Web Based Remote Surveillance of Mobile Robot

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Abstract

This work addresses visual remote surveillance through the World Wide Web. A mobile robot built at the RISC lab is controlled via the Internet with the help of images obtained from a network camera. The user specifies the desired position by utilizing the real time web based visual interface. The autonomous robot moves to that location avoiding obstacles.

Keywords: Autonomous mobile robot, web-based, visual surveillance

1 Introduction

The RISC team at University of Bridgeport has developed a WWW based wireless robot for remote applications. The mobile robot "UBROBO" allows remote control over the Internet using a Java-enabled web browser. A network camera installed in the lab provides real time feedback to the user regarding the robot's position.

A variety of web based remote control interfaces for robots has been developed over the last few years. Xavier [1] can be advised by Web users to move to an office and to tell a joke. Rhino [3] and Minerva [2] were deployed as interactive museum tour guide and could be operated over the web. The robots mentioned above operate in known environments with pre-stored map during their navigation. UBROBO can operate in unknown environments provided a camera is installed in the area of operation.

2 System Architecture

The server hardware in the system architecture shown in figure 1 is a Pentium based PC with Windows 2000 Professional, running the web server with JSP support. It is composed of three major modes: a web interface, a wireless interface and a remote robot (UBROBO) (figure 2). A user logged on to the web server can observe the robot's current location with the images obtained by a network camera installed in the lab. The network camera (AXIS) is installed on the ceiling of the robotics lab, facing the floor to provide the user with a top view of the lab (figure 3). To command the robot, the user clicks on the desired location visible on the image. As soon as the user clicks, the web server transmits the desired coordinates to the robot via the wireless link. Once the robot receives the command, it moves to the desired location avoiding all obstacles on the way. A camera temporarily installed on the robot transmits the images to the web server (figure 4).

3 UBROBO Architecture

3.1 Hardware Structure

The physical structure of UBROBO can be seen in the

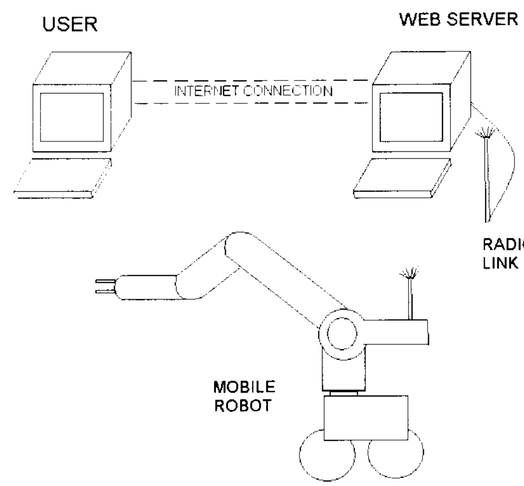

Figure 1 System Configuration

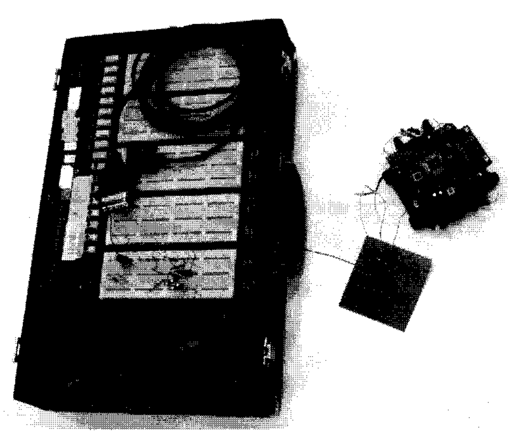

Figure 2 System Overview, with wireless interface on the left, UBROBO on the right

images shown in figure 5-8. UBROBO is equipped with ATM 103 MCU, 4 sets of infrared sensors and emitters for object detection and avoidance, 2 sets of infrared sensors and emitters for wheel encoding, a PC video camera (LEGO) and a RF transceiver for wireless connectivity with the web server. Differential drive mechanism has been adopted for locomotion. The robot is powered by two 5V DC shunt motors. To maintain balance, pivots are placed on the four corners of the robot. The wheels have horizontal projections at the edge of the rim. These projections are used by an infrared emitter and a sensor for the purpose of encoding. The PC video camera is placed on top of the rectangular frame of the body in the front portion. For the purpose of obstacle avoidance, two sets of infrared emitters and sensors are placed on the front (left and right corner), one set on the left side and one on the right side. The entire unit is powered by a 6V battery.

