Information Display System using Active Projector in Intelligent Space
-Integration of distributed devices based on RT-Middleware

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Abstract

This paper presents information display system using active projector in Intelligent Space. Intelligent Space has distributed sensors for observing and actuators for acting in the space, in order to provide various services to human. Proposed Information display support in Intelligent Space has realized providing interactive information based on the human movement using active projector, which is installed in this space.

To make the environment space or several applications easily to be applicable with our active projector system, RT-Middleware is used (AIST, Japan) due to its features in flexibility and expansion of the system in the future.

First, Information display system using active projector in Intelligent Space and its implementation configuration are introduced. Next, the solutions of issues on active projection are described. Finally, the system design of Intelligent Space based on RT-Middleware is discussed.

Key Words: Intelligent Space, RT Middleware, Active P rojector, Information display

1 Introduction

This paper presents information display system using active projector in Intelligent Space. Intelligent Space is an environmental system realized by cooperation of Robot technology (RT) elements such as robots, sensors or actuators inside a space (room, corridor or street) and has distributed sensors for observing and actuators for acting in the space, in order to provide various services to human [1]. The purpose of proposed information display system is to provide informative support and has realized providing interactive information based on the human movement using active projector, which is installed in this space.

The concept of information display system in Intelligent Space is shown in Fig. 1. On observation of Intelligent Space, the space can obtain human movement as user information, and the space can obtain object information (embedded information in the space) such as the position of bookshelf, the direction of emergency exit or their contents as spatial or environmental information. By using those information, active projector provides interactive informative services based on human movement.

Active projector is located on pan-tilt stand, which is able to project toward any position. Also it is network based and micro-controller embedded [2].

By utilizing the interactive information, many applications can be realized, for example, walking path guidance, the sign or mark illustration in the public space or private space in daily life.

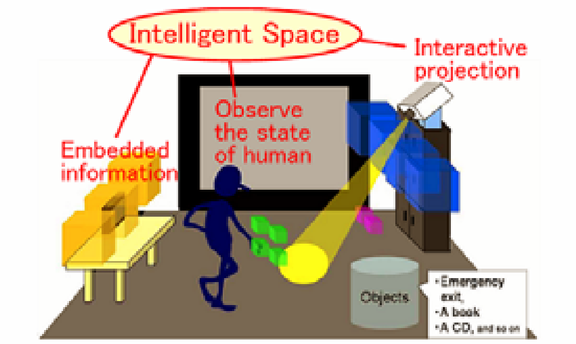


Fig. 1 Information Display System in Intelligent Space.

2 Information display system based on RT-Middleware

2.1 RT-Middleware based system

In the case of the environmental system such as Intelligent Space, the system tends to be large-scale and complex and it is one of the essential problems. Intelligent Space desires more flexible and more expandable system to correspond the change of the environment or scenario because we assume various spaces as Intelligent Space. So the system requires easy integration and cooperation with RT devices and simple addition, modification or deletion of devices and functions. RT-Middleware supports new framework to make composite components for RT-Component [3]. In the other words, RT-Component becomes robot technology module which has common input/output channels. Therefore, by making and preparing RT-Components for sensors, actuators or applications, and connecting those RT-Components, we can integrate flexible system.

RT-Component-Lite[4] is a Component for small devices as micro controller and active projector, we developed, is embedded RT-Component-Lite for expansion of application into daily life.

2.2 Configuration of hardware

The configuration of information display system is shown in Fig. 2. In this system, ultrasound 3D location system ZPS (Furukawa Co.) is used for human positioning. ZPS consists of ultrasound receivers and transmitters. A lot of receivers are installed on ceiling and two transmitters (tags) are held on user's neck and hand. User information is given as position and direction of user by calculation vector of its two tags.

This user information is sent to active projector through RT-Middleware installed in PC. OpenRTM-aist (AIST, Japan) is used as RT-Middleware. Finally, active projector realizes projection according to applications.

