

An Exhibition Environment with 2D Markers for Guide Robot

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Abstract

The guide robot in an exhibition environment is expected to entertain visitors and reduce the maintenance cost of updating the robot database according to the changes in exhibition contents. The exhibition comprises printed panels for humans and a 2D marker printed with ultraviolet ink for robots. 2D markers are attached to the bottom of the exhibition furniture to make the markers invisible to visitors. The exhibition point may change depending on the contents of the exhibition. By searching for 2D markers autonomously in an exhibition space, the robot can update its internal database. This enables us to keep both the printed panel and the robot database without changing the robot database by users. The experiment is conducted in an exhibition environment, and the success rate in finding the exhibition point is evaluated.

Keywords: Guide robot, Kachaka, 2D marker, ArUco marker, Invisible printing, Exhibition environment

1. Introduction

Service robots are being developed for commercial environments. These robots typically have a camera and laser sensor for autonomous movement and a microphone and speaker for communicating with humans [1][2][3][4]. The guidance of facilities is one of the tasks of service robots. These robots must move autonomously to guide the environment. Two-dimensional markers and/or laser sensors are typically used for the localization of the robot.

Fancy is the base of the Research Center for Neuromorphic AI Hardware, which has an exhibition, meeting, work, and relaxation area. This study focuses on an exhibition area of Fancy and an environment for a guide robot. The robot in Fancy is required to guide the

guests of the research center and explain each display item to the guests. The display items and their explanation boards are located on a white exhibition platform. The update procedure for the robot database with changes in the display content should be simple. Non-experts in robots will change the display items; therefore, the internal robot program should not be modified each time.

This paper summarizes the environmental design concept of Fancy and a system with a two-dimensional marker that matches the environment to locate the position of the display item for a robot.

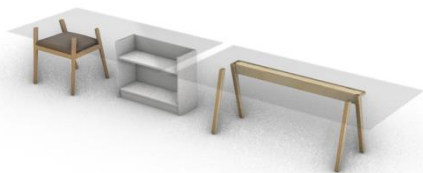


Fig. 1 The design concept of the exhibition platform

2. The Design Concept for the Exhibition Environment

The exhibition platform of Fancy is composed of furniture in a hall, bedroom, kitchen, and living room in the home environment. The Furniture was cut to a height of 60 [cm] and an acrylic board was placed on it. The design concept of Fancy is inspired by the idea of robot sensing range: home service robots only detect a part of the space. In particular, a robot with 2D LiDAR detects the bottom of the space. The area that the robot can detect is represented by the white part of the furniture, and the acrylic surface is the limit of the robot's perception (Fig. 1).

The Display items are typically located under the acrylic surface, and the explanation panel is located on top of the acrylic surface. The position and content of the display items change; therefore, the destination position and contents for explanation are also updated. The surface layout of each exhibition furniture is different. However, the variance of the foot in each exhibition furniture is less than that of the surface. The requirements of the robots in Fancy are as follows:

- (i) The robot should not collide with the acrylic surface at a height of 60 cm.
- (ii) An update of the display items is included in the guide.
- (iii) Modification of the exhibition platform should be minimal.

We propose an environment in which ArUco [5] markers are printed with invisible ink and attached to the foot of the furniture. The robot can identify its position with a serial number using an ArUco marker. By linking each display item with the serial number and its position, the robot can reach the destination position for guidance. We used invisible ink that reacts with ultraviolet (UV) light. Under daylight, the two-dimensional marker is invisible to humans; however, under UV light, it becomes visible. This contributes to maintaining the design concept of the room and conveying necessary information to the robot (requirement (iii)).

2.1. The operation flow of updating display items

The flow for updating the display items is as follows:

- (i) Users update the positions and/or contents of the display items.
- (ii) Users attach a two-dimensional marker to the foot of each exhibition furniture under the display item.
- (iii) Users link the display item and marker serial number on a database

Here, humans simply link the display items and serial numbers of the two-dimensional marker, and users are not required to set the coordinates of each exhibition position.

3. Guide Robot

The guide robot has two operation modes: guide mode and update mode.

