Proceedings of the Fifth International Conference on Machine Learning and Cybernetics, Dalian, 13-16 August 2006

DESIGN OF THE MENDING ROBOT BASED ON VIRTUAL REALITY AND INTELLIGENT DECISION SYSTEM

FENG CUI, MING-LU ZHANG, BING-QING LIU

School of Mechanical Engineering, Hebei University of Technology, Tianjin 300130, China
E-MAIL: cfpaper@163.com

Abstract:

A semi-autonomous intelligent control system with layered structure for the telerobot is established and described in detail. It is applied in the virtual environment with real scene reappearance and teleoperation functions to plan and control locomotion and trajectory of the virtual robot instead of controlling the real robot directly. The virtual robot autonomously sends every planned motion instruction to the real robot via WLAN (Wireless LAN) in order that these two robots can move synchronously. Because modeling error of the virtual environment and slide phenomena of wheels exist inevitably, the real robot always can not arrived at the desired destination precisely. Here, operators should adjust position and pose of the real robot with remote video and landmarks abidance to eliminate these errors. The virtual environment is made in OpenGL and both the virtual robot animation and the environment simulation are running smoothly. Experiments prove that the intelligent decision platform is reliable and efficient. With intervention of the operator, the mending task can accomplished successfully.

Keywords:

Intelligent decision; Virtual reality; Mending robot; Path planning

1. Introduction

Currently, telerobotic systems have been shown to have an increasing potential for a variety of applications including remote control [1], manufacturing [2], surgery [3], training [4], and education [5]. Especially, telerobotic systems based on virtual reality provide significant benefits in terms of mending the leaking chemical container. The commonest way is to take advantage of virtual reality technology to establish a human-machine interface of teleoperation, then the operator controls the telerobot directly by using a joystick, a mouse or a keyboard [6]. But in this way, operators must have good operation skills and many experiences. Their randomness operation may lead the robot not to work in the optimal scheme or to be damaged. Reference [7] adopts autonomous decision system to instead of operators' directly manipulation. This method is still a challenge in complicated work, because modeling error and cumulating error of locomotion exist inevitably. These factors will reduce forecast precision and cause misoperation. Furthermore, some paroxysmal incidents may occur on the spot. If the system has not preset respond measure, these paroxysmal incidents can not be solved. So, the human-machine cooperation manner is more suitable for teleoperation of the mobile robot.

This paper establishes a work scheme for the mending robot based on virtual reality and intelligent decision system. The intelligent decision system with layered structure plays primary role of teleoperation. It provides efficient motion and trajectory planner for the mending robot. However, the intelligent decision system does not control the mending robot directly but control motion of the virtual robot which is the agent of the mending robot in the virtual environment. Through transmitting telecommands via WLAN, the virtual robot and the real robot move synchronously. But wheels' slip and slide phenomena bring position variance for these two robots, the operator's duty is to judge whether position and pose of these two robots appear variance through observing remote videos and adjust them to keep consistent. Moreover, operators also can directly use the joystick to control locomotion of the real robot without the intelligent decision system. The paper is organized as follows. Section 2 introduces structure of the mending robot. Section 3 describes the layered structure of the intelligent control system in detail. Experimental results are presented in section 4. Finally, section 5 closes the paper with some brief concluding remarks.

2. Structure of the mending robot

The mending robot, shown in Figure 1, in this paper is used to repair the leaky ammonia reactor. It is composed of a mobile vehicle and a five-degree-of-freedom manipulator. This manipulator is composed of five links, and their joints are all rotary pairs. When the vehicle arrives at the

1-4244-0060-0/06/$20.00 ©2006 IEEE

instructed position and adjusts its posture, the leaky container can be repaired by constantly changing the postures of the manipulator. Sixteen ultrasonic sensors are arrayed circlewise on the vehicle to detect and avoid obstacles. Two cameras are on the mobile vehicle to provide online live video display and identify landmarks of the destination. Two cameras are on the manipulator to provide online live video display and image identification. An onboard AP (access point) is responsible for transmitting telecommands and video from cameras of robot to the virtual environment.