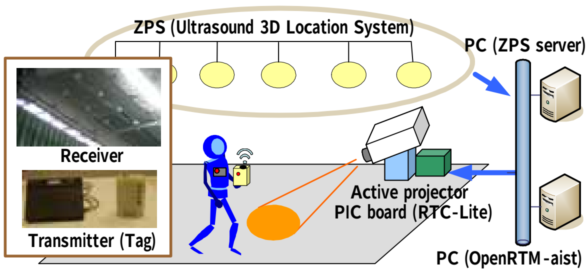


Fig. 2 Configuration of information display system.

2.3 System architecture using RT-Components

The system architecture based on RT-Middleware is shown in Fig. 3. The system is built up with the combination of RT-Component and consists of three component parts. Sensing Components obtain user information. ZPSOut2 Component receives two tags position data from ZPS server. HumanState Component calculates position and direction of the user by two tags position and sends user information to Application Components.

Next, Application Components decides reference for active projector and calculates image filename and characteristics of an image (projection target, image size, image direction) according to the application. By preparing Application Components and switching the connection of Components, various applications could be realized.

Finally, Device Components control the projected image generation and the pan-tilt drive according to the request. Image Projection Component outputs projected image according to image source, image size and direction. MovePConverter Component converts pan-tilt angle from reference target position by this coordinate transformation equation. RTUnitCtrl Component is connected with RT Component-Lite through the control panel so that we could control active projector.

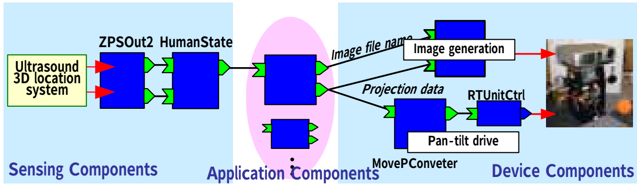


Fig. 3 System architecture based on RT-Middleware.

3 Solutions of Issues by using Active Projector

3.1 Occlusion Avoidance

When projection light is obstructed by human or objects, projection occlusion prevents providing correct information. Therefore to avoid occlusion problem, the system modifies projected position. In this system, occlusion avoidance method is built up as one RT-Component and is connected between Application Components and Device Components. The developed Component receives projection data and user information and sends modified projection data by occlusion avoidance method (see Fig. 3).

Proposed occlusion avoidance method is divided into two steps: detection and avoidance.

1) Occlusion detection

Occlusion occurs when human enter into the area where human himself obstruct the projection. Therefore, by creating occlusion area and human model and judging the overlap between those each other, occlusion can be detected. In Fig. 4, geometrical image of active projection is shown. The below figure is overhead view of upper figure and the figure is transformed into 2D. Occlusion area is projection light and the shape is corn. But when the projection is projected over human's body, occlusion does not occur. In the other word, occlusion occurs in the area under the human's height. Hence, Human model can be assumed as a circle and by estimation the margin, occlusion area can be assumed as a sector on 2D. Finally, we judge the overlap between those 2D models.

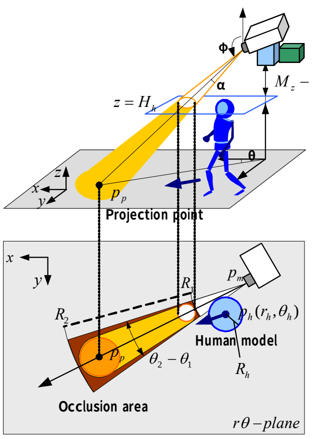


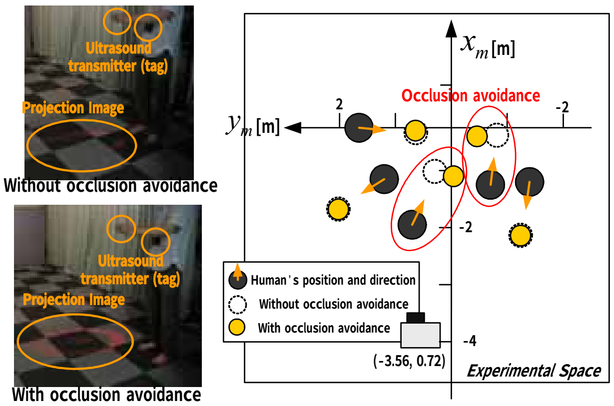
Fig. 4 Transformation of geometrical human model and occlusion area from 3D to 2D.

