A 3D GUI System for Controlling Agent Robots

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Abstract: Recently, there are lots of concerning on the integration of robot and virtual reality with the trends of the research of intelligent robot and mixed reality. In this paper, a 3D GUI system is proposed based on Internet for remote controlling and monitoring of agent robot working for itself. The proposed system is consists of a manager ordering a new position and displaying the motion of robot, an agent robot moving to the destination according to the indication, a positioning module detecting the current position of robot, and a geographical information module. A user can order the robot agent move to a new position in a virtual space and watch the real images captured from the real sites of the robot. Then, the agent robot moves to the position automatically with avoiding collision by using range finding and a path detection algorithm. We demonstrate the proposed 3D GUI system is supporting a more convenient remote control means for the robots.

1. Introduction

The concerning on the intelligent robot based on Internet enables us to operate robots remotely, watch the 3D graphic images of geometric motions, and see the images of the real sites of robots.[1-3] One of the emerging topics of intelligent robot is the coordination of robots which they work together with cooperation. The remote operation of a number of robots simultaneously for the cooperative job, we may have time-delay from the networks. For diminishing the problem, it is more rational just to transmit small job commands and to make the robots do detailed behaviors for themselves. For adapting to this situation, the concept of agent robot was introduced[6]. Agent robot is able to receive commands from manager, execute organized works according to the directions, and cope with unexpected conditions. For the control of agent robots, we need a humanized interface environment: a man gives commands to the agent in a virtual 3D graphic environment, the agent realizes the directed job, and the virtual environment shows the motion of them. Generally, the virtual environments are constructed by integrating object models initially and just changing them geometrically, and it is difficult to express the real scene. For the purpose of integrating the virtual and real environments, mixed reality is an alternative research area[4,5]. The mixed reality is a multiform concept of real and virtual environments, which is within the scope of augmented reality accentuated with virtuality on the basis of real environment, and augmented virtuality stressed reality on the basis of virtual environment.

In this paper, a 3D GUI system adopting the concept of the mixed reality is proposed based on Internet for remote controlling and monitoring of agent robots. The proposed system is designed as a manager ordering a destination position and displaying the motion of robot, the agent robots moving to the destination automatically according to the indication, a positioning module transferring the current position of robot to the agent, and a geographical information module. When a user orders the robot move to a new position by clicking a mouse at the virtual 3D environment, he can watch the virtual 3D motion and real images captured from the real sites of the robot. Then, the agent robot moves to the position automatically with avoiding collision by using range finding and a path detection algorithms. The proposed system is designed for applying it to home robot and the cooperation job of multi-robot at the in-door environment.

The first part of the paper will present the system design and the operation of the proposed GUI system. The second part will describe the details of 3D GUI system of the agent robot according to the functions. The next part will show the experimental results and conclude the paper with discussing the feasibility of the system.

2. System design

The proposed 3D GUI system for agent robots consists of a manager, robot agents, a positioning module, and a geographic information module. Figure 1 shows the schematic of the proposed system. In the manager, there is a 3D graphic space describing the real terrain centered on the robot. The graphic space also shows the three-dimensional drawings of the robot at the matched position with the real location. It has an image display window showing the scene of the real surroundings from the camera of the robot. The agent robot is a mobile robot can move in a real terrain. It has a laser range finder for detecting objects located at the front and avoiding obstacles. A color camera is attached on the front part of the robot for transferring captured images to the manager for monitoring and using as a input image of range finder. The geographical information module has a database of geographical information and transmits the data to the manager for constructing a 3D graphic space of the surroundings. The positioning module can acquire the real position of the robot and transmit it to the agent.

The basic operation of the proposed system is started at the manager. When a user directs the destination position using a mouse at the 3D GUI environment at the remote place, the robot moves to the destination. The motion of the robot is followed by the information of the current position received from the positioning module and the moving path determined by an optimal path detection algorithm of the robot. If there are some differences between the path and the position, the robot corrects the errors and follows the path. The map data of the geographical informatin module is an information of past, the real terrain could be changed. In this case, the robot adapts itself to the new surroundings. When an unexpected situation is occurred such as a obstacle is appeared, the robot is able to detect it by using range finder and avoid the obstruction by using anti-collision algorithm. Therefore, the network is just used for transmitting the command information, and the problem of time-delay is not serious. As the robot moving, the 3D GUI space is displaying the motion of the robot simultaneously. Since the 3D map is centered by the position of the robot, the 3D map is revised automatically when the robot is moved to another place. The position information is transferred to the manager, and the manager moves the robot model to the new position. In addition to that, the images acquired from the camera of the robot are transmitted to the manager and displayed at the same time. So the user can monitor the moving of the robot more conveniently. Even if there is some time-delay on the networking, it is not serious to the system because the data is just for showing the current position of the robot.