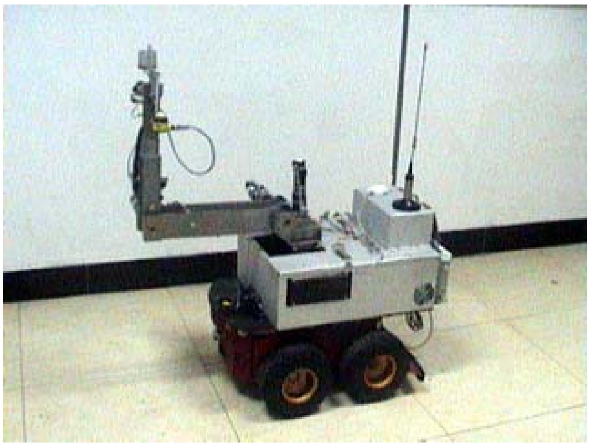

Figure 1. Mending robot

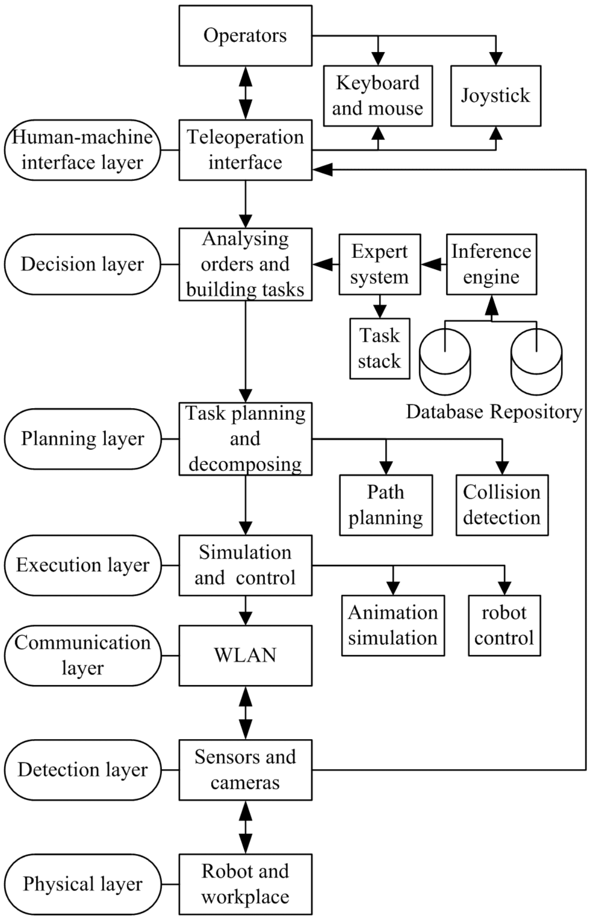

Figure 2. Layered structure of the intelligent control system

3. Layered structure of the intelligent control system

The system adopts layered structure. Its structure is shown in Figure 2. It consists of human-machine interface layer, decision layer, planning layer, execution layer, communication layer, detection layer and physical layer. Thereinto, human-machine interface layer, decision layer, planning layer, execution layer constitute the intelligent decision system. Function of every layer of the intelligent decision system is introduced in the following part respectively.

3.1. Decision layer

Decision layer is responsible for establishing a mending task according to alarm messages from sensors on the spot or operators' commands. First, decision layer analyzes instructions and translates them into discriminating task inside the system. Then, inference engine resolves and decomposes this task according to database and repository. The database has stored decision information, environment information, geometry information of robots and chemical containers, position and shape of leakage, disposal information, and so on. The repository has stored all kind of rules, expert experience and causality. Also, decision layer has an expert system. When multi teleoperation tasks appear, the expert system will arrange these tasks in term of priority and press them into the task stack. The basic principle of priority is that simple aim takes precedence of complex aim, and paroxysmal incident takes precedence of routine incident.

3.2. Planning layer

Planning layer is the key part of controlling the robot. It is mainly used to establish execution plan and scheduling of every task and search suitable inference. According to commands from decision layer, planning layer plans path and detects collision of the robot. Because the robot constitute of a mobile vehicle and a five-degree-of-freedom manipulator, path planning divide into two phases. The A* algorithm is adopted to plan path of the mobile vehicle. Trajectory and pose of the manipulator are reckoned by Matlab program according to the inverse kinematics principle. Figure 3 is the interface of inverse kinematics program. Every joint posture is calculated by choosing the track shape and mechanical structure; the data can be conducted in the calculating process of the direct kinematics to prove the rightness of the inverse kinematics program. In addition, the program has other functions such as data storage and flash demonstration. In order to ensure the security of the robot, two security ways are used. One is that sixteen ultrasonic sensors on the vehicle are used to detect and avoid obstacles all along. The other is that we add collision detection function based on AABB (axis-aligned bounding boxes) in the virtual environment. However, the mending task can hardly be completed if the robot only depends on the path that calculated by the planning layer because of modeling error and wheels' slide phenomena. Operators must participate in adjusting position and pose of the virtual robot and the real robot to keep sameness through observing remote videos. An environment inspector is added in the planning layer. It can display videos from cameras on the robot and on the spot. It helps operators find position difference of two robots easily. Then operators manipulate robots to move synchronously through using a mouse, a keyboard or a joystick. Planning layer also redetermine action of robots at once.