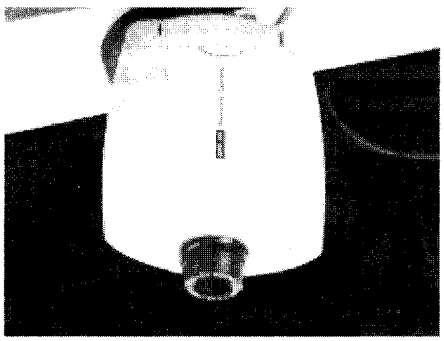

Figure 3 Overhead network camera installed in the lab

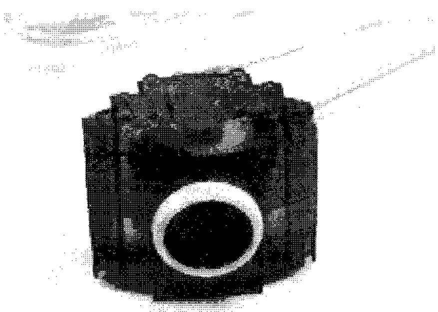

Figure 4 Lego camera used temporarily to record UBROBO activities from the robot's view

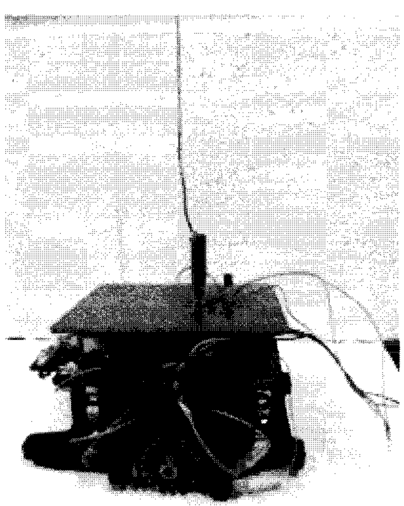

Figure 5 UBROBO side view

3.2 Embedded Software in MCU

ATMEL's ATM 103 is used as the central control unit of UBROBO. The embedded software in the MCU can be divided into the modules shown in Figure 9.

3.2.1 Obstacle Avoidance Module

The sensors are located in such a way that the robot avoids all obstacles in its motion. Since the infrared sensors are sensitive to color, the obstacles are so selected such that there are no wide variations in color. Whenever an obstacle

