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A Mobile Robot Localization using External Surveillance Cameras at Indoor

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Abstract

Localization is a technique that is needed for the service robot to drive at indoors, and it has been studied in various ways. Most localization techniques let the robot measure environmental information to gain location information, but those require high costs as it use many equipment, and also complicate the robot development. But if an external device could calculate the location of the robot and transmit it to the robot, it will reduce the extra cost for the internal equipment needed to recognize the location, and it will also simplify the robot development. Therefore this study suggests an effective way to control the robot by using the location information of the robot included in a map made by visual information from the surveillance cameras installed at indoors. The object in a single image is difficult to tell its size because of the shadow components and occlusion. Therefore, combination of shadow removal technique using HSV image from indoors and images from different perspective using homography to create two- dimensional map with accurate object information is suggested. In the experiment, the effectiveness of the suggested method is shown by analyzing the movement result of the robot which applied the location information from the two-dimensional map that is based on the multi cameras, which its accuracy is measured in advance.

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*Keywords:*Localization; Mobile Robot; Surveillance; Camera; Indoor; Homography, Air View

1. Introduction

Recently various Localization technologies for the mobile robot have been studied through acquirement of accurate environment information. Generally, a mobile robot has its self-organized sensors to get the environment

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information. However, the robot is very expensive and has the complicate body structure. Since structural information of indoor environment is usually known-state, many researches of localization have been carried out via getting the required information from external sensors installed out of robot body. One of the reasonable approaches is the calculating the distance between a robot and an object by measuring the flying time of RF signal from WLAN[1]. A simple and reliable method is to use landmark[2] features of the workspace as external reference sources. However, those methods are difficult for installation and maintenance because of requiring additional equipment and not enough accurate. Therefore, we focused on the more simple and cheap external sensor for map-building of the localization.

Indoor surveillance cameras are usually installed without blind area and those visual data are transferred to the central data server and processed for analysis. If a mobile robot gets its position by using the indoor cameras, the robot don't need to have extra sensors for localization and it could be applied to multi agent of mobile robots[3,4]. But, there exist several problems for realization. Firstly, lens distortion comes out from cheap lens of the surveillance cameras and shadow effects from indoor light sources. Secondly, information of occlude objects can't be obtained from single camera.

In this paper, we proposed a localization method of a mobile robot to overcome the above mentioned problems at indoor. Two dimensional map with the position information of robot and object is made by using several neighboring surveillance cameras. Homography technique to create two-dimensional map with accurate object information is suggested. In the experiment, the effectiveness of the suggested method is shown by analyzing the movement result of the robot which acquired the robot's location information from the two-dimensional map.

2. Two-dimensional Visual Map by using the Homography

2.1. Projected Image Plane for Two Dimensional Map

Indoor surveillance cameras are usually installed to view same object from opposite direction. Such images have information of the ground area occluded by objects on floor as shown Fig. 1. Therefore, two images of an object viewed from each opposite direction need to be united as one image. We tried it by using the homography.

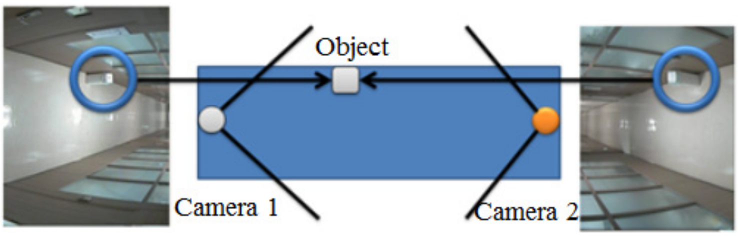

Fig. 1. Two images viewed from two neighboring surveillance cameras at indoor.

Homography means the projection which a plane is transformed to another plane in space. A surveillance camera is slantly mounted and get an image as Fig. 2(a). To see the position and size of an object viewed from the camera the image of Fig. 2(a) is transformed to the air view of Fig. 2(b) by the homography.

