# Indoor Robot localization using Adaptive Omnidirectional Vision System

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**Summary**
The typical omnidirectional vision sensor predicts the location of mobile robots based on the information of the wall. With this method, following the location of landmarks is available and it is possible to predict where the target is in broad areas, but the location error increases according to the increasing distance from the feature point. In this paper, we suggest the new omnidirectional vision system using a convex lens to remove such a weak point. The system makes it possible to acquire the image information on a ceiling and a wall at the same time by a single camera. We realize the suggested vision system and should check whether the location accuracy is improved through the driving test.

***Key words:* *Omnidirectional vision, single camera, Mobile Robot Localization,.***

## 1. Introduction

The autonomous navigation technique of mobile robots recognizes the spatial environment, make the map of it, predicts the exact location of a robot based on the map, plans the ideal course to the target and makes it possible for robots to avoid the obstacles on the course and in doing so, the algorithms of real time, exact locating technique, environment recognition and avoiding obstacles is necessary. The main detailed techniques are making maps, predicting the location, planning the course, avoiding obstacles and sensor technique for tracing and driving.

The aim of the indoor localization technique of mobile robots among the autonomous navigation techniques is to provide stable and trustworthy information of the localization for robots to coexist with humans by deciding precisely the locations of people or objects. In the typical researches, there are the methods to use Active Beacon, ultrasonic wave sensor, GPS, laser scanner, infrared sensor and Vision system etc. to recognize their own locations.

In the current trend, the research to develop the low-cost driving technique by using vision sensor or RFID sensors is under way. The more researches are going on to acquire the autonomous navigation technique because we can get much information of the space and realize it with low cost through vision system.

When we classify it based on the objects to observe, there are two kinds such as the ceiling vision system to mostly use the image of a ceiling and an omnidirectional vision system to mainly use the image of a wall.

In a ceiling vision system, the camera is located at the angle of 90 degree with a robot, the map of a ceiling is made by extracting the specific point of its image acquired through wide-angle lens and after that, it finds out the location of a robot. As the most common way of its kind, there is a location predicting method[1] Thrun once applied in Minerva in which the location of a robot is found by Markov location prediction based on the information of lightings in a ceiling. As mentioned, it does its job to predict the location of a robot using the information of the ceiling so even when people surround a robot, we can find out its location, but, just part of a ceiling can be seen as the height of a ceiling is low in inside of a common building so in the current research trend, a map is made by the specific point and the location is predicted by using the point on the map[2]. In case of indoor places, there is no big change in the height of a ceiling so it has such a good merit as the error is even and small in measuring the location. But, we should store the specific point of the total environment in Database so we need lots of memory and it is difficult to modify the map once it is made and we have to depend on odometry or other sensors in case of wide places where there is no specific point within the viewing angle of a camera

In the omnidirectional vision system, we can acquire the field of vision of $2\pi$ and get the information of robots' location easily. Accordingly, it is possible to gain the broad field of vision in the applied fields such as observation or driving and chasing[3] of robots, which makes real time processing available[4][5]. Many scientists have studied the self recognition of its location using this system. The method has been suggested to use the correlation between the image of the map already made before and the image a robot gets in a random position to carry out the robot's omnidirectional location recognition. There are several ways to get the correlation

Manuscript received April 5, 2010
Manuscript revised April 20, 2010

such as Fourier descriptor[6], vertical edge matching of omnidirectional image[7] and horizontal line matching of omnidirectional image[8]. Especially, in case of the vertical edge matching, the extraction is available with only the condition of the line moving toward the center point of a omnidirectional image so in this method, faster operation is possible than any other methods. As long as the vertical line which appears in the omnidirectional image doesn't meet obstacles, the continuous chasing is available in a image, which makes it easy to chase the location in broad space.

