Web based remote mobile robot control

Jaroslav Hanzel
Institute of control and industrial informatics
Faculty of Electrical Engineering and Information Technology
Slovak University of Technology in Bratislava
Bratislava, Slovakia
jaroslav.hanzel@stuba.sk

Abstract—**The paper deals with the internet based robotics. The attention is focused on the proposal and implementation of the experimental web based interface for the remote control of the mobile robot. The proposed system contains visual feedback to assistance the operator for safe navigation of the robot in dynamic environments. The control system utilizes the client - server architecture and is mainly implemented in the platform independent Java programming language.**

Mobile robot; telerobotics; visual feedback control; Human Machine Interface

I. Introduction

With increasing use of the internet, the number of smart devices or systems dedicated to service, safety and entertainment is growing. These are composed of the distributed computer systems with use of the observation cameras, manipulators and mobile robots. As the idea of web robots or web-based robots is relatively new, it draws attention and interest of researchers. In addition to the control in hazardous environments, which are traditional telerobotic operations, internet extends the limits of real robots using robots in the areas known as telemanufacturing, teleeducation, telesurgery as well as a guide to a museum, in traffic control, space research, in the rescue operations during disasters, domestic cleaning or care. Although the internet provides for the teleoperations inexpensive and easily attainable information channel, there are many problems that must be resolved before the successful achievement of its real use. These problems are mainly due to the limited bandwidth and the arbitrarily large transmission delays that significantly affect the performance of telerobotic systems based on the Internet. For these reasons, it is necessary to equip the robot with a high level of autonomous behaviour. An intuitive user interface for operators is required for controlling the robot remotely.

Web based robotics uses a web browser for remote control of the robot and it differs from the traditional teleoperations in several aspects. The delay and throughput of the Internet are highly unpredictable, unlike traditional teleoperations, where the interfaces have known and guaranteed delays. Web based remote controlled robot also needs a high degree of resistance to the loss of the data packets. Web robots are controlled in most cases by people with little expertise and limited experience, unlike traditional tele-robots, which are operated by trained operators, and therefore their behaviour also become an important factor in the system design. Web robots deal with problems of a complex, dynamic environment in terms of the unpredictable delays in the network communication. Therefore their design and execution itself bring many challenges in addressing these problems.

This contribution deals with mobile robot control system via a web interface. The system should include a standard network protocol and interactive Human Machine Interface (HMI). Using a web browser, a remote operator can control a mobile robot with visual feedback over the internet. Using an intuitive user interface allows internet users to control mobile robot and implement useful tasks remotely.

II. System design

Research on remote controlled systems deals with a new generation of network telerobotic systems for real use, such as telemanufacturing [1], teleteaching [8] and telemedicine [7]. These systems combine advanced networking technology with intelligent mobile robots [2], [5], [6]. Modern telerobotic systems should have several properties to enable their efficient and flexible use. Among those there is the requirement of the:

- universal interface for easy integration of different types of robots into the system,
- intuitive user interface and the adequate feedback,
- easy expandability of the system for adding more complex function,
- implementation of the cooperative approaches to solve complex tasks,
- high degree of autonomous robot behaviour and intelligence.

With the rapid growth of the internet, several available communication technologies are implemented in a networked environment. Current internet protocol used by web browsers is the Hypertext Transfer Protocol (HTTP). A Communication Gateway Interface (CGI) is attended to link the external applications with the web server. By means of a Hyper Text

Markup Language (HTML) a requirement from the client to the server to start the process of executing a certain predetermined actions on the server can be specified. Dynamically generated HTML page can return results to the client. On the other hand, CGI has a number of shortcomings such as relatively slow speed of response. It must be also generated a complete HTML page with every client request. So this method of communication is not very suitable for remote control in real time. Contrariwise Java (object oriented programming language) offers the possibility to implement network connections and thus avoid restrictions of the CGI.

The relatively flexible and extensible approach for such tasks is to use a central server architecture [4], as shown in Fig. 1. All clients and servers are connected to a central web server. It is necessary to know the location of the web server and the reciprocal communication with each other through a web server. With this architecture all the video services and robot control services can either be provided for a single computer, or it may be possible to connect multiple computers. It is very easy to add more computers to control the robot and to process the graphical data or for the purpose of the control of more robots.

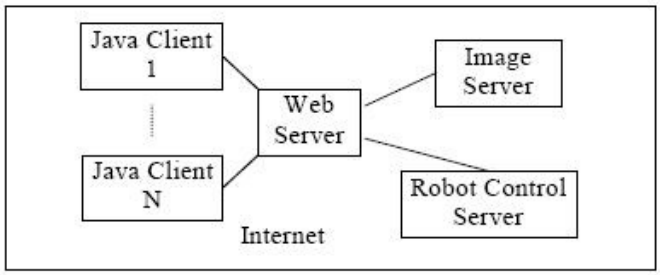

Figure 1. System architecture [4].