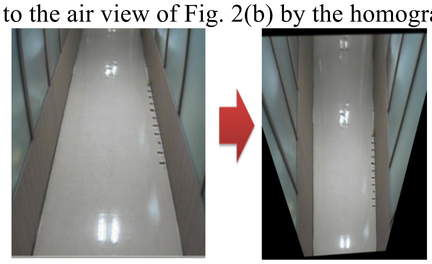

Fig. 2. (a) original image; (b) air view image of (a)

To transform an original image of a surveillance camera to an air view image a feature point Q of the original image should be matched with corresponding point q of the air view image as shown in Fig. 3. We used a big placard of chess board to match same feature points between two images of the original and air view.

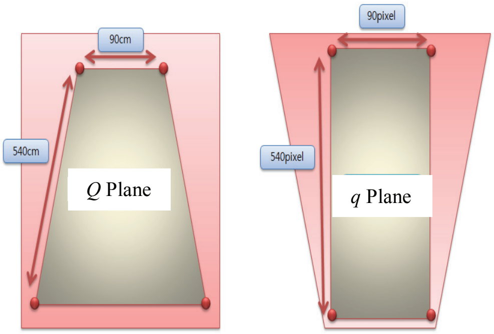

Fig. 3. (a) Q plane of the original image; (b) q plane of the air view image of (a)

Homography matrix $H$of Eq. (1) is obtained by using each four points of plane Q and plane q.

$$q = HQ \tag{1}$$

Homographically transformed positions of same feature points of two images from two surveillance cameras is united on the new projected plane in Fig. 4 ① and then results in single united plane as Fig. 4 ②. We can the two dimensional map of Fig. 4 ③ by extracting the ROI(Region of Interest) of actual floor area from the single plane.

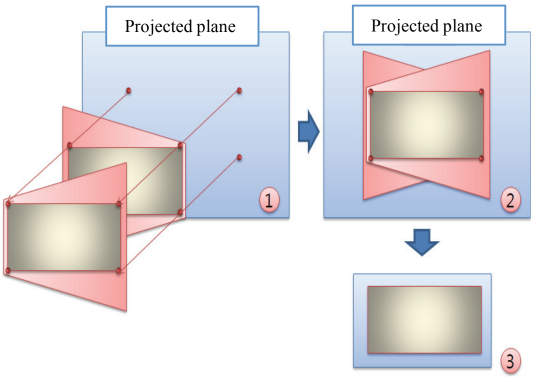

Fig. 4. Extracting the two dimensional map from two projected images by homography

2.2. Object Area on the Two Dimensional Map

In this section, we present a method for acquiring the position and size of an object image on the above two dimensional map. Since two neighboring cameras watch an object from opposite direction, each images of same object are different. But the floor area occupied the object is same at two images. Therefore if the rest of the image except for the floor area is deleted, we can obtain the actual floor area of the object on the two dimensional map.

In order to obtain the object floor area on the two dimensional map, two projected images are transformed from the original images as shown in Fig. 5. Fig. 5(a) are original images of two cameras, Fig.5(b) are binary image of Fig. 5 (a) removed shadow effect and Fig. 5(c) are the projected image of Fig. 5(b) by homography. If the coordinates of two projected images are similar, the size and position of an object contacting with the floor of the image are nearly same with real value. If the rest of the images not including the floor area is eliminated, the object image can be expressed on the air view. Eq. (2) represents the size and position of an object on the projected plane $H(x, y)$.