3.3. Execution layer

Execution layer directly controls the virtual robot and the real robot to execute planned locomotion by planning layer. In the control end, execution layer is responsible for simulating locomotion of the real robot. VC++, OpenGL, 3DS MAX are adopted to carry out the virtual environment and the virtual robot. OpenGL has the strong three-dimensional modeling ability and real-time graph interactive operation function. The technology of its double buffer storages makes the three-dimensional cartoon quality as smooth and fine as movies. So it is very suitable for simulation system. The 3DS MAX software is applied in this program to draw scene, the 3ds graph format is produced, which is introduced and read in OpenGL. The digital camera is used to take photos on the spot, and these

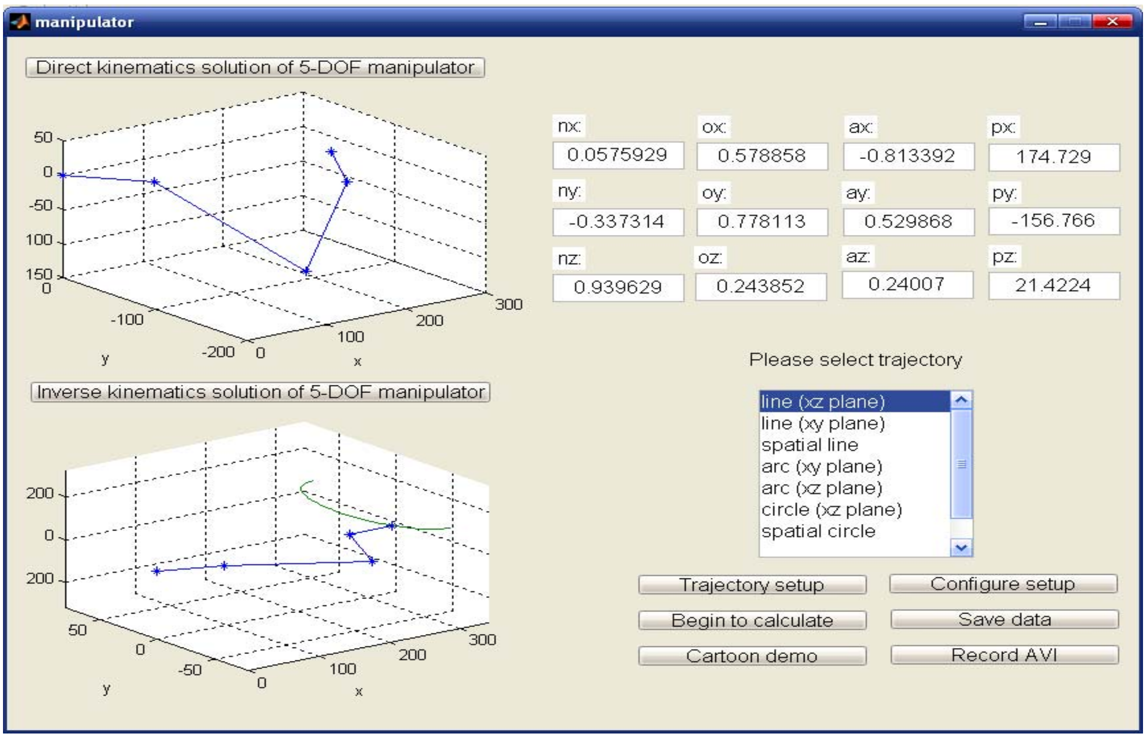

Figure 3. Solution to direct and inverse kinematics problem of manipulator

photos are bound to the model with textures by texturing map. In order to make the scene more vivid, material property and normal vector of each object are setup according to the actual physics character, and the lighting is created to enhance the illuminated effect. The system also provides the function of viewport shifting in order that operators can observe the robot by choosing different view angles.

The system's virtual environment operation interface is shown in Figure 4. The interface includes three areas. Left above is the area of aerial view. The absolute position and moving direction of robot can be shown in this view. Left below displays current rotation angle of every link of the manipulator. Middle is front view. It shows independent locomotion of the virtual robot controlled by intelligent decision system in the virtual environment. Front view and aerial view are refreshed synchronously. Right is the area for the control panel of the robot. It provides some control commands and displays alarm message from which sensor.