3.1. Guide mode

The robot uses the 2D LiDAR information for localization to move to specified positions. To provide an explanation, the robot moved to the destination position specified in the database.

3.2. Update mode

In this mode, the robot updates its internal database, serial number for each exhibition, and position by scanning a two-dimensional marker under UV light during the night. Guests are not in the exhibition environment and external light does not exist; therefore, it is suitable for the robot to scan two-dimensional code under UV light at night. The robot travels to a predefined scanning position, and if the robot detects markers at different locations in the previous scan, it updates the destination position for explanation.

4. Marker detection method

The ArUco marker is printed using special ink that is visible under UV light (blacklight ink). The ink emits light when it is exposed to UV light. The area where the ink is printed appears white, unlike a normal printed area. The inverted marker is printed using blacklight ink, as shown in Fig. 2, where (a) is the marker size, (b) is the

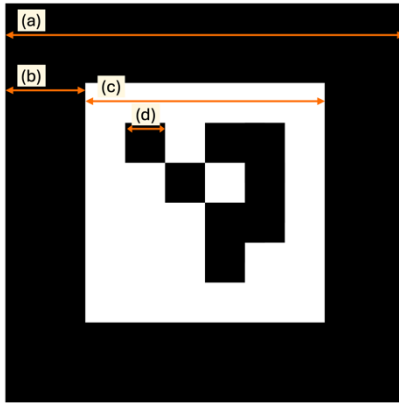


Fig. 2 ArUco marker for black light ink printing.

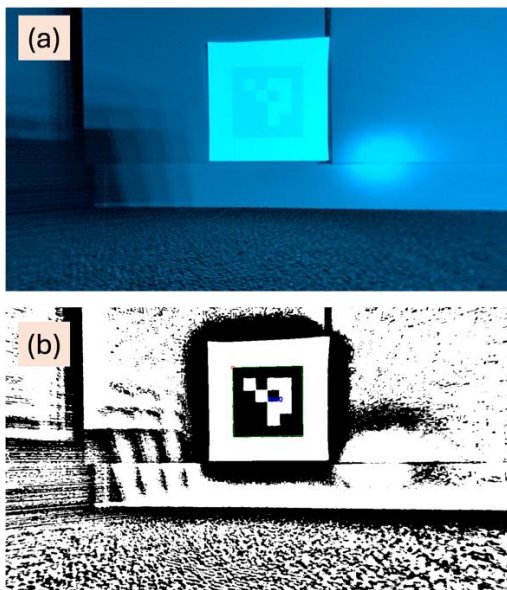


Fig. 3 Marker detection (a) Distortion-corrected input image (b) Binarized image with detection result (The detected bounding box and the ID of the marker is displayed in the image)

margin size, (c) is the module size, and (d) is the cell size. In addition, the robot maintains its distance from obstacles, and the robot cannot reach too close to the marker. Thus, the marker size is important for stable detection.

The distortion-corrected image from the camera was converted into a binarized image (Fig. 3 (a)). The adaptive Gaussian thresholding method [6] was applied to binarize the images (Fig. 3 (b)). Finally, the coordinates of the marker in the map were calculated and stored for guidance.

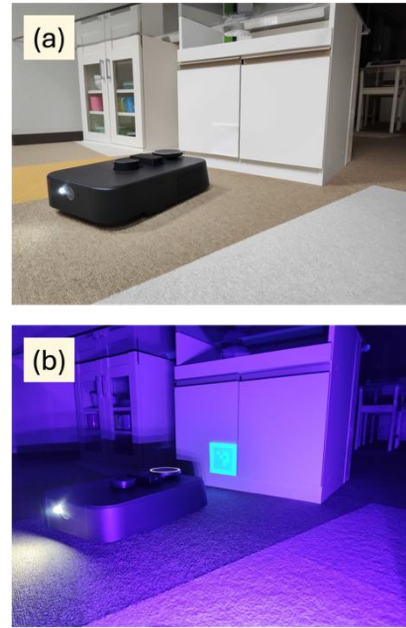


Fig. 4 Experiment Environment and marker (a) Under the daylight (b) Under the UV light

5. Experiment

The experiment setup is illustrated in Fig. 4. The ArUco marker was printed in blacklight ink and attached to the bottom of a white exhibition platform. Kachaka [1][2] was used as a guide robot, which is much lower than that of acrylic surface. Kachaka has a camera in front and LiDAR sensor for navigation, and a speaker for audio

Table 1. Detection results by margin size

Marker ID	A1	A2	A3	A4
Margin size (b) [cell]	2.0	1.5	1.0	0.5
Module size (c) [pixel]	180			
Is detected	Yes	Yes	Yes	No

Table 2. Summary of the result.