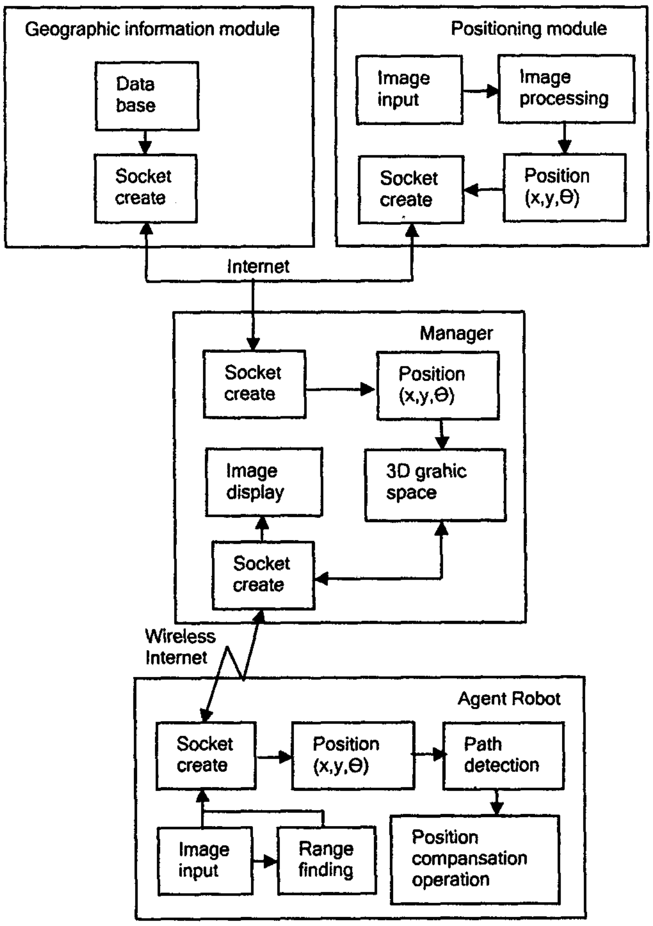

Figure 1. Schematic of 3D GUI system of agent robot

3. 3D GUI system of agent robot

2.1 3D GUI environment

In the initial state, the present terrain and the robot are modeled graphically and located at the 3D graphical space. The manager receives the current position (x, y, θ) of the robot from the positioning module, and gets the geographical information of the surroundings of the robot from the geographic information module. Then, the manager displays models of terrain at the 3D graphic space and describes a robot at the matched position by using OpenGL graphic library. By clicking the 3D GUI states bar, it is possible to watch the surroundings of the robot; enlarge and reduce the size of the models, and translate and rotate the viewing points. The robot has a camera to acquire images for transferring it to the manager, and the user can watches it at the GUI environment. Generally, the 3D GUI has two modes; surveillance and direction modes.

At the surveillance mode, a user can set viewing transformation, projection transformation, and view port transformation for watching the robot at the omni-directional views by the view button of the GUI. This mode is used for monitoring the moving process of the robot.

The direction mode is used for ordering a destination position to the robot. For matching the coordinates of mouse position to the real world coordinates, the view position is located at the top of the center of the robot by setting viewing and view port transformation with an orthographic projection of projection transformation. When a user sets up the position of destination by clicking a mouse at the direction mode, the coordinates are transmitted to the robot. The robot begins to move to the destination.

The agent robot can determine the optimal path using geographical data and get the current position periodically. Therefore, the robot compares the difference between the path and the current position of the robot, and revises the moving operation of the robot.

