image sensor devices, such as CCD and CMOS. This error is call as the quantization error. Our research results can show that the measurement accuracy is improved by averaging intersections using multi-cameras. Concretely, ten cameras were used for one observation target point in this glacier observation. Then each target position is calculated by averaging over 20 measurement values. This process can reduce the quantization error dramatically. Our computational method is described in detail in the reference [6].

1.3. Experiments in this paper

In this paper, two experiments are described. Experiment 1 was carried out to verify the accuracy of positional measurement. In Experiment 2, the observed movements of the glacier are shown as one application of our high-precise 3D measurement system.

2. Experiment 1

2.1. Purpose

The purpose of this experiment is to verify the accuracy of positional measurement of the glacier.

2.2. Experimental equipment, placement of cameras and target

- In this experiment, we used eight digital cameras, Optio W60 (PENTAX Inc., 10 mega pixels), that were used in the glacier observation. One camera group is made up of four cameras.
- The target color is similar to the glacier color. Conretely, the target color is white on the back board. The size of target is small compared with the real glacier. This difference is thought to contribute to improving the error of measurement.
- To carry out the camera calibration, the optical position measurement instrument, Total Station was used. The range discrimination and the angle discrimination of Total Station is plus or minus 1.0 mm and plus or minus 20 [arc second], respectively.
- We carried out the experiment on the scale of 1/10 compared to the placement of glacier observation (refer to Fig. 2). Therefore, the distance from the camera to the target was 100 m.

2.3. Measurement procedure

- Before measurement, we measured three-dimensional coordinate of the target and camera groups by using Total Station.
- The target images were photographed with each camera.
- The corresponding point of target was extracted on each image.
- Then, the position of the target was calculated

based on the principle of the stereo vision method by using the measured coordinate of each camera pair.

2.4. Results of Experiment 1

Figure 1 shows results of measurement of the target. This graph is drawn as a plan view. In this experiment, the maximum error of this experiment is 9.0 mm.

Our previous experiment reported that the maximum error tended to be proportional to the distance between cameras and target. For example, the maximum error at the distance 200 m increased about 1.6 times the maximum error at the distance 100 m. That is, it is inferred that the maximum error at the distance 1000 m increases 8 - 10 times the maximum error at the distance 100 m. As a result, it is thought that the accuracy of positional measurement of the glacier is the plus or minus 70 - 90 mm. The error of plus or minus 70 - 90 mm is under 10 % of the error rate because the movement speed of Perito Moreno glacier is reported to be 1 - 2 m/day. This accuracy is thought to be enough for this glacier observation.

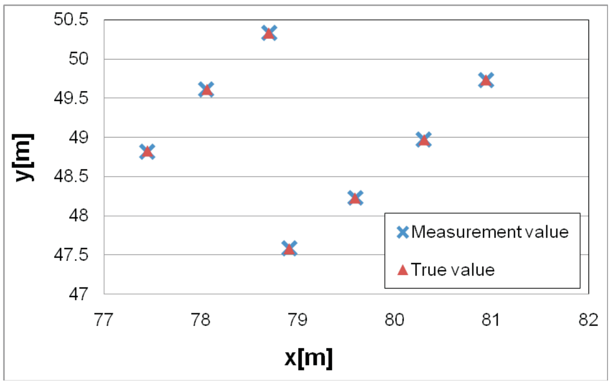


Fig . 1. The measurement results of the target.

2.5. Discussions of Experiment 1

The accuracy of the positional measurement of the glacier could be confirmed by Experiment 1.

For details, the result of Experiment 1 shows that the maximum error is 410 mm by using two cameras and the maximum error is 9.0 mm by using eight cameras, respectively. Accordingly, the maximum error has improved by about 50 times by using eight cameras. The average error is 60 mm by using two cameras and the average error is 3.5 mm by using eight cameras. Thus, the average error has improved by about 20 times by using eight cameras. As a result, it is said that Average Method is effective in accuracy improvement.

3. Experiment 2

3.1. Purpose and background

The purpose of this experiment is to measure the movement of Perito Moreno glacier with high precision. Perito Moreno glacier in Argentina is famous as the World Natural Heritage Site. This glacier has fast movement speed and is called "an alive glacier". It is thought that that earth environment change is sensitively reflected on this fast glacier movement. Moreover, some unsolved problems of this glacier should be researched.

For the measurement of this glacier, the method of using an optical measuring instrument and GPS is general. Since our system can realize the high-precise 3D measurement, this experimental result and other experimental results can be complemented mutually.

3.2. Observational days

From December 2008 to January 2009, about two weeks, at Perito Moreno glacier on Patagonia in Argentina, we measured the movement of the glacier by using ten cameras. We have been trying the high-precision observation of the glacier using the stereo camera system for about five years.

3.3. Experimental equipment, placement of cameras and target

Optio W60 has the appropriate features for the glacier observation. The most useful feature is the interval photography function that enables unmanned observation for a week. The other reasons why we selected this camera are its small size, waterproof function and so on. Further, this camera lens does not extend outside of its body. This mechanism can reduce the effect of strong wind. One camera group is made up of five cameras. We set one pair of camera groups at the downstream of the glacier. The positions of camera groups and calibration points were measured by Total Station for the camera calibration. Peaks of the glacier were selected as calibration points. The calibration point and camera group are shown in Fig. 2. Distance from camera groups to calibration point is about 1,000 m. Distance between two camera groups is 470 m.