In the research using this, we can predict where a robot is mixing a laser scanner one-dimension range measuring instrument and vertical information and make the map or in case we already know the location of a vertical line, the research is under way to predict the location of a robot through predicting the angle of direction using two vertical landmarks. But, the laser scanner is expensive and under the real situation, it is not available to measure the environmental location on the vertical line. Besides, the resolution of a image decreases to secure the field of view, the valid information on the input image is small due to 'hiding effect' of reflector in front of a camera and it hides the area of a ceiling when placed vertically.

In this paper, we propose 'Adaptive Omnidirectional Vision System' which can acquire both the image of a ceiling and an omnidirectional image at the same time by a single camera.

The content of this study is as follows. In chapter 2, we design the single camera adaptive omnidirectional vision system using a convex mirror and wide-angle lens this study tries to propose. In chapter 3, we will predict the location of a robot through the omnidirectional images achieved by the system and provide the simple example of an experiment. Finally, in chapter 4, we will give you the conclusion of this study and suggest the future assignment.

## 2. Adaptive Omnidirectional Vision System

### 2.1 Omnidirectional Vision System

The common way to get an omnidirectional image is using a convex mirror and a camera. We place the image plane of the camera and the central axis of a convex mirror on the same line, which makes it possible to get the images of every direction at once[3]. To get the omnidirectional image using the convex mirror is possible by mosaic mixing of several images through many cameras or rotating a single camera and in this way, compared to getting a panoramic image, the spatial resolution of the image is relatively low, but the system to get the image is very simple and the speed to do it is fast. Fig. 1 shows the image achieved by the omnidirectional vision system.

**Fig. 1 Omnidirectional vision image.**

The convex mirror used for getting the omnidirectional image is usually conic, spherical or hyperbolic which many companies make and sell for the purpose of research. Fig. 2 shows the concept map of an omnidirectional vision system located vertically from the robot.

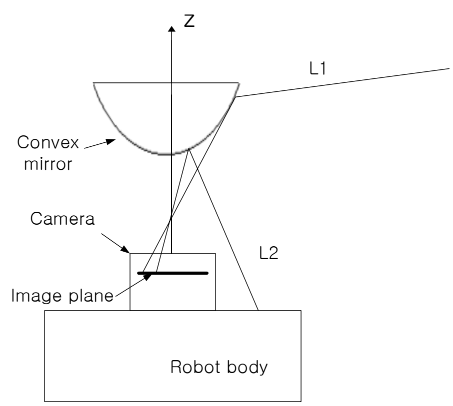



**Fig. 2 Omnidirectional vision system**

It is composed of the convex mirror for gathering light from every direction, a support, a camera to get image and driving sector of a robot. L1 and L2 are light reflected from a camera. L1 is reflected from a convex mirror and moves toward the image plane of the camera. L2 is hidden by the robot body. Finally, the field of view with every direction ( at the angle of 360° ) is acquired but the valid information at the center of the image is wasted by the robot and the camera.

### 2.2 The Proposed Adaptive Omnidirectional Vision System

The characteristic of the wide-angle lens to penetrate light is added to the existing omnidirectional vision system in the suggested one. The hole is made in the central part of the convex mirror and the wide-angle lens is placed there to penetrate light. Fig. 3 is the concept map of the suggested adaptive omnidirectional vision system. L1, the reflected light, is concentrated on the outer surface of the image plane through the convex mirror in the same way as the existing system does. L2, the incident ray, is concentrated through the wide-angle lens and condensed on the central part of the image plane.

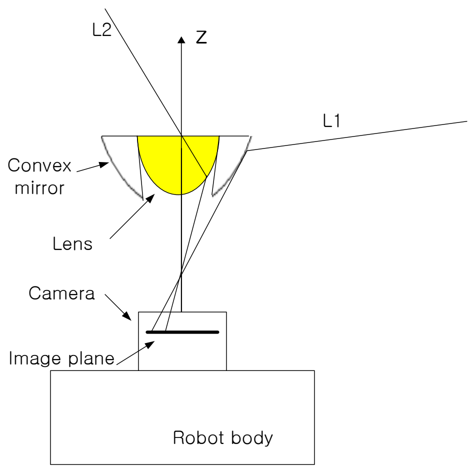
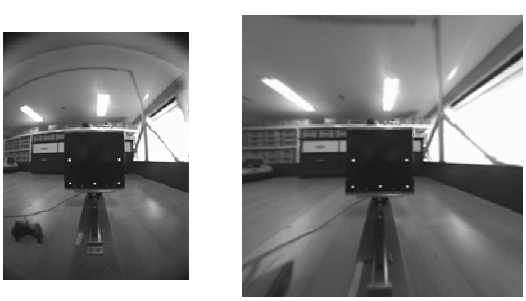



