Projection-based Augmented Reality Robot Prototype with Human-awareness

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***Abstract*— Since projection augmented reality (AR) robot can provide a lot of information through projector, it can be useful in museums and art galleries that need to provide information to the crowd. Therefore, it is necessary to continue to interact with people, and human-aware path planning is also needed. We prototyped projection AR mobile robot implemented human-aware path planning and wrote about future research direction.**

Keywords—Projection Augmented Reality; Human-aware Path Planning, Service Robot; Mobile Robot; Human-robot Interaction

I. INTRODUCTION

Recently, service robots are becoming popular as next-generation innovation industries. Researches on interaction between users and robots are actively being carried out accordingly. There are several ways for a service robot to provide information to the users. The most commonly used method is to use a display that supports touch screen. It also provides information/feedback through voice. Alternatively, the projector may be mounted. This type of robot is called a projection robot [1]. The most important feature of a projection robot is that it needs a plane to project information to provide information. Such a projector can provide more information at a time than a display that can only confirm information in a relatively narrow area [2]. It is also very effective in constructing an augmented reality (AR) environment. This is because the robot can run on its own and augment information by projection on the required area [3]. Therefore, these projection robots can be used as docent robots in museums and art galleries.

In order to be used in the AR environment in which the projection robot provides real information, several path planning must be implemented. Basically, local path planning is required for user tracking and obstacle avoidance. Next, there is global path planning that can use simultaneous localization and mapping (SLAM) to identify its position in space and move to the desired location. Finally there is a human-aware path planning that locates crowds and provides appropriate social manners. In this paper, we focus on human-aware path planning. Moving to a position where information is needed to be provided through the robot driving algorithm has been a subject of much research in the past. On the other hand, it has been only a few years since the research that started to run socially without discomfort or inconvenience to users has begun. In particular, projection robots can project walls or floors with projector and damage users in this process. If the projector's strong light is projected in the user's direction without consideration of the user, severe glare may occur. Also, since the screen is hidden by the user, it may be difficult to provide information properly. Therefore, it is indispensable to carry out human-aware path planning to the projection robot. In this paper, a robot prototype structure and a human-aware path planning are shown.

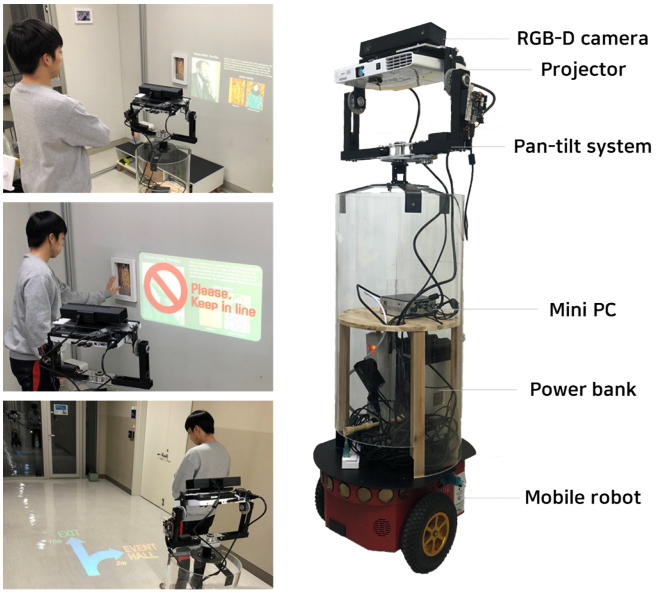

Fig. 1. The appearance and configuration of a projection AR robot that can provide information to the user by projection.

II. HARDWARE CONFIGURATION

The hardware configuration of the projection AR robot we prototyped is as follows. At the bottom is the mobile robot Pioneer 3-dx. The mobile robot is basically equipped with eight sonar arrays. The sonar array can be used to create local maps and to avoid obstacles. At the top is a projection system. A pan-tilt system is used to provide information on projections anywhere in the space. The pan-tilt system covers almost all angles in the horizontal and vertical directions. The pan-tilt system is controlled via the servo motor control of the Arduino. In addition, the projector and RGB-D camera installed in the pan-tilt system can help not only to provide information but also to interact with the user. There are various wired connections for controlling the mobile robot and the projection system. The body of the robot made of acrylic can be mainly divided into two parts. Here, a power bank for supplying power to the projector and the camera is mounted on the first part.