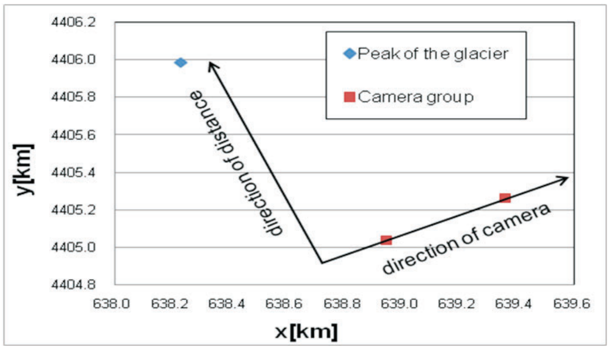


Fig. 2. Placement of camera groups and peak of the glacier.

3.4. Measurement procedure

Optio W60 took pictures of target glacier every one hour for two weeks. An example image is shown in Fig. 3. In this figure, numbered points are targets. No.1 is the calibration point. During taking pictures, the cameras were vibrated by the strong wind. Then, we corrected each image based on the edge of the mountain and the sky. Concretely, the images were shifted by some pixels for compensation of the vibration.

3.5. Correspondence point search

In general, the same target on each camera image is called corresponding point. In this research, clear peaks were selected in each camera, and centers of gravity of peak area of the glacier were used as corresponding points.

The glacier melting was seen in this observation as shown in Fig. 4. However, the peak melting is small for one day. As a result, when we measured the glacier movement, it is thought that it is appropriate to chase the peak of the glacier.

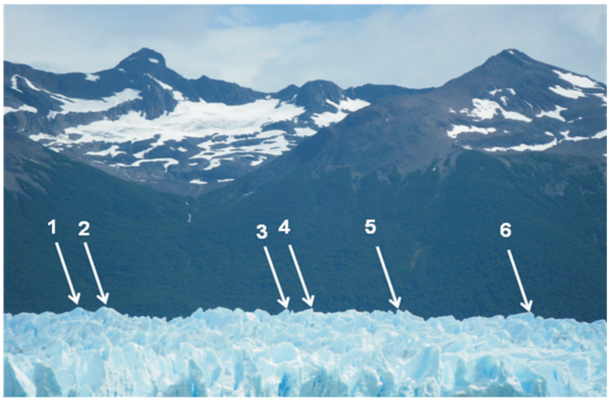


Fig. 3. Target image.

(a)

(b)

Fig. 4. Shape change of target (peak of glacier);(a) first observation; (b) after about one week.

3.6. Results of experiment 2

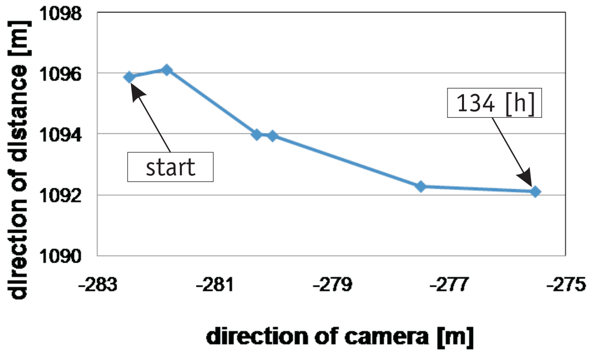
Figure 5 shows the measurement results of each target movement. The time interval of plots is about half day and about one day in this figure. Measurement errors are smaller than the size of each plot.

3.7. Discussions of Experiment 2

Results of Experiment 2 show that each targets moved almost same directions. These results are similar to both the previous observation results last year and other observation methods. Furthermore, the observed average movement speed of the glacier was 1.6 m/day] in this year. This speed is corresponding to the report which the moving speed of Perito Moreno glacier is 1-2 m/day. Thus, it is thought that our results are valid in general.

In this figure, it appears that there is slightly change in a peak movement and the differences in peaks. The flow velocity distribution on the surface of the glacier is thought to generate such a little difference because it decides by various elements about the hydraulic pressure, thickness of ice, and the surface tilt, the temperature of ice.

(a)



(b)

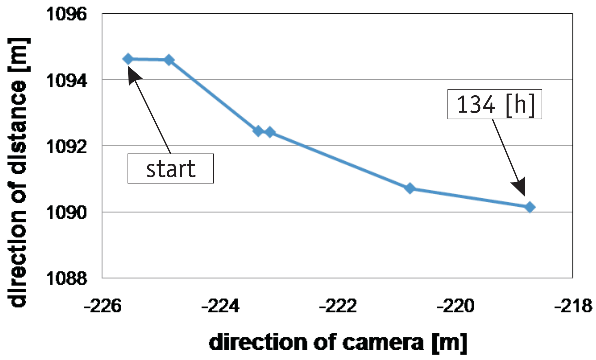


Fig. 5. Glacier movement measured with a high-precision 3-D multi-camera system; (a) target 1; (b) target 2 .

4. Conclusions

In this research, it was proven that there is accuracy enough to measure the glacier by Experiment 1. Experiment 2 can show that the unique results of glacier peak movement and our high-precise 3D measurement system can work well at the natural environments.

In future, we have to construct the counting system that doesn't receive the wind effect, and securing a more suitable camera installation location in the lacier observation. Finally, the glacier observation at Perito Moreno should be continued and expanded to measure the global and dynamic motion of this glacier. Valuable observation data at Perito Moreno glacier will be expected to contribute the global warming and other science theme.

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