CEILING FEATURE DETECTION FOR GEO-REFERENCING IN SLAM

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ABSTRACT: In this study, we focused on ceiling features, such as illuminators, emergency sign boards, and Wi-Fi routers, to cancel accumulated errors in simultaneous localization and mapping**.** First, point cloud data in indoor spaces are acquired using a time-of-flight camera. Second, ceiling surfaces are estimated from the acquired point cloud data with the random sample consensus algorithm. Third, ceiling features are estimated to be used for reference features. Then, gravity points of the estimated features are estimated to be used for reference points. Finally, an indoor environment map is generated with the reference points. Through our experiments in indoor environments, we clarified that our methodology can detect ceiling features to be used for reference points.

1. INTRODUCTION

There are various location-based services, such as pedestrian navigation, infrastructure management, and autonomous robots. Location-based services mainly require mapping, positioning, and navigation techniques. Recently, there are many techniques related to mapping, positioning, and navigation in indoor environments (Parijat Mazumdar, et al. 2014. Indoor maps are becoming popular as spatial infrastructure, because pedestrian require maps for navigation and wayfinding, in indoor environment. Indoor positioning and navigation are also becoming popular for mobile device users. In indoor environment, Global Navigation Satellite Systems are not available, thus, various indoor positioning systems, such as Wi-Fi, Radio-Frequency Identification (RFID), iBeacon, and Indoor Messaging Systems, have been proposed(Adriano et al. 2011). In mapping techniques, simultaneous localization and mapping (SLAM) algorithm (Durrant-Whyte et al. 2006, Bailey et al. 2006) is applied for mapping in unknown indoor environment. The SLAM can estimate an environment map and position simultaneously. Moreover, the SLAM can be improved with a loop closure adjustment and reference points to cancel accumulated errors. However, a plenty of time are required for setting reference point installation. Therefore, we try to use ceiling features, such as illuminators, emergency sign boards, and Wi-Fi routers, as reference points. Although object recognition techniques are required to recognize these features, we expected that the ceiling features can be used for clear reference points and landmarks for 3D mapping. In our research, we proposed a methodology to use existing ceiling features for reference points in indoor mapping. Through our experiments in indoor environments, we verify that our methodology can detect ceiling features to be used for reference points. Moreover, we clarify that our approach can generate accurate 3D maps using existing ceiling features as reference points.

2. METHODOLOGY

Our methodology consists of four steps. First, point cloud data of indoor spaces are acquired using a time-of-flight (TOF) camera (Jan Wülfing, 2010). TOF camera is a range imaging camera system that resolves distance based on the known speed of light, measuring the TOF of a light signal between the camera and the object for each point of the image. The TOF camera is more robust than optical stereo cameras against illumination changes in indoor environments. Second, ceiling surfaces are estimated from the acquired point cloud data with the random sample consensus (RANSAC) algorithm (Schnabel et al. 2007). The RANSAC is an iterative methodology to estimate several parameters with mathematical model from a set of observed data that contains outliers. Third, ceiling features, such as illuminators, emergency sign boards, and Wi-Fi routers, are estimated with labeling processing on range data to be used for reference features. Then, gravity points of the estimated features are estimated to be used for reference points. Finally, the reference points are used in mapping with an iterative closest point (ICP) algorithm (Holz et al. 2010). Our processing flow is shown in Figure 1.

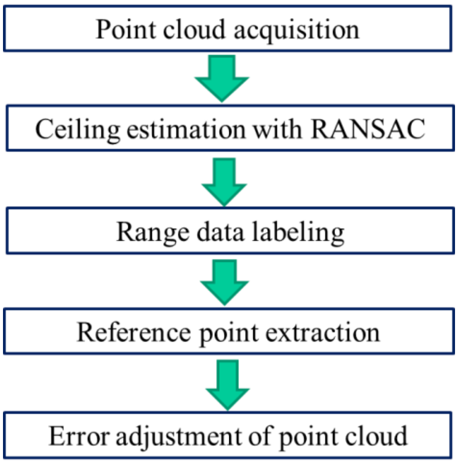

Figure 1. Overall processing flow

In this study, we assume to develop 3D measurement system in indoor environment, as shown in Figure 2. This system consists of the orientation part, the localization part, and the point cloud acquisition part. In this paper, we focus on the orientation part with TOF camera. Figure 3 shows a sample output point cloud in orientation processing.