2.2 Positioning

The positioning module is needed for the detection of the current position of robot. Therefore, we can use various solutions such as GPS(Global Positioning System). In this paper, since the test is fulfilled in the indoor environments, a vision based positioning method is used. A camera is attached at the ceiling and detects the LEDs fixed on the above of the robot. The camera grabs images with optical filter for acquiring the IR image of LEDs from the robot, and the positioning module processes it to get the current position using low-pass filtering and thresholding. The robot has two LEDs, one is larger then the other, and we can calculate the position and orientation of the robot from them. Then, the position data are transferred to the robot and the agent. At the 3D GUI space of the agent, the position of the robot is revised according to the position data.

2.3 Moving of robot

At the moving of the robot, there are two modes; autonomous mode and tele-operation mode. In the case of autonomous mode, the robot compares the difference between the received position (x, y, θ) and the computed path, and compensates the differences. The moving path is obtained from the computation of a optimal path out of the movable regions. The tele-operation mode is used for an emergency state is occurred. The 3D GUI can be changed to the tele-operation mode, and we can control the robot directly by using control buttons and watching the images of real scene.

2.4 Collision avoiding

The robot can detect obstacles using a laser range finder. The laser range finder is designed with a camera and a stripe-light laser, and used triangulation based laser range finding method. In this paper, one camera is used for range finding and monitoring. It means that the acquired image is transferred to the manager for monitoring of robot, and the same image is used for detecting 3D information of the laser range finder. For being used as the sensor, the laser light region is segmented from the color image using a color processing. It is formulated by transforming RGB model to HIS(hue, saturation, intensity) model at the image, and segmenting the red region by threshoding of the hue image. For collision avoiding, the robot detects the depth of the objects located at the front by using the laser range finder periodically. Even though the robot meets unexpected conditions, it can avoide collision and evade pits by using the laser range finder, and can reach the destination.

4. Experimental results

The proposed 3D GUI system and an agent robot are constructed. The agent robot has two motors to change direction and supply driving forces, and PIC16F84 micro controller is used as motor driver. It has an IBM PC as a host computer of the robot and programmed with Visual C++. A range finder using a USB camera and a stripe-light laser is attached at the front part of the robot. The acquired image from the camera is used for transmitting real scene to manager as well as range finding. Two LEDs are attached on the above of the robot for detecting the position of the robot. The manager consists of IBM PC and programmed with Visual C++ and MFC library. A wireless HUB and a wireless LAN are used for communication between manager and agent robot. In the indoor environment, we make-up a terrain for simulation, and its geographical information is modeled at the 3D GUI environment. The positioning module uses an IBM PC and uses Meteor board of Metrox as an image grabber. It has a CCD camera with optical filter for acquiring the image of the LEDs from the robot. Figure 2 shows the computers of the manager and the positioning module. Figure 3 shows the agent robot located at the initial position and the constructed terrain. Figure 4 shows the 3D GUI environment. The left side of 3D GUI environment is the 3D virtual space, and the right-up side of it is image display window showing the moving image of the real scene of the robot. The right-down side has panels for tele-operation mode. Since the screen is set as the direction mode, if we determine a destination position by clicking the mouse, the robot moves to the destination. Figure 5 is an example of monitoring mode of 3D GUI showing an obstacle at the front. Figure 6 shows the operation of positioning module. Figure 6(a) is the acquired image, and Figure 6(b) shows the result of detecting two positions of LEDs meaning the position of the robot. Figure 7(a) is the image of the front part of the robot when an obstacle is appeared, and Figure 7(b) is the result of color processing for detecting the laser light from the image. Figure 8 is the scene of the robot detecting an obstacle, avoiding it, and then moving again to the destination.

5. Conclusions

In this paper a 3D GUI system adopting the concept of mixed reality is proposed for controlling agent robots. First, a system model is designed which consists of agent robot, manager, positioning module, and geometrical information module. At the manager, the 3D GUI environment shows the models of the real terrain and the robot, and a user can direct a job at the virtual environment using a mouse. The robot can receive the current terrain information and the position of it, move to the destination, and solve unexpected situations for itself. When the robot moves, the images of the real scene is transferred to the manager and makes the user watch the real sites. The proposed system is constructed and tested at an indoor environment and shows that it is useful as an interface system of home robot and multi-robot application. For out-door application, the positioning module should be modified as self-positioning techniques like stereo imaging. If the proposed system is tested in real environments and modified properly, it can be applied to home robot, intelligent vehicle, game and industrial application, and military area.