2) Occlusion avoidance

To modify (move) projected position toward easily viewable position, avoidance method results from the direction of projected position in the view of human position. In the situation that projection target is on the left side of human model, modified position moves to the left which is closer than to the right direction to avoid occlusion. On the contrary, when projection target is on the right side of human model, it moves to the right for the same reason. If limited rotation angle is reached, the radius direction to projection position is kept away to avoid occlusion.

Over more, not only human but also other objects such as chair and table could cause occlusion problem, our proposed method can treat those objects as the human model and perform the occlusion avoidance algorithm.

The result is shown in Fig. 5. The information display system performs projection toward the front of user. As Fig. 5(a) shows, in projection without occlusion avoidance, image is obstructed by user. On the other hand, in projection with occlusion avoidance correct image projection is realized. Fig. 5(b) is the results of several situation in experimental space. When occlusion occurs (two cases), projection position is modified. We can verify successfully activation of occlusion avoidance.



(a) Comparison (b) Several situation in experimental space.

Fig. 5 Occlusion avoidance.

3.2 Compensation of projection image

In the case of active projection, the shape of projected image is not same as that of the source image because projection is not always orthogonal to the projected surface and the distance to projected surface from projector is not constant. The change of projection target causes image distortion and varies the image size. Therefore, projected image requires compensation of distortion, size and rotation to provide uniform image to user. In the system based on RT-Middleware, this compensation is performed in Image Projection Component (see Fig. 3). Compensation method is described respectively as the follows.

1) Image size

Projector light radiates out so that projected ima ge size depends on distance to projected surface. By calculation the relation of those factors, it is a ble to pre-compensate projected image size to req uest size W. resize ratio α is given by Eq. 1. Wh ere $t(d)$ is a image size on projection direction d.

$$\alpha(d) = W / t(d) \tag{1}$$

2) Rotation

Projection image (source image) is rotated according to the request from Application Component. For example, it enables the arrow toward any position or projection in response to human direction. So we (user) don't want to see the sign or the mark upside down.

3) Distortion

Distortion is caused by the angle-relation between projector and projected surface. Geometrical definition is shown in Fig. 6. As this figure shown, active projector projects toward Op. where plane Q is projected surface and plane R is orthogonal to projection direction through Op. r1 to r4 are assumed as corner of source image or non distortion image. And q1 to q4 are corresponding points with r1 to r4. A relation between a point p_R on plane Q and a point p_R on plane R is shown in Eq. 2 as perspective conversion. This conversion matrix H_{QR} is a 3×3 matrix and the degree of freedom is 8. Therefore, if more than four sets of corresponding points of p_R and p_R are given, we can find H_{QR} and represent image distortion. The corresponding points can be found by the intersection of plane Q with the line through r_i from projection origin (lens). Finally, inverse matrix of H_{QR} represents compensation of distortion image and we can get pre-compensated output image.

$$\begin{pmatrix} p_Q \\ 1 \end{pmatrix} \cong H_{QR} \begin{pmatrix} p_R \\ 1 \end{pmatrix} \tag{2}$$

Proposed method uses normal vector of plane Q for finding the corresponding points. Plane Q shows projected surface so that it is possible to compensate projection toward any surface by setting normal vector according to the space.

Comparison of projection image with and without compensation is shown in Fig. 7. The system performs the projection of double-rectangle. As shown in this figure, the projection without compensation causes inexpectant projection image depending on projection

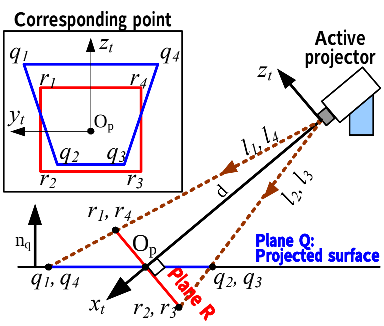


Fig. 6 Geometrical definition of image distortion

target. On the other hand, the projection with compensation provides correct information (considered size, direction and distortion of projection image) compared with the one without compensation.