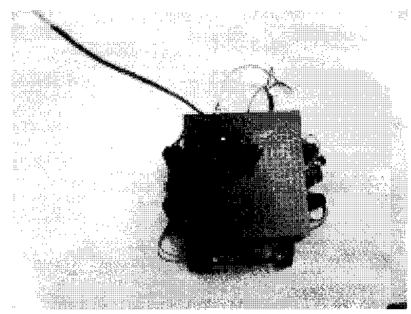

Figure 6 UBROBO top view

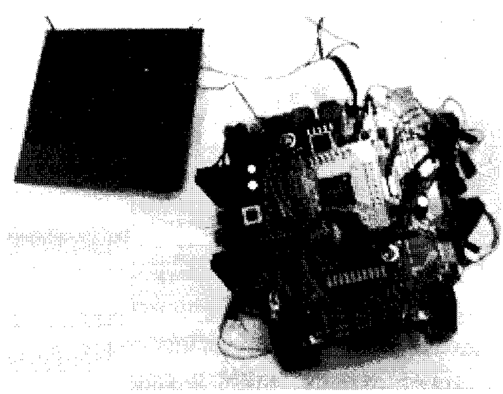

Figure 7 UBROBO and wireless link connectivity

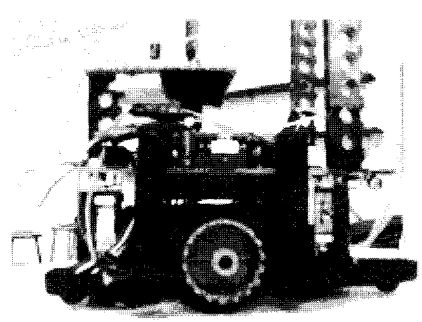

Figure 8 Encoders of the wheel

is detected by the left front sensor, the robot moves to the right side till that the left side sensor can no longer detect the obstacle. A reverse sequence of actions is performed when the right front sensor detects an obstacle. If both the left and right front sensors detect an obstacle, the robot performs a left turn. The obstacle avoidance module signals to the navigation module whenever an obstacle is detected.

3.2.2 Navigation Module

The Navigation module operates on data obtained from encoders, obstacle avoidance module, and the desired goal position coordinates sent from the web server. To make inverse kinematics as simple as possible, the robot always tries to maintain a straight-line path. The goal position coordinates are converted into the following parameters:

1)Angle: the angle that the robot has to rotate

2)Distance: the direct distance between the initial position and final position

Navigation is carried out in a straight-line path until an obstacle is detected. The trajectory of the robot around the obstacle is recorded till the obstacle is cleared .The goal position is recomputed from the new position of the robot.

3.2.3 Motor Control Module

To maintain a straight path, both wheels have to be driven at the same speed. The robot fails to maintain a straight path even if there are minor changes in the speeds of the two wheels. The motor control module operates on feedback from the encoders to adjust for the differences in speed.

4 Wireless Link Interface

Radio communication is based on Linx RF receiver module RXM 433 LCS installed on the robot (figure 10, 11) and transmitter module TXM 433 LCR installed on a breadboard (figure 12, 13). It is interfaced with the MAX 232 level converter (figure 14). The data is transmitted serially from the PC to the robot at a baud rate of 2400 bps.