III. Hardware and software configuration

When designing the hardware structure of the telerobotic system, it is necessary to consider several factors related to the intended practical use of the system and it is also necessary to take financial possibilities into account. Fig. 2 shows the proposal of a hardware system for the simple remote controlled robot.

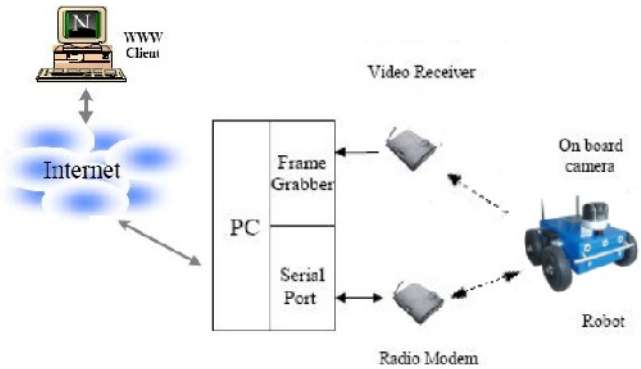

Figure 2. Configuration of the robotic system.

Main host computer communicates with a mobile robot through a radio modem connected to a serial port. The main computer is connected to the network by standard network interface. The front part of the robot is equipped with a camera, that gives the user a clear view of the environment appearing before the robot. The robot can also be equipped with various sensors (eg ultrasonic, laser), which help to provide a more complex sight of the robot working environment. Video signal from the camera located on the robot is captured by the frame grabber of the main computer and it is sent to the client.

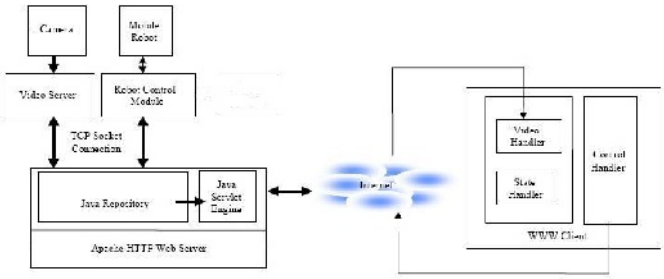

Figure 3. Software architecture.

As a web server the application Apache HTTP web server working on multiple platforms such as MS Windows or Linux is used. The entire software system consists of several independent modules for optional services, each of which contains a server-side program and client-side Java applets. Java servlet in the Apache web server handles the communication between clients and servers, as shown in Fig. 3.

IV. Control and visual module of the system

Operating of the mobile robot is performed by the robot control module. In the primary stage of the implementation of the control module, certain basic functions such as the controls for the movement, change of the speed and stop function are inserted. More intelligent forms of the behaviour are possible to integrate afterwards.

When the system begins to function, the Java program will run and accepts commands sent from the client and controls the movement of the mobile robot by the radio modem connected to the serial port. The robot can be controlled at the same time only by one user and other users have to wait in a queue until the current operation is completed. At the same time the program sends the information from the robot, such as the ultrasonic sensor data and state of the robot, to the clients. In order to reduce transmission time, any information is transmitted in the form of the character strings and sent to all clients connected to the server. These strings are interpreted and displayed on the client side.

A key element of the mobile robot remote control is an image from a camera placed on the robot transmitted to the client side. The image quality and speed of transmission should be sufficient to provide maximum information in real time for the safe and efficient remote robot control. Number of projects dealing with the transfer of images via web are using server push technology. The video is composed from a stream of static images sent by the Java program via sockets to the Java applets. In this system, the images captured from the frame

grabber are compressed into JPEG format by the software implemented in C++. Subsequently these images are sent from the image server to the web server. Java program streams these JPEG images to all clients connected to this web server. On the client side Java applet restores the image after its receiving.

V. Web interface

Simple user interface is designed to provide basic information necessary for safe remote control of the mobile robot and it also provides the necessary basic controls. The user interface may consist of several Java applets, as shown in Fig. 4.