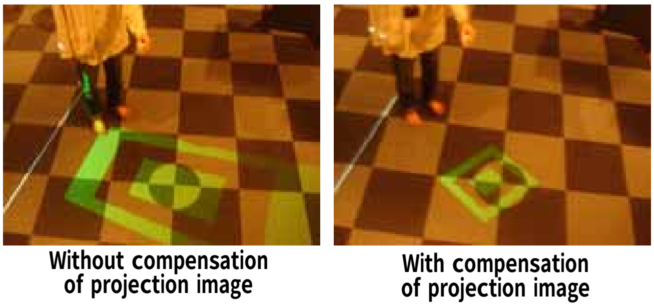


Fig. 7 Compensation of projection image with and without compensation.

4 Integration of distributed devices based on RT-Middleware

RT-Middleware is a kind of software platform based on distributed object middleware. As described in section 2, it is suitable for environmental system such as Intelligent Space. Intelligent Space is considered to have RT elements in a space to utilize RT-Middleware for the integration of its system. And Intelligent Space is expected to become useful and easy to integrate for system development. By using RT-Middleware as platform, Intelligent Space is intensive stage of RT (Robot Technology).

Proposed system based on RT-Middleware is considered as integration with various distributed devices as Intelligent Space system. The system design of information display system (Intelligent Space) based on RT-Middleware is shown in Fig. 8. Environmental system including Intelligent Space will be integrated with various sensors or actuators and has difficulty to implement as whole system. As shown in Fig. 9, the system based on RT-Middleware enables the system to be flexible, which is not depends on the hardware device. For example, various sensors can be treated as position or posture sensors according to their features. Over more, by converting various actuators or devices to the components, it is possible to send the command to control and interact with those actuators. As an example, we developed a RT-Component for mobile robot. This mobile robot is implemented in Hashimoto lab.(The Univ. of Tokyo, Japan) [5]. Because only the interface part is created as the component, the robot's required subsystems such as feedback control, mapper are not needed to be modified. Therefore, Application Components sends target position as command to robot. By demonstration using active projector and mobile robot (however the sensor that used to recognize the user's position is not integrated into the system yet), when an active projector provides a message" Calling robot …" toward a user, the robot can come to a user as shown on Fig. 9.

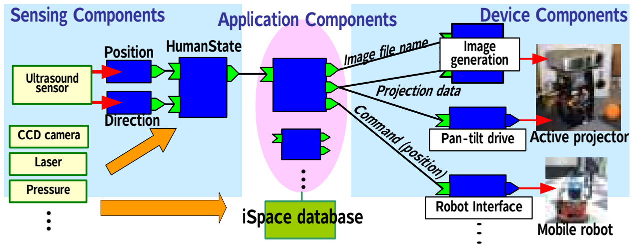


Fig. 8 System design based on RT-Middleware.

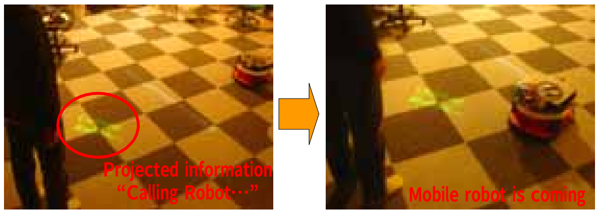


Fig. 9 Demonstration using active projector and mobile robot.

5 Conclusion

This paper presents information display system using active projector in Intelligent Space. Active projector provides interactive informative services for user. To realize this purpose, as two solutions of issues on active projection occlusion avoidance and compensation of projection image are described. We plan to develop smooth working according to human movement and demonstrate the effectiveness on informative services.

Proposed system is based on RT-Middleware. With the feature of RT-Middleware, we will integrate information display system with other devices such as vision sensors or robot, and as a first step, the cooperation of active projector and mobile robot had been performed as described in this paper. In the future, we plan to design and implement the Intelligent Space system by using RT-Middleware.

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