Marker ID	B1	B2	B3
Marker size (a) [mm]	88	112	105
Margin size (b) [cell]	2	2	1.5
Module size (c) [mm]	66	84	84
N_d / N_t (ratio)	10/15 (0.666)	10/10 (1.000)	10/118 (0.085)
b [pixel]	151	191	191
\bar{z} [mm]	0.23576	0.22813	0.27732
s_z [mm]	0.00075	0.00033	0.00620

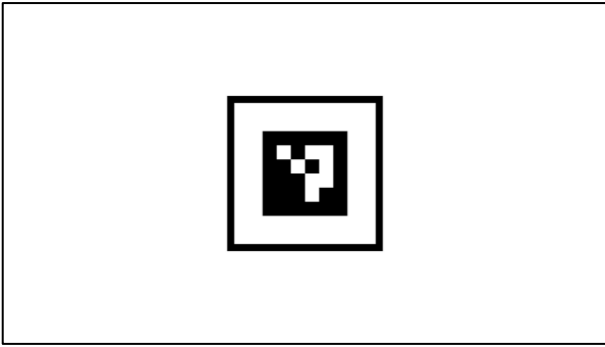


Fig. 5 ArUco marker used in a simulation experiment (marker A1)

guidance; thus, it meets the requirements (i) and (ii) of the robot in Fancy and is suitable for a guide robot.

5.1. Margin around the module (simulation)

The binarized image contains a black frame around the marker. The necessary margin size around the module is confirmed using a simulated detection image, as shown in Fig. 5. A simulated image module with 180 [pixel] and 15 [pixel] of black frame was prepared. Four different proportions of cell margin size were evaluated. The results of the experiments are shown in Table 1. We confirmed that at least 1.0 [cell] of margin is required to detect the marker.

5.2. Marker size

We evaluated three different markers: B1, B2, and B3. Kachaka was navigated 0.23 [m] in front of the exhibition platform. The detection was performed every second. The number of detected markers (N_d) and the total number of trials (N_t) were counted, and the detection ratio was calculated. The distance from the front camera of Kachaka to the marker (z), the average (\bar{z}), and the standard deviation (s_z) were evaluated.

The experiment results are shown in Table 2. The detection rate of B3 was lower than that of the other markers. The standard deviation of B3 was also larger than those of the other two markers. Despite the simulation results, 2.0 [cell] of the margin was required for reliable detection. Markers smaller than B1 were not detected.

6. Discussion

In a real-world environment, a larger margin was required for marker detection. We think this is because the property of detection, such as noise, is not sufficiently reflected in a simulation environment. However, the margin size might also affect the binarization of the image; therefore, the detection accuracy is not only a problem of the ArUco marker itself. The detection performance of the marker increased with module size, and the margin size was larger. Markers B1 and B2 had sufficient accuracy for guiding robot applications. We

can conclude that marker B1 is suitable for harmonizing with the design, and marker B2 is suitable for more stable detection.

7. Conclusion

We summarized the design concept of Fancy and explained the guide robot system for locating each exhibition item. The special ink reacted to UV light and was applied to create an invisible marker in the daylight. The invisible marker has sufficient ability to locate exhibition contents and position them in a darker environment with UV light. Marker size and detection accuracy have a tradeoff, and two suitable marker sizes were found in the experiment. The implementation of the guide function and the evaluation of human acceptance will be planned in the future.

Acknowledgments

This project was supported by a crowdfunding project, “Create a Future Space Where Humans and Robots Live Together”.

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