**Fig. 3 the proposed adaptive omnidirectional vision system.**

The condensed light by wide-angle lens forms the distorted image by the distortion of the lens. The process of camera calibration to remove distortion is necessary to measure the physical coordinate of the feature of the ceiling. The most distorted elements in a wide-angle lens are radial distortion and tangential distortion. Fig. 4 is the calibrated image to get the statistical estimate of the radial distortion coefficient by the least square solution from the distorted image input using a calibration pattern.

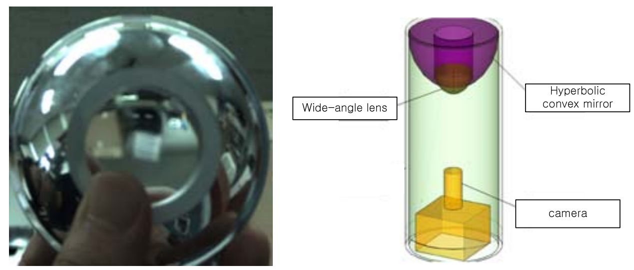


**(a) input image (b) calibrated image**
**Fig. 4 Camera calibration**

## 3. Experiment and Result

3.1 Implementation of Adaptive Omnidirectional Vision System

Fig. 5 shows the lens part of the system and the structures of a camera, a tube and lens part. The convex mirror is the hyperbolic convex mirror whose diameter is 77mm and height is 20mm. The diameter of the wide-angle lens is 32 mm and it is inserted in the center of the mirror and constitutes the lens part. As Fig. 5(b) shows, the lens is located 120mm away from the front side of the camera and supported by the transparent tube.




**(a)lens part (b) system structure**
**Fig. 5 The structure of the manufactured adaptive omnidirectional vision system.**

The manufactured vision system is located in the rotating center of a mobile robot. Therefore, it has such a merit as the distance from the vertical feature line doesn't change when a mobile robot rotates. And the Fov at the direction of a ceiling which is inputted on the camera is 90° and the Fov at the direction of the wall is 45° and accordingly, it has omnidirectional Fov of 360° within these ranges of the degrees.

**Fig. 6 the robot equipped with an adaptive omnidirecti -onal vision system**

3.2 Driving test in indoor environment

Fig. 7 is the input image of the manufactured vision system. In (a), the circular shaped area at the center is the image of a ceiling and in (b), the circular shaped area is the omnidirectional image of the wall. The omnidirectional image of the wall shows the height of the wall is decreasing at the direction of the center of the image, but, the image of the wall shows its height is decreasing in the opposite direction. (c) shows the vertical line of the wall. This line is formed in the direction of outside from the center of the image in the image of the ceiling as well as in the omnidirectional image. This is the vertical line feature in which chasing is possible even though it gets away from the wall

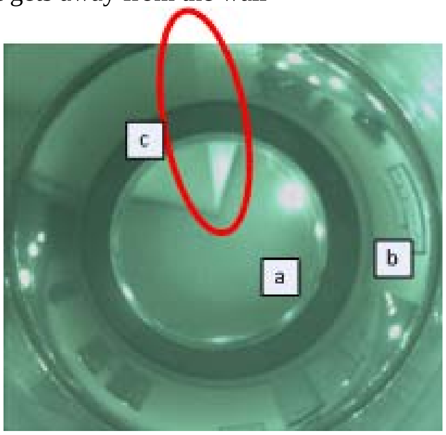



**Fig. 7 Adaptive Omnidirectional image : (a) ceiling image (b) Omnidirectional image (c) vertical line**

The driving test is done at the indoor space indicated in Fig. 8. The mobile robot is travelling along the outline of the wall and we did the experiment to make an outline map of the wall using the ultrasonic wave sensor. We carried out the SLAM based on the vertical line of the wall surface by both the existing omnidirectional vision sensor and the suggested adaptive omnidirectional vision system on the same route.