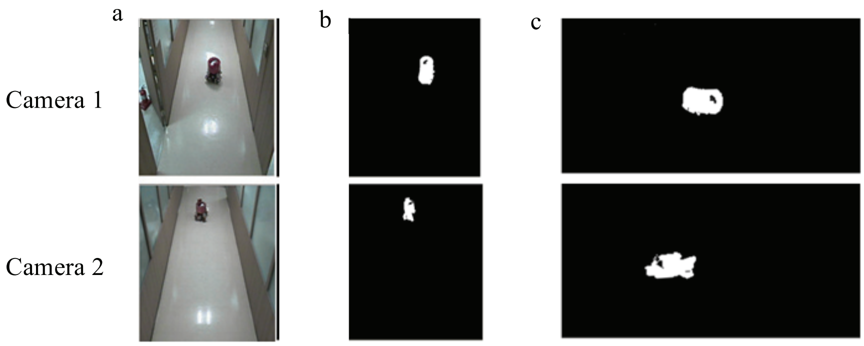

Fig. 5. Projected images of two surveillance cameras by Homography

$$H(x,y) = \begin{cases} 1, & if\left[I_1^H(x,y) \,\&\, I_2^H(x,y)\right] = 1 \\ 0 & otherwise \end{cases} \tag{2}$$

where $I_1^H(x,y)$ is the projected image of camera 1 and $I_2^H(x,y)$ is the projected image of camera 2.

The common area of camera 1 and 2 in Fig. 5(c) can be presented at Fig. 6. The area means the object image at the two dimensional map based on the homogpahy.

Fig. 6. Common area of the projected images of camera 1 and 2 in Fig. 4 (c).

Now, the size and center position of the object image in the two dimensional map might be calculated. The contour technique is applied for finding its size and center position at high speed. In order to compare the object area with real position the actual floor image is transformed to the projected plane as Fig. 7 and the object area detected by the contour processing is represented at Fig. 7.

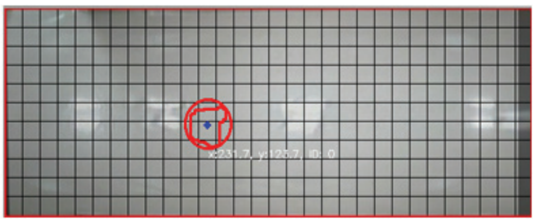

Fig. 7. Two dimensional map combined with the object area and the projected floor image.

2.3. Error Compensation of the Detected Object Area

When the size and center position of the object area obtained from contour processing are compare with the actual values of the object, there are considerable error between them. We measure difference of the position of the real and visually detected object by using the grid as shown in Fig. 8.

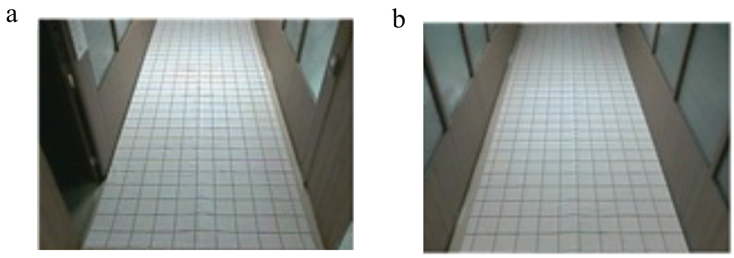

Fig. 8. Grid placard for measuring the position error of visually detected object area (a) camera 1; (b) camera 2.

A cylindrical object with 20cm diameter was used for error measuring experiment. After 1st measurement of detecting the object area the error compensation was carried out by using the homography. When the visually detected grids were mapping to the floor image on air view, we got the position error bound with 7.1cm in the 2 dimensional map. Fig. 9 represents the error compensated results of the object area detected by homography.

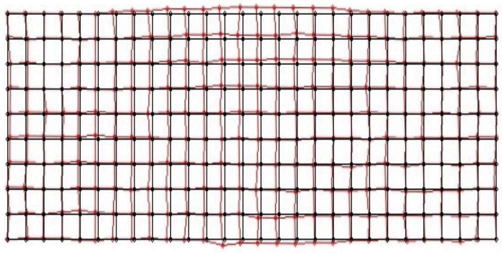

Fig. 9.Results of error compensation for the object area detected by homography.

3. Experimental Results

A series of experiments were carried out to show the effectiveness of the proposed two dimensional map based localization method by using the indoor surveillance cameras. Dimension of the floor viewed by two neighboring cameras is 2.2m width and 6m length. The detected two dimensional map by homography represents the area of the floor viewed the two cameras on air view. A self-developed mobile robot with omnidirectional wheel was applied for the experiment. The surveillance camera has resolution of 320 x 240 pixels and 3 channels of RGB.

