CAMERA PATH DESIGN
FOR PANORAMIC IMAGEACQUISITION

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ABSTRACT

Recently, image acquisition becomes easier with GPS cameras, panoramic cameras, and fisheye cameras. In particular, panoramic images from ground viewpoints have been used for map services, urban planning, and disaster monitoring. Images taken from a camera mounted on micro unmanned aerial vehicles (UAVs) have also been used for various applications. Moreover, there are many studies related to 3D modeling, augmented reality application, building information modeling, and construction information modeling. Three-dimensional (3D) models can be created from images with a low-cost software and open source software. Recently, 3D modeling is popular in building information modeling (BIM), construction information modeling (CIM) and augmented reality (AR) applications, such as map services, urban planning and disaster prevention. In the 3D modeling, the efficiency and integrity in image acquisition are significant because of working time limitations, such as a short flight time in a micro UAV's operation. Conventional image acquisition approaches for 3D modeling are based on photogrammetry. However, when we measure complex and large objects from ground viewpoints, a path design would become more complex. Recent image acquisition approaches for 3D modeling are based on Structure from Motion (SfM). That is, images can be taken from various viewpoints randomly. However, the SfM using many images requires a plenty of processing time. Therefore, the efficiency and integrity in an image acquisition should be improved to achieve shorter image acquisition time and processing time. First, we focused on a path design for 3D modeling using panoramic images. A panoramic image could be assumed as integrated images taken by some cameras. Thus, we prepared images taken by some cameras for our experiments. Second, we evaluated some path designs based on Structure from Motion in our experiments. Through our experiments, we confirmed that the efficiency in a panoramic image acquisition depended on a camera path design.

1. INTRODUCTION

Recently, image acquisition becomes easier with GPS cameras, panoramic cameras, and fisheye cameras. In particular, panoramic images from ground viewpoints have been used for map services, urban planning, and disaster monitoring. Images taken from a camera mounted on micro unmanned aerial vehicles (UAVs) have also been used for various applications. Moreover, there are many studies related to 3D modeling, augmented reality application, building information modeling, and construction information modeling. Three-dimensional (3D) models can be created from images with a low-cost software and open source software. Recently, 3D modeling is popular in building information modeling (BIM), construction information modeling (CIM) and augmented reality (AR) applications, such as map services, urban planning and disaster prevention.

In the 3D modeling, the efficiency and integrity in image acquisition are significant because of working time limitations, such as a short flight time in a micro UAV's operation. Conventional image acquisition approaches for 3D modeling are based on photogrammetry. However, when we measure complex and large objects from ground viewpoints, a path design would become more complex. Recent image acquisition approaches for 3D modeling are based on Structure from Motion (SfM). That is, images can be taken from various viewpoints randomly. However, the SfM using many images requires a plenty of processing time. Therefore, the efficiency and integrity in an image acquisition should be improved to achieve shorter image acquisition time and processing time.

In our study, we focused on a panorama camera path design to improve the efficiency in image acquisitions. A panoramic image could be assumed as integrated images taken by some cameras. Thus, we prepared images taken by some cameras in our experiments. Moreover, we tried to confirm that the efficiency in a panoramic image acquisition depended on a camera path design through experiments using a digital camera and panorama camera. We evaluated some path designs based on Structure from Motion in our experiments.

2. METHODOLOGY

We conducted preliminary experiments with a camera calibration based on Zhang's approach. Figure 1 shows a result in an image orientation using 32 images. We could reconstruct 3D object using these images. However, we could exclude unnecessary images to reconstruct approximate same camera parameters, as shown in Figure 2. Although required number of images depends on object's shape complexness, a minimum number of images for 3D reconstruction could be an index to determine the efficiency in an image acquisition.

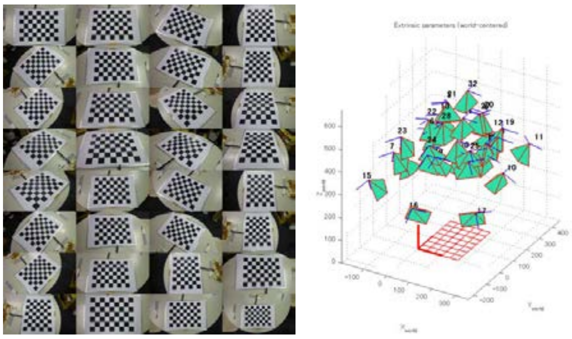

Figure 1. Camera position arrangement in a gaze observation (1)

