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Localization for Indoor Service Robot Using Natural Landmark on the Ceiling

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Abstract**—**In this paper, we present a localization of a mobile robot with localization modules which have two ceiling-view cameras in indoor environments. We propose two kinds of localization method. The one is the localization in the local space; we use the line feature and the corner feature between the ceiling and wall. The other is the localization in the large space; we use the natural features such as bulbs, structures on the ceiling. These methods are installed on the embedded module able to mount on the robot. The embedded module has two cameras to be able to localize in both the local space and the large spaces. The experiment is practiced in our indoor test-bed and a government office. The proposed method is proved by the experimental results.

Keywords**—**Robot, Localization, Indoor, Ceiling vision, Local space, Large space, Complex space.

I. Introduction

WHEN a mobile robot performs their missions, the localization is needed basically. Several past researches established how to obtain their location information from the environment by using a distance sensor or a camera. However, these methods have map-making problem when the environment changes and localization problem while the robot moves from sensing features has typical affine and occlusion characteristics.

To deal with these difficulties, ceiling vision based robot navigation has been popular that adopts landmark from ceiling which has less changes of environments relatively. Existing ceiling vision localization uses point feature matching at their researches. Almost every point features like Harris corner [1], SIFT [2], and SURF [3] are sensitive to environmental variations and it is a major cause of incorrect data association.

This limitation of monotonous patterns in ceiling makes researcher use molding line of ceiling area or another feature mounted on ceiling such as fire sensor, sprinkler or lamp on ceiling. In spite of these approaches, the researches still have problem of affine and lack of feature issues. To overcome the lack of feature problems, we propose another approach. We segment upward camera images and extract ceiling area using relation rules between camera and ceiling. It is simple and less complexity enough to be adopted embedded system. The Fig. 1 is our mobile robot system embedded the localization module.

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Fig. 1 Siya (Mobile robot system with the localization module)

II. Localization Module

The proposed localization module consists of two parts, a main board, and a vision board in Fig. 2. The main board has an ARM Cortex-A8 CPU, NAND Flash 1GB and SDRAM 1GB. The Operation system is Linux 2.6.22 and the compiler is gcc-4.2.1. The vision board is composed of 1/3 inch, 1.3 mega pixels CCD and two lenses with different field of view.

There are lots of several indoor environments where a robot can provide services. We assorted the place into two kinds depending on the ceiling height, and named the former ‘local space’ and the latter ‘large space’.

Fig. 2 Localization module

III. Localization Method

There are lots of several indoor environments where a robot can provide services. We assorted the place into two kinds depending on the ceiling height, and named the former ‘local space’ and the latter ‘large space’.

A. Local Space

Local space is a place with a ceiling height of not less than 3m such as office room, corridors and house rooms as in Fig. 3.

We proposed the localization method using the line feature and the corner feature between the ceiling and wall when a robot is in the local space as shown in Fig. 4. We can obtain the molding edges immediately from the ceiling area with simple edge detection algorithm and we extracted Harris Conner feature only included in ceiling area [4]. The map is a grid map about boundary between the ceiling and wall.

(a) (b) (c)

Fig. 3 Local space (a) Office room (b) Corridor (c) House room

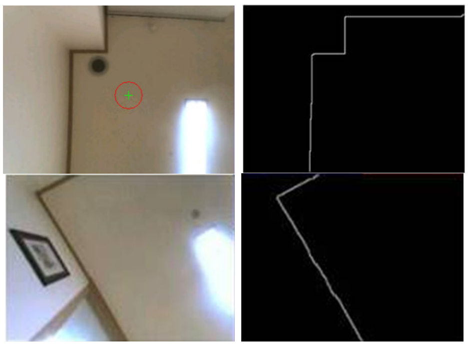
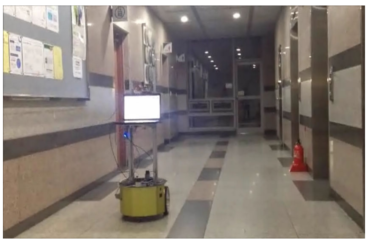
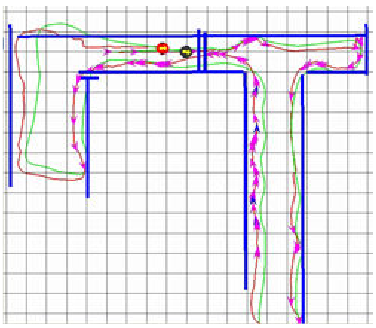


Fig. 4 Line and corner features in the local spaces

We verified the result and the actual data. The ground truth is measured by a ruler. It takes 143.24 ms to complete to SLAM and localization mean error is 9.59cm in 20m by 5m. Fig. 5 is obtained through the corridor experiment result of mapping and localization.