Fig. 10 shows two images viewed by two neighboring surveillance cameras. There are several objects on the floor. A mobile robot was controlled to move one position to the opposite position by using the proposed localization based on the two dimensional map in section 2.2. A* algorithm was used for the path planning method of the mobile robot. The objects on the floor was detected as the object area in the projected plane by homography and the robot's moving path was planned considering the object area in two dimensional map. The experimental result of the robot's path control is shown in Fig 11. The error bound between the planned and actual moved path of the robot was ±5 cm. This means that the proposed localization method might be effective for the mobile robot at indoor.

Camera 1 Camera 2

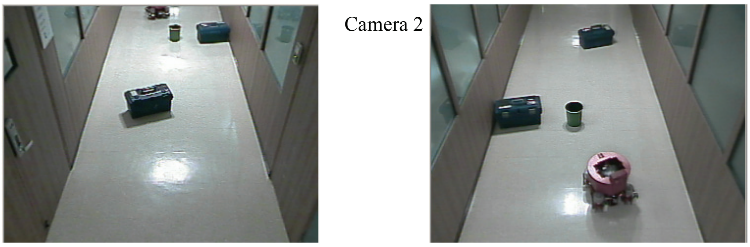

Fig. 10.Objects in experimental environment.

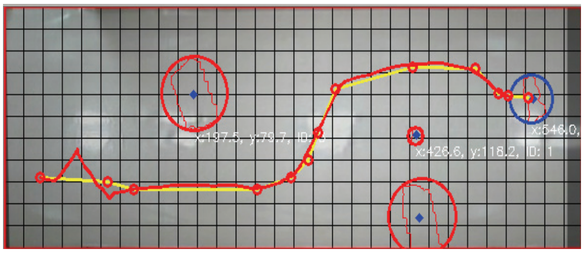

Fig. 11.Experimental results of a robot's path control by using the proposed localization method.

4. Conclusions

We presented a new vision-based approach for mobile robot localization in an indoor environment by using two remote ceiling-mounted cameras. The approach used two dimensional mapping technique between camera image and ground image plane coordinate systems. Particularly homography was applied for transformation of image plane. Two camera image planes were united to one ground image plane on air view and resulted in two dimensional map. Position error bound of the developed two dimensional map was within 7.1cm. A series of experiments were carried out to show the effectiveness of the proposed two dimensional map based localization method. Among several fixed obstacles in floor a mobile robot could successfully maneuvered to destination position using only the two dimensional map without help of any other sensors. As a future work, we plan to extend the proposed method to localization of multi mobile robots at indoor.

References

1. Hyung-gon C, Seol-young J, Soon-ju K. Modified indoor localization using the fingerprint duplicate type of wireless signal intensity in sensor-network. *J Korean Communication Society 2012*;**37(8)**:731-40.
2. Sungho H. Ultrasonic interference reduction technique in indoor location sensing system. *J Korea Academia-Industrial Cooperation Society 2012*;**13(1)**:364-69.
3. Emin K, Aaron RR. Mobile robot localization via efficient calibration technique of a fixed remote camera, I*nt. J of Science and Informatics 2012*. ;**2(1)**:23-32.
4. Purarjay C, Ray J. External cameras & a mobile robot: a collaborative surveillance system. *Australasian Conference on Robotics and Automation 2009*; 1-10.
5. Philipp A, Henrik C. Behaviour coordination for navigation in environment. *AIEEE/RSJ Int. Conf. on Intelligent Robots and Systems 2002*.
6. Huuiying C, Kohsei M, Jun O. Self-calibration of environmental camera for mobile robot navigation. *J Robotics and Autonomous Systems* 2007;**55(3)**:177-90.
7. Ioannis MR, David M, Gregory D. Simultaneous planning, localization and mapping in a camera sensor network. *J Robotics and Autonomous Systems* 2006;**54(11)**:921-32.