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(a) (b)
Figure 2. The host computers of (a) the manager, and (b) the positioning module

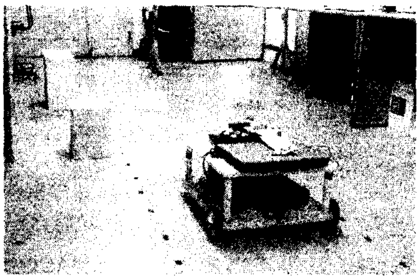


Figure 3. Agent robot and the test environment

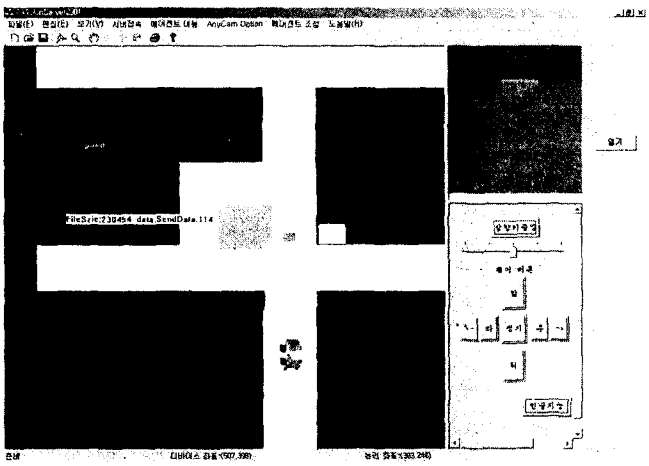


Figure 4 . 3D GUI environment of direction mode

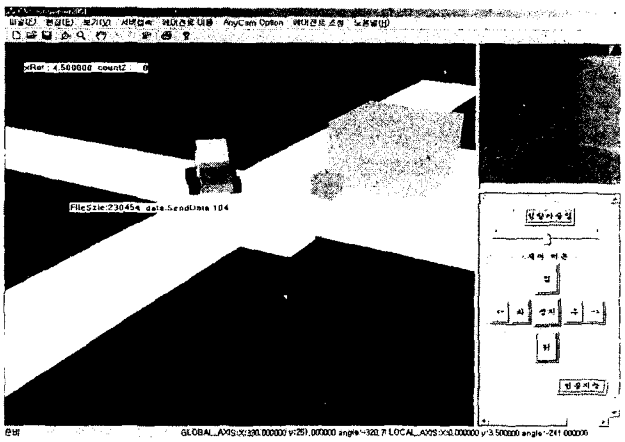
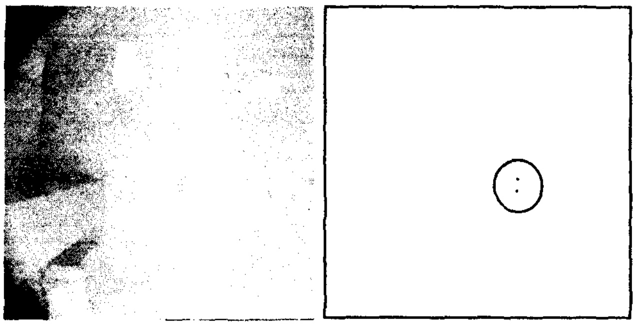
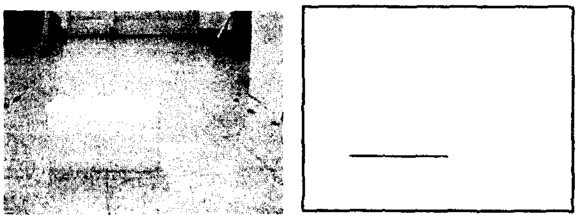


Figure 5. 3D GUI environment of surveillance mode



(a) (b)
Figure 6. The operation of positioning module
(a) The acquired image, (b) The result of detecting two positions of LEDs



(a) (b)
Figure 7. The image of laser range finding
(a) The acquired image, (b) The result of color processing

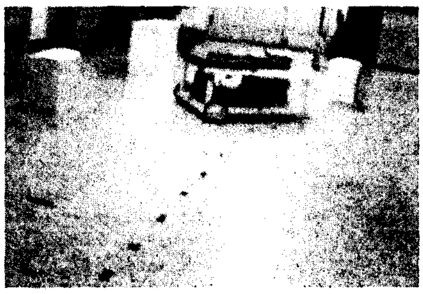


Figure 8. The motion of the robot after avoiding the collision