To the real robot, execution layer realizes teleoperation to it via WLAN. WLAN of the BSS (Basic Service Set) pattern, shown in Figure 5, is adopted in this paper. Execution layer establishes communication link according to WLAN protocol. WLAN is used to transmit commands from the virtual environment, position information of the real robot, leakage position of ammonia reactor, remote videos from the real robot and workplace, and so on. The bandwidth of this WLAN is 11Mbps, which is wide enough for our communication system and video transmission. But control center is far from the real robot, and several buildings are among them. Common WLAN can not finish data transmitting in such long distance, so we add a high gain antenna and an amplifier to enhance transmitting performance of WLAN. Then, communication distance of this intensive WLAN can be extended to over 30km.

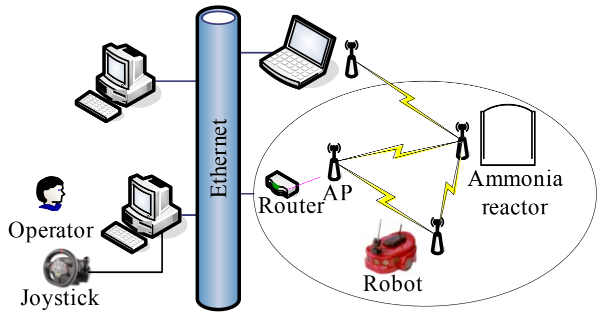

Figure 5. BSS (Basic Service Set) Pattern WLAN

3.4. Detection layer

Detection layer is the external interface of the system to get outside world information. Sensors and cameras on

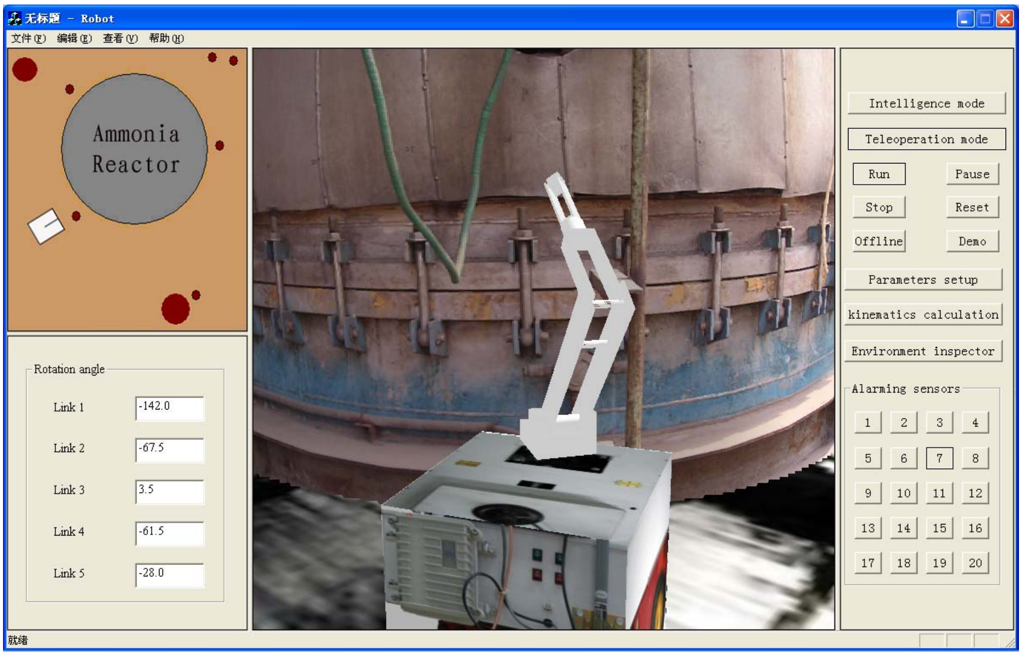

Figure 4. Virtual environment interface

the spot are the major instrument of the detection layer. If operators want to know the scene of the mending process, they can press buttons in the environment inspector interface to connect cameras on the spot or on the robot. Figure 6 shows environment inspector interface. It can show all videos from cameras on the robot and on the spot. Three transmission modules are used in this system. Because of WLAN bandwidth limit, we should avoid opening too many video windows at the same time. One transmission module should be occupied by one camera, so we can open three live video windows synchronously. In Figure 6, the main window embedded in the interface displays video from the camera on the spot, and the other two floating windows display videos from cameras of the manipulator.