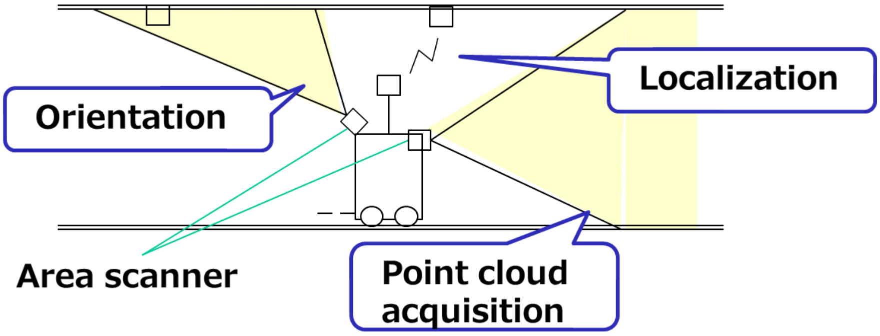

Figure 2. 3D measurement system in indoor environment

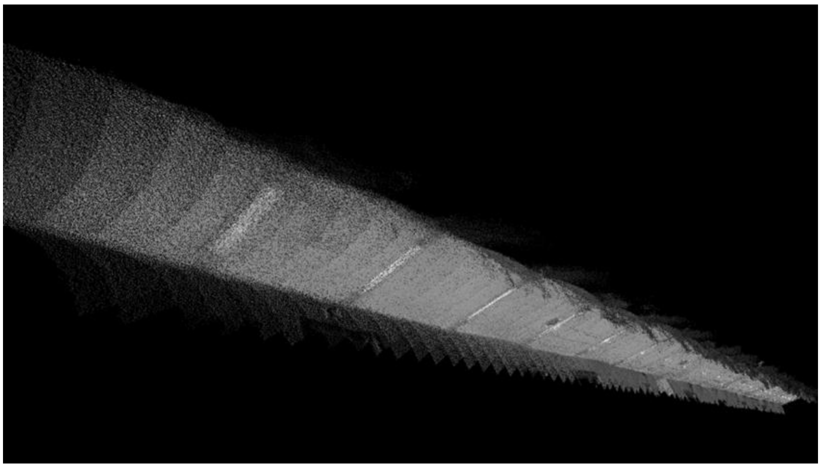

Figure 3. Sample data (ceiling)

3. EXPERIMENT

3.1 Study Area

We selected corridors in our campus as our study area. This corridors consists of walls, ceiling, and windows, as shown in Figure 4

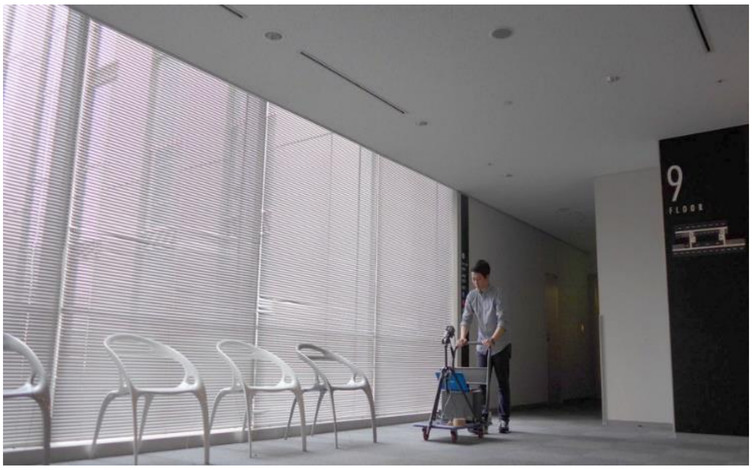

Figure 4. Study area

Figure 5 shows examples of ceiling features in our experiments.

Figure 5. Ceiling features (left image: Wi-Fi router, right image: emergency sign board)

3.2 Equipment

We used a TOF camera (SwissRanger SR4000, MESA) in our experiments. Figure 6 shows the specification of TOF camera. The imaging range of TOF camera covers from 0.3m to 5.0m, and the frame rate is up to 50 fps.

Pixel array	176 (h)×144 (v)
Wavelength	850 nm
Angle of visibility	43.6° (h)×34.6° (v)
Measuring range	5.0 m
Frame rate	Maximum 50 fps
Frequency	30 MHz

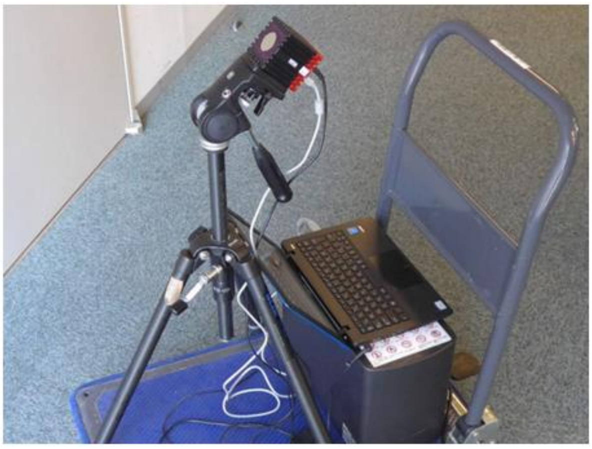

Figure 6. Equipment (top image: TOF camera, bottom image: TOF camera installed on a cart)

4. RESULTS

4.1 3D measurement with TOF camera

Figure 7 shows emergency sign boards as measured objects. Figure 8 shows rendered point clouds from eight viewpoints.