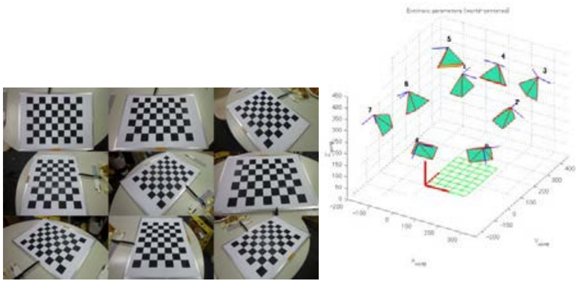

Figure 2. Camera position arrangement in a gaze observation (2)

Optimized camera positions and path can be basically designed based on the following two points. The first point is an overlap rate. We would keep the overlap rate from 60 % to 80 % to achieve a stable camera parameter estimation and 3D modeling. The second point is the uniformity of spatial resolution in an image acquisition. The spatial resolution can be estimated from a focal length of the camera and distance from a camera to objects approximately.

In this paper, we verified that these points could be used for a design of camera positions and path. We proposed an approach to evaluate a performance in camera parameter estimation and 3D modeling with SfM processing from number of images, processing time, and point cloud density. Moreover, we verified that the two points could be used for panorama images acquired from omni-directional camera.

2.1 Structure form Motion

Structure from Motion (SfM) is often applied to generate 3D data. Figure 4 shows an example in our preliminary experiment. The SfM is point-based matching and 3D modeling using corresponded points estimated with Scale-Invariant Feature Transform (SIFT). The SfM is useful approach to generate 3D data from images of random viewpoints. However, the SIFT requires a plenty of time to detect feature points and corresponded points from multi-images.

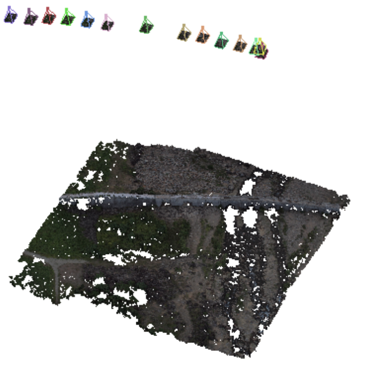

Figure 3. SfM processing using images from a UAV

2.2 Panoramic image

An omni-directional camera can acquire a panorama image. We expected that Omnidirectional the omni-directional camera is an effective tool to reduce mistakes in an image acquisition without a camera direction design. However, image matching using panorama images is not easy because of the large lens-distortion of the camera and image stitch errors.

Therefore, we used images before an image stitch processing. For example, an omni-directional camera consists of two cameras, two images are processed separately.

3. EXPERIMENTS

We conducted two experiments to create a 3D model of an object with VisualSFM as open source SfM software. We prepared an aluminum bottle as a measured object. The bottle was 6 cm in diameter and 17 cm height. The distance between a camera and the bottle was 45 cm.

In the first experiment, we focused on a camera path. We used EXILIM Hi-ZOOM EX-H20G (see, Figure 4) in this experiment. Moreover, we prepared two datasets, as shown in Table 1. The first dataset (dataset 1) was 16 images taken along a designed path, as shown in Figure 5. The second dataset (dataset 2) were 54 images taken from random viewpoints, as shown in Figure 6. Then, we generated a point cloud using each dataset with the SfM software. Figure 7 shows a result after point cloud generation using images of dataset 1. Moreover, Figure 8 shows a result after point cloud generation using images of dataset 2. Finally, we compared a result from the dataset 1 with the other result from the dataset 2.

Focal length	4.3~43mm
Image size	4320x3240 pixel
Image sensor	1 / 2.3-inch square pixel

Figure 4. EXILIM Hi-ZOOM EX-H20G

Table.1 Dataset 1 and 2

	Dataset 1	Dataset 2
Number of images	16	54
Processing time	176 seconds	913 seconds

Figure 5. Images acquired with EXILIM Hi-ZOOM EX-H20G (dataset 1)

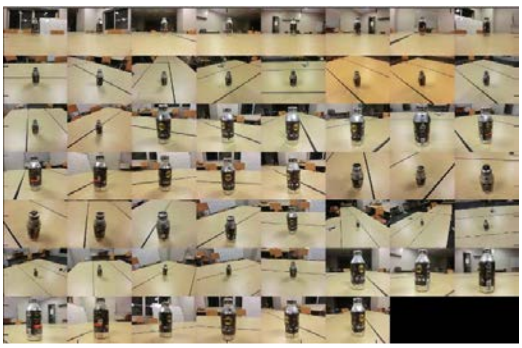

Figure 6. Images acquired with EXILIM Hi-ZOOM EX-H20G (dataset 2)