(a)



(b)

Fig. 5 Result of corridor experiment (a) Corridor (b) Result (blue bold line : map, red line : estimated path, green line : odometry path)

B. Large Space

Large space is a place with a ceiling height of 3m or more, such as an exhibition hall, an airport and a lobby as in Fig. 6. We present the localization method using the natural features such as bulbs, structures on the ceiling when a robot is in the large space as shown in Fig. 7. We make the landmarks from the natural features in the nodes of the topological map. The robot knows the position in the topological map using ICP matching with the registered image of the node and the current image [5].

(a) (b)

Fig. 6 Large space (a) Exhibition hall (b) Station lobby

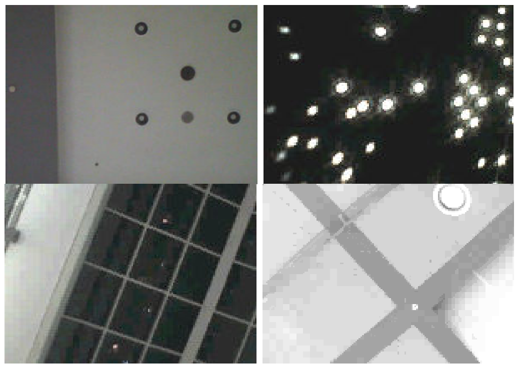
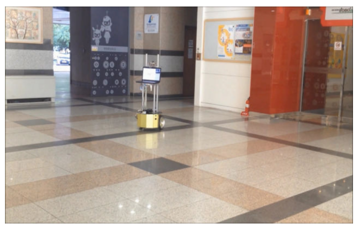
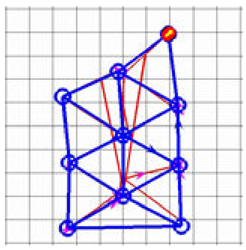


Fig. 7 Natural features in the large spaces



(a)



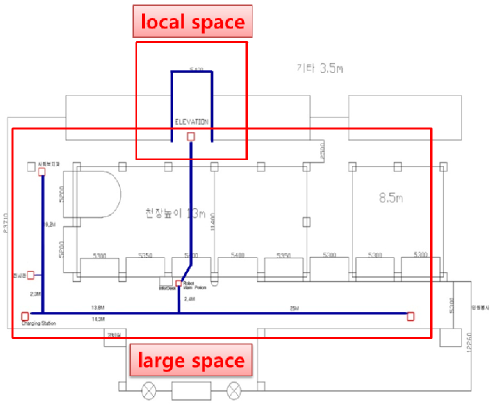
(b)

Fig. 8 Result of lobby experiment (a) Lobby (b) Result (blue bold line : map, red line : odometry path)

It takes 145.29ms to complete to SLAM and localization mean error is 10.25cm in 20m by 15m. Fig. 8.

C. Complex Space

There are the space with a local space and a large space such as a government office as shown in Fig. 9. We named the space 'complex space'. The blue line is the map about ceiling and wall in the local space. The red square is the node of topological map and the blue line is the path of a robot in the large space.

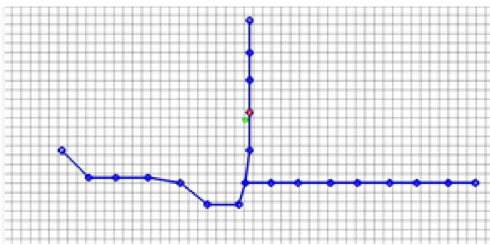


(a)

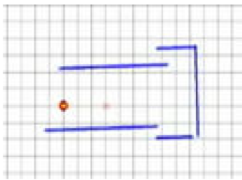
(b)

Fig. 9 Bucheon city hall (a) Floor plan (b) Ceiling image

We experimented with the performance of the localization method in Bucheon city hall which is a government office. Fig. 10 (a) is the result of grid map building of the lobby and Fig. 10 (b) is the result of topological map building of the elevator area. Table I shows the error of the experiment 22 times and the average error is 10.47 cm.



(a)



(b)

Fig. 10 Result of Bucheon city hall experiment (a) Lobby (b) Elevator area

IV. Conclusion

This paper proposed the localization module and localization method in indoor environment. The module we developed has two cameras looking up the ceiling which are inexpensive and easy-to-get everywhere. In the local space, line features are extracted from images by the ceiling grouping method. The line features have advantages over point features for its robustness to environmental variation and structural information helpful to data association. In the large space, nodes with the natural feature groups are extracted from images of high ceilings. We verified the validity of the actual experiment and the proposed method can be applied to the localization of a service robot.

Acknowledgment

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