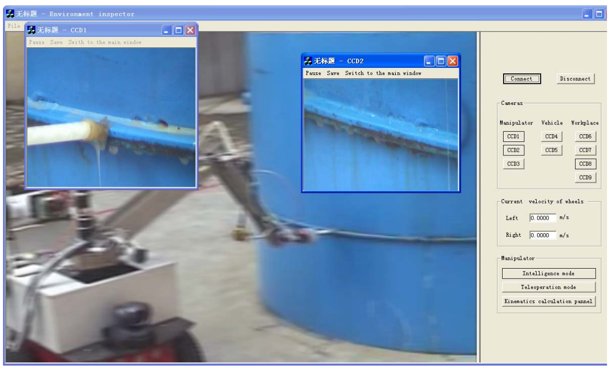

Figure 6. Environment inspector interface

4. Experimental results

We have conducted a great deal of experiments in the workplace. Four cameras are placed on the four corners of it respectively. The operator can switch these four cameras, cameras on the vehicle or cameras on the manipulator to inspect mending process. Because three transmission modules are used, we can open three video windows at the same time. We have conducted teleoperation experiments in the places where are 100m, 1km and 5km away from the real robot respectively. The result of experiments demonstrate that the nearer the distance is, the better video transmission quality is.

Because slide and slip phenomena exist inevitably, the real robot can hardly arrive at the destination accurately. With the operator's adjust, the robot can reach the destination successfully and locate accurately according to landmarks. The real manipulator and the virtual manipulator can move consistently without adjustment. Because video transmission has a little delay, images in the virtual environment always are prior than the remote video several seconds. In the whole process, no collisions happen. Experiments demonstrate that this method has good practicability and security.

5. Conclusions

This paper has proposed an autonomous teleoperation method of the mending robot. Besides above teleoperation function, this method also can be used to the simulation platform of robot's kinematics. We can analyse comprehensively the whole system, observe and experiment the moving conditions and reliability of every part by using the simulation software to simulate the real motion of the robot in the virtual environment. The design deficiency can be found earlier, the best plan can be figured out to produce the physical prototype, thus the designing costs can be reduced greatly.

The system is open architecture and can be used for several purposes including real-time data acquisition and visualization of robots in factory or in other fields with a few amendments, such as dismantling explosives, antiterrorism, and etc. Of course, more research should be done to perfect some aspects in the future, for example, building perfect virtual reality system with head mounted display, tracker and data gloves, adding dynamics analysis function.

Acknowledgements

This work is supported by the National Hi-Tech R&D Program (863) of China (Grant No. 2003AA421040), Tianjin Nature Science Fund (043601811).

References

[1] Kim Sewoong, and Hamel William R, "Design of Supervisory Control Scheme for Fault Tolerant Control of Telerobotic System in Operational Space", IEEE International Conference on Intelligent Robots and Systems, Vol 3, pp. 2803-2808, 2003.

[2] Nof Shimon Y., "Design of effective e-Work: Review of models, tools, and emerging challenges", Production Planning and Control, Vol 14, No. 8, pp. 681-703, December 2003.

[3] Sun Li-Ning, Xie Xiao-Hui, Fu Li-Xin, and Du Zhi-Jiang, "Internet-based telerobotic surgery: Problems and approaches", Journal of Harbin Institute of Technology, Vol 35, No. 2, pp. 129-133, February 2003.

[4] Munasinghe Sudath R., Lee Ju-Jang, Usui Tatsumi, Nakamura Masatoshi, and Egashira Naruto, "Effectiveness of naked-eye vision feedback for training human teleoperators", 2004 5th Asian Control Conference, Vol 2, pp. 1119-1124, 2004.

[5] Rothrock L., Kantamneni S.P., Harvey, C., and Narayanan, S., "A configurable telerobotics system for human factors education and research", International Journal of Modelling and Simulation, Vol 24, No. 4, pp. 239-249, 2004.

[6] Park. J.B., Lee, B.H., and Kim. M.S., "Remote control of a mobile robot using distance-based reflective force", IEEE International Conference on Robotics and Automation, Vol. 3, pp. 3415-3420, 2003.

[7] Hasegawa. Tsutomu, Nakagawa. Kousuke, and Murakami. Kouji, "Toward on-line transition to autonomous teleoperation from master-slave manipulation", IEEE International Conference on Robotics and Automation, Vol. 2004, No. 4, pp. 3715-3720, 2004.