Figure7.Measured object

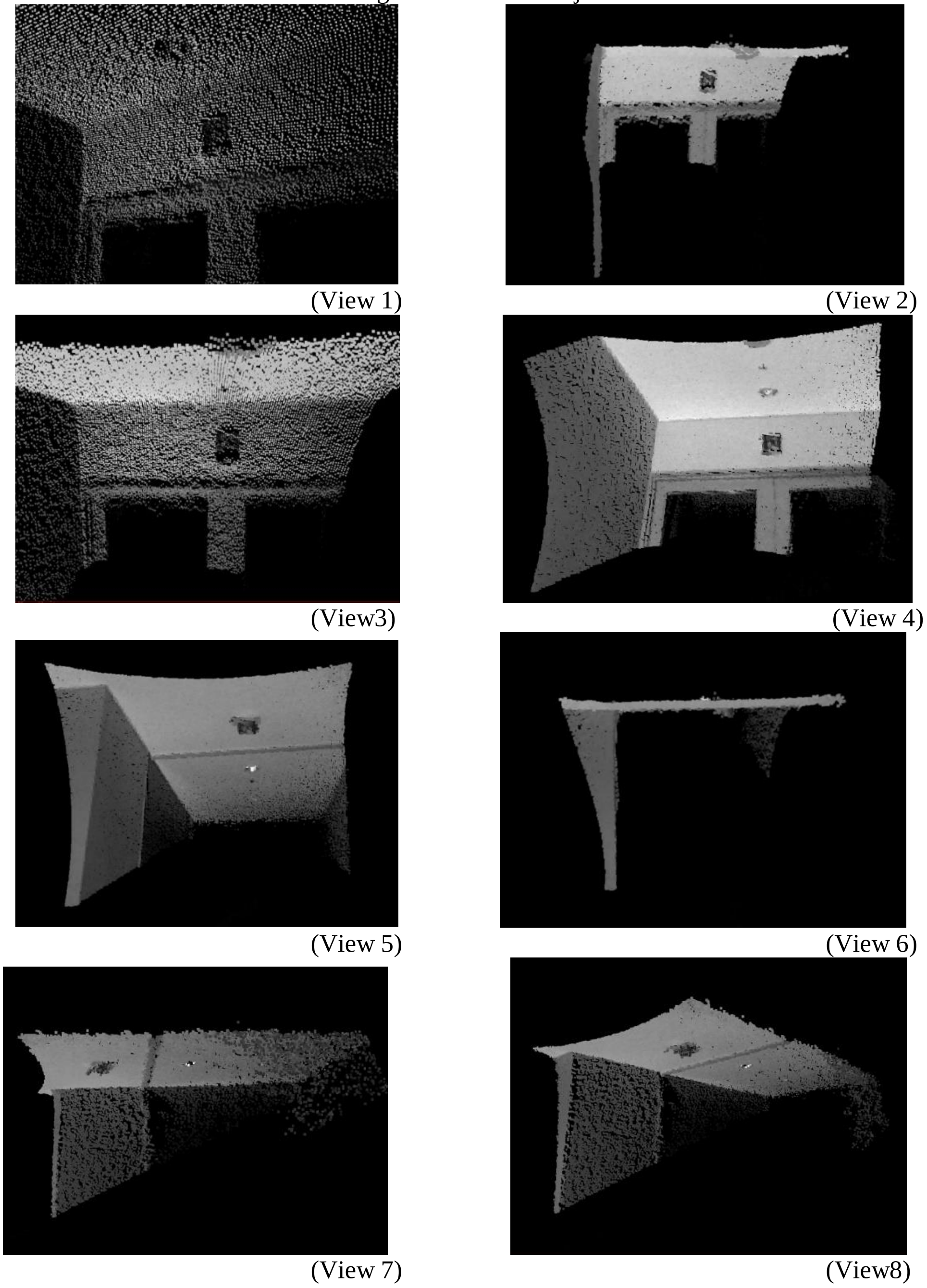

Figure 8. Point cloud acquired with TOF camera (View 1-8)

Figure 9 shows a Wi-Fi router as a measured object.