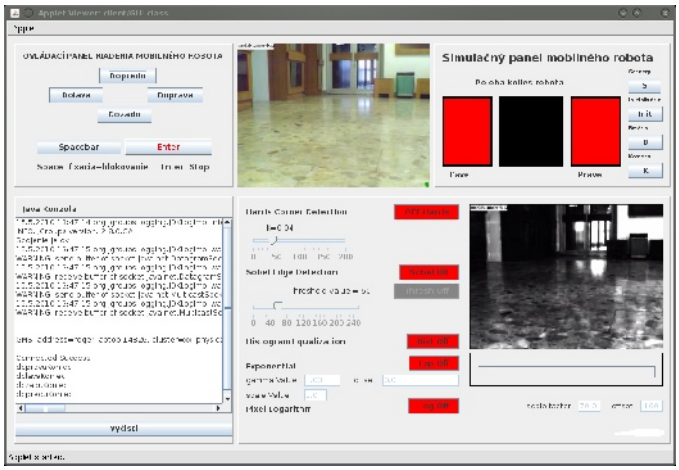

Figure 4. Implementation of the web interface.

On-line instructions for the robot are processed by the control panel, which may be formed in the basic version of the four directional buttons. The user can directly control the mobile robot by clicking on the direction buttons on the control panel, or by use of the keyboard for fast and complex control, such as change or adjust the chosen speed, or eventually by input of the coordinates of the target. The image display applet shows a visual feedback in form of the continuous stream of JPEG images. The virtual environment applet can show some basic information about the mobile robot and workspace, and analyse the feedback information from the mobile robot for example in the form of an environment map. Users can monitor for example the obstacles near the robot, the travelled path and current position and speed of mobile robot. The active user can control the movement of mobile robot through interface with visual feedback. Other users can only track the visual and sensory feedback and they have to wait until the first user logs off the network to control the robot.

VI. Application practice

The experimental remote control system is intended to gain the practical experiences with telerobotic systems and to find effective approach for implementation of systems capable of operation in the environment of public network. The aim of the implementation was to prove the correctness of the proposition. The system is presently actively developed and there is a strong requirement for searching of its optimal structure and experimenting with its final solution. Though, the initial testing experiments in the local network afford opportunity to control the robot in loopback with small enough delays and with sufficiently fast video refresh rate.

Properly designed telerobotic system can be successfully utilized in the education process how it exemplifies the similar telerobotic system [3]. The proposed telerobotic system was primarily dedicated for an inspection robot designated for exploration of unknown environments. Although the system is still in development stage, in the future, after some minor changes, it can be applicable also in the process of education. With the use of this telerobotic system, students can obtain the beneficial experiences with teleoperations and telepresence.

VII. Conclusion

The aim of the paper is to analyse the options and outline a possible structure and implementation for an experimental network telerobotic system for internet users, who can control a mobile robot in dynamic environment remotely from their home. The system allows internet users to control the mobile robot with utilization of the data obtained by the robot sensory system using a web browser. On the client side the obtained information is processed in order to encourage operator to safely control the robot. The visual feedback module provides fast image updates and presents a relatively credible real time visual information for the web users.

Acknowledgment

The work has been supported by grant VMSP-P-0004-09 “Inteligentné riadenie servisného robota”. This support is very gratefully acknowledged.

References

[1] M. J. Bailey, “Tele-Manufacturing: Rapid Prototyping on the Internet,” IEEE Computer Graphics and Applications, vol. 15, no. 6, pp. 20-26, Nov. 1995.

[2] W. Burgard, et. al., “The interactive museum tour-guide robot, Proceedings of the fifteenth national/tenth conference on Artificial intelligence/Innovative applications of artificial intelligence,” Madison, Wisconsin, United States, pp. 11 – 18, 1998, ISBN:0-262-51098-7.

[3] P. Petrovič, A. Lúčny, R. Balogh, D. Ďurina, "Remotely-Accessible Robotics Laoboratory", Acta Mechanica Slovaca., June, 2006. Vol. 10(2-A), pp. 389-194.

[4] A. Sayouti, F. Qrichi Aniba, H. Medromi, “Control Architecture design for a Mobile Robot via the Internet,” 9th International PhD Workshop on Systems and Control: Young Generation Viewpoint, 1. - 3. October 2008, Izola, Slovenia.

[5] D. Schulz, W. Burgard, A. B. Cremers, “Predictive simulation of autonomous robots for tele-operation systems using the world wide web,” in IEEE/RSJ International Conference on Intelligent Robots and System, Victoria, B.C., Canada, October 1998.

[6] R. Simmons, “Xavier : An autonomous mobile robot on the web,” in International Workshop On Intelligent Robots and Systems (IROS), Victoria, Canada, 1998.

[7] D. Wright, L. Androuchko, “Telemedicine and developing countries,” J Telemed Telecare, 1996, 2(2), pp. 63-70.

[8] S. Yuanchun, et. al, “The smart classroom: merging technologies for seamless tele-education,” Pervasive Computing IEEE, April-June 2003, vol. 2, iss. 2, pp. 47 – 55, ISSN: 1536-1268.