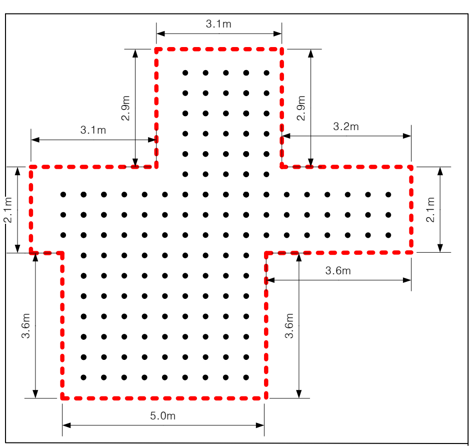



**Fig. 8 Experiment space.**

Fig. 8 is a floor plan of the experimental space. In Fig. 8 dot is a position to measure the robot's location. Dots are placed at intervals of 50cm. A total of 144 times were measured location error at the dot position. The average location error by the existing omnidirectional vision sensor method was 17.85 cm. The average position error by the proposed scheme was the 8.6cm.

Fig. 9 is the driving map of the robot which moved based on the information of the location acquired by the existing omnidirectional vision sensor. Fig. 10 is the driving map made by the suggested system and we can be confirmed that it is similar to the map of the real experimental space in Fig. 8.

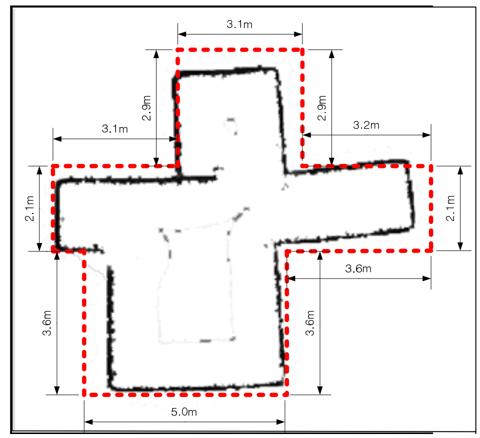



**Fig. 9 the driving map by the omnidirectional vision sensor**

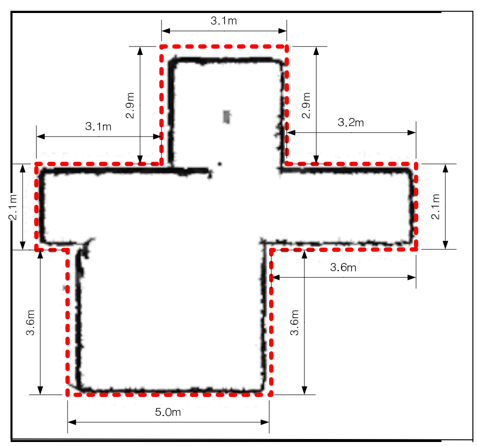



**Fig. 10 the driving map by the adaptive omnidirecti - onal vision system.**

## 4. Conclusion

In this study, we suggested the adaptive omnidirectional vision system to complement the existing omnidirectional vision sensor.

We developed the system which can acquire the image of the ceiling and the omnidirectional image at the same time using the hyperbolic convex lens.

We compared the performance of the system with that of the existing sensor and we proved the performance improvement in the suggested system in terms of the accuracy. We can expect that these two systems, the location recognition methods both based on the ceiling and based on the wall surface, can make up for each other's weak points.

For further study, we have a plan to develop the indoor location determination technique which can operate fast and be endurable from the environmental change of lighting.

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