The second part is equipped with a mini PC that selects and provides robot navigation, pan-tilt system control (Arduino control), and appropriate projection information. The projector is equipped with a wireless display adapter. In addition, the acrylic behind the robot is cut inside to allow maintenance, and the hinges are attached to the acrylic.

III. Software Configuration

Unlike conventional mobile robots, projection mobile robots require not only simple driving but also etiquette / manners for driving. This is a field of research that is of great interest in the recent HRI field called human-aware path planning. Consider a projection mobile robot that can be applied as a docent robot in the future. The robot moves along the users or guides the users to a specific destination. Now the user is stopped in front of the work of interest, and the robot must provide the relevant information as a projection. In such a situation, a problem arises when the robot projects a projection onto the optimal plane detected without considering the human being. In particular, when a person exists between the projector and the projection plane, occlusion occurs in the image to be projected. But a more serious problem is that it creates a glare to the user. Bright light projected directly from the projector can easily damage people's eyes. Therefore, it is essential to carry out additional movement considering the positional relationship of the users who want to provide information.

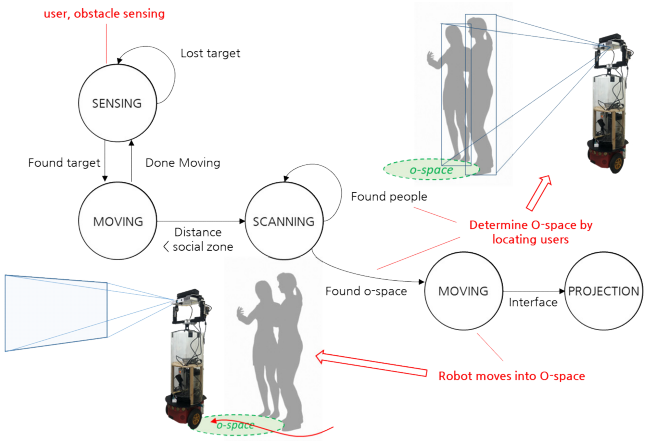

Fig. 2. Finite state machine of projection AR robot.

We have defined rules using O-space for this additional movement algorithm as shown in Fig. 2. O-space refers to the inner circle of interacting people [4]. First, the projection robot should maintain a natural distance to interact and maintain the social zone with people. This makes it possible to reduce discomfort caused by sudden movement of the robot. The next step is to go to O-space and provide projection information. Through this, it is possible to naturally induce the projection to the human eye.

IV. Application

Projection AR robots with such a system can be usefully used in exhibitions such as museums and galleries. Projection AR is used to project relevant information around the work so that more immersive information can be transmitted. Therefore, it is possible to view the exhibition effectively and support active and selective works. Several application scenarios can be derived as shown in Fig. 1. First, it can become a navigation robot. At the exhibition hall, the robot can project the guidance information on the floor. Through the augmented information, the user can easily navigate to a desired work. Next, you can give a description of the work. In general, docent will arrange the order of viewing the works, and viewers will passively appreciate them accordingly. Therefore, there is a disadvantage that the listening time is limited according to the moving line of the docent. However, the projection AR robot that supports the docent function follows the audience and provides a description of the desired work. Therefore, the users can enjoy the work more actively. In addition to this, it is expected that there will be more diverse scenarios, such as displaying warnings when viewers approached the work, or informing the direction of exit when viewing is finished.

V. Conclusion

There are a lot of things to consider in terms of hardware and software when prototyping projection AR mobile robots. In the case of hardware, the total elongation of the robot, the actual use time according to the capacity of the battery, and the wiring problem. In addition, a structure with an internal access is required for easy maintenance. On the other hand, in the case of software, it is essential to grasp not only basic autonomous navigation but also user's movement and positional relationship. This is directly related to human-aware path planning and must be included in order to implement human-robot interaction. In this paper, by defining the driving rule using the O-space concept, we can naturally provide the projection AR without damaging the user. In the following research, it is necessary to evaluate how comfort, naturalness and sociability of the docent robot applying these human-awareness through actual user test.

Acknowledgements

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