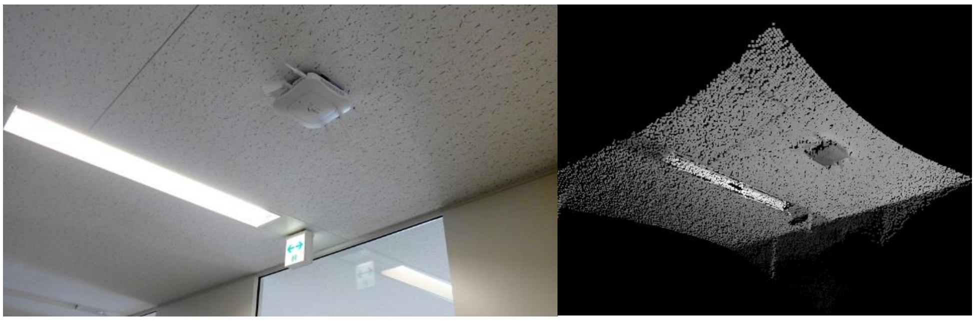

Figure 9. Wi-Fi router (left image: photo, right image: point cloud)

4.2 Feature point extraction from point cloud

Figure 10 shows point cloud and feature points as detected reference points. Blue points indicate acquired point clouds with the TOF camera. Moreover, red crosses indicate extracted feature points as reference points.

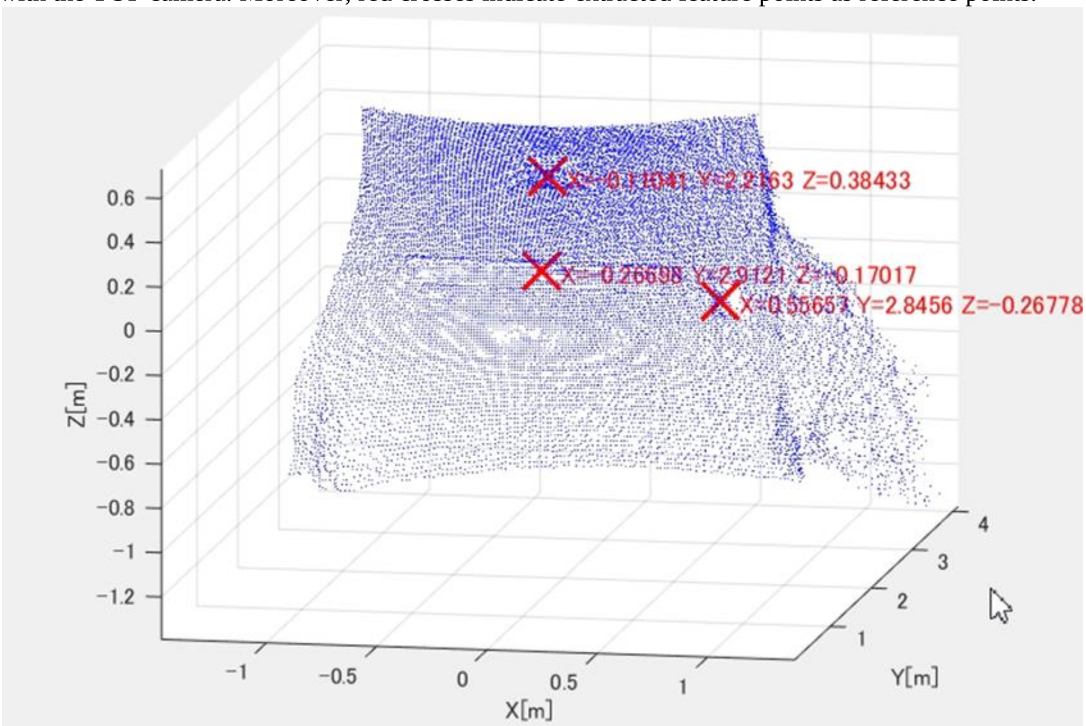

Figure 10 Point cloud (blue points) and feature points (red crosses).

5. DISCUSSION

In this study, we confirmed that emergency sign boards and Wi-Fi routers are were detected from point cloud data. In our experiment, we also confirmed that these ceiling features can be used for clear reference points and landmarks for 3D mapping. However, we could not detect and estimate geometries of small ceiling features, such as sprinklers. Moreover, we confirmed that emergency sign boards were difficult objects to be measured with TOF camera completely, because the boards included transparent parts. Therefore, we tried to estimate a gravity point of each object as a reference point. We would discuss about the required accuracy in reference point detection to adjust errors in SLAM in our future works.

6. CONCLUSION

In this paper, we focused on ceiling features, such as illuminators, emergency sign boards, and Wi-Fi routers, to cancel accumulated errors y in 3D indoor mapping. First, point cloud data of indoor spaces were acquired using a TOF camera. Second, ceiling surfaces were estimated from the acquired point cloud data with the RANSAC algorithm. Third, ceiling features, such as illuminators, emergency sign boards, and Wi-Fi routers, were estimated to be used for reference features. Then, gravity points of the estimated features were estimated to be used for reference points. Finally, an indoor environment map was generated with the extracted reference points. Through our experiments in indoor environments, we clarified that our methodology can detect ceiling features to be used for reference points. In our future works, we will improve our approach for accurate indoor mapping.

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