Figure 7. Point cloud generated from the dataset 1

Figure 8. Point cloud generated from the dataset 2

In the second experiment, we tried to reconstruct 3D model using panorama images. We used RICOH THETA (see, Figure 9) in this experiment. The RICOH THETA is a camera consisted of two fisheye cameras. A panorama image can be generated from two images from these fisheye cameras. We prepared 8 panorama images, as shown in Figure 10. Additionally, a matching result afterthe SIFT to reconstruct 3D model using panorama images, as shown in Figure 11.

Minimum focus distance	10cm~
Image size	3584x1792 pixel
ISO speed	100~1600

Figure 9. RICOH THETA

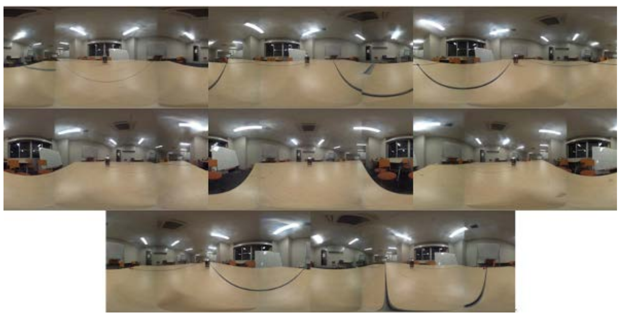

Figure 10. Acquired panorama images

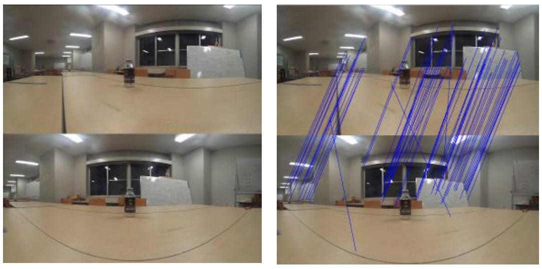

Figure 11. Image matching result using panoramic images

4. DISCUSSION

Although we confirmed that denser point cloud was generated from the dataset 2, the dataset 2 required a longer processing time than the dataset 1. Moreover, we confirmed that the feature points were extracted well from images of the dataset 1. Thus, we verified that images taken from the designed path had an advantage of the efficiency in data acquisition. However, a point cloud density would be depended on object surfaces and the performance of image matching. Therefore, we conducted additional experiments to verify the performance of point cloud generation in the SfM processing. We prepared some measured objects such as a can, mug cup and miniature car. Moreover, we prepared 16 images to generate a point cloud of each object. Figure 12, Figure 13 show a part of image matching and point cloud generation results. We summarized the number of images, the processing time and point cloud density in the additional experiments, as shown in Table 2.

Figure 12. Generated point cloud (mug cup)

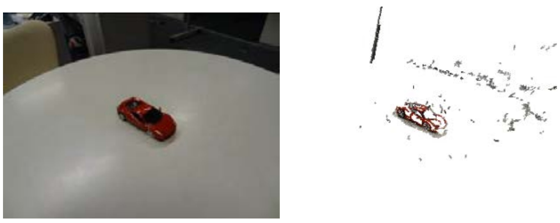

Figure 13. Generated point cloud (miniature car)

Table 2. Result of can, mug cup, and car model

	Processing time	Number of images	Point cloud density
Can	176 seconds	16	Enough
Mug cup	201 seconds	16	Low
Miniature car	166 seconds	16	Low

Although a point cloud density of can was enough to represent 3D shape. On the other hand, point cloud density of mug cup and car model were rough. One of differences between these objects was a density of feature points. Thus, we confirmed that the path design depended on the density of features on object surfaces.

CONCLUSION

We focused on an approach to improve the efficiency in image acquisitions for 3D modeling. In our study, we conducted two experiments to create a 3D model of an object with the VisualSFM. In the first experiment, we focused on a camera position and path. In the second experiment, we tried to reconstruct 3D model using panorama images. Simple objects could be modeled with a few numbers of images. However, complex objects were not easy to be modeled with a few numbers of images. Thus, we conducted additional experiments of point cloud acquisition based on the SfM. In these experiments, we evaluated some path designs based on Structure from Motion in our experiments. Moreover, we confirmed that the efficiency in a panoramic image acquisition depended on a camera path design.

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