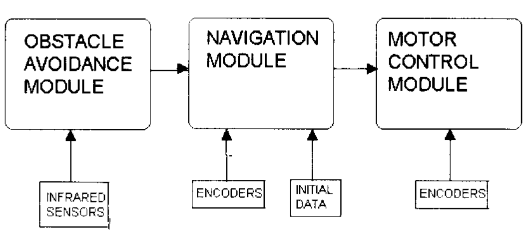

Figure 9 System Architecture of Embedded Software in MCU

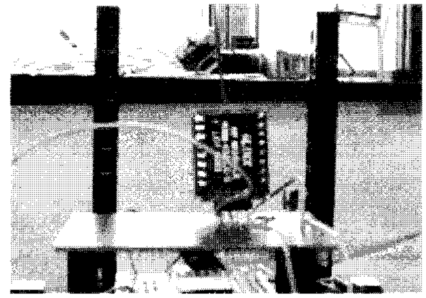

Figure 10 Linx RF receiver module RXM 433 LCS installed on the robot

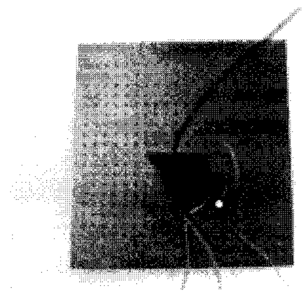

Figure 11 RF receiver top view

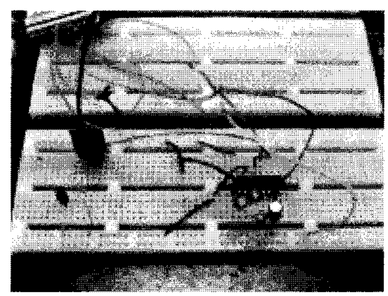

Figure 12 Interface overview between Max232 and TXM433 LCR based on breadboard

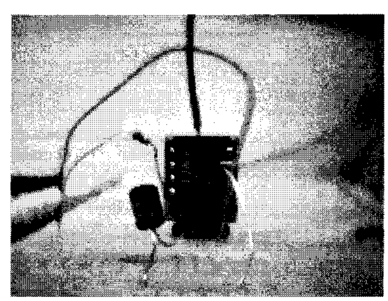

Figure 13 Transmitter module TXM 433 LCR installed on a breadboard

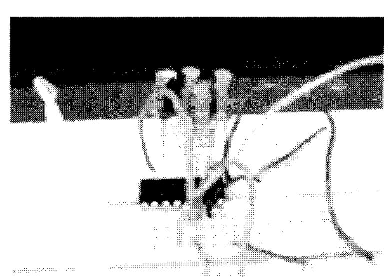

Figure 14 Max232 level converter

5 Web Interface

The web interface has been developed with Java Server Page Technology, Servlet and Java(tm) Communications API. Java Communications API contains support for the RS232 serial ports and performs asynchronous I/O with its updated functionality. The web interface is the frond end that interacts with the user, and enables the user to control the wireless robot. Through Servlet, the Java Communications API communicates with the serial port, which connects with the Wireless Link Interface, as shown in Figure 15.

6 Results

This section includes results from a robot web control sample. First, the user logs on to our web server using the username "guest" and password "demo", as shown in figure 16. Second, the user clicks on the image with the robot and watch the robot moves to the desired clicking point with live video. Updates on the web services and server availability information will be posted under www.bridgeport.edu/~beiwang/paper2/. There are several video clips available on the website which shows the robot in action, while avoiding obstacles along the path. There is also a video clip available which shows the actual control process on the web interface.

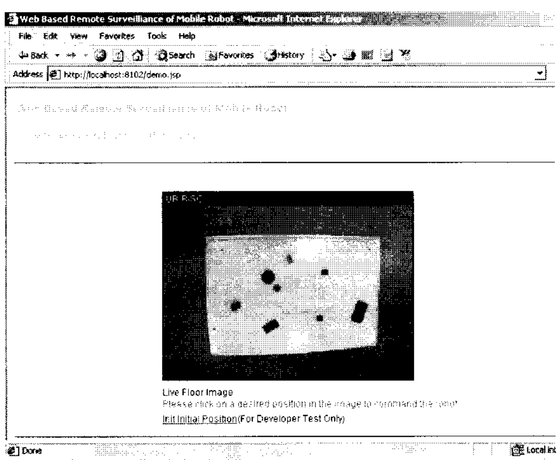

Figure 15 Web interface to command mobile robot. Robot is shown avoiding obstacles along the path.

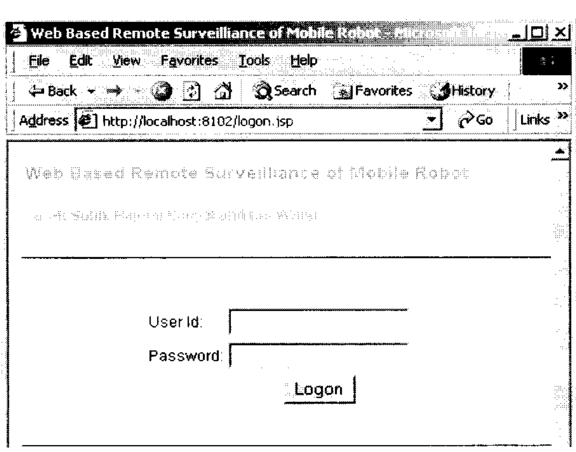

Figure 16 User login web interface

Positional errors have been observed during the operation of the robot. These are primarily due to the low pulse rate of the encoders (32 per revolution). To minimize the positional errors being accumulated, the robot has to be manually reset to the default position and orientation after 10 operations. Positional errors are also due to jerky motion during running. By reducing the running speed of the motors, these errors can be minimized.

7 Future work

Future work to be performed on the robot includes:

1)Adding a suitable RF transceiver for the LEGO CAM.
2)Installing better encoders to reduce positional errors.
3)Adding a module on the embedded software in the MCU, this will manage smooth starting and stopping of the motors.
4)Enabling multiple web users.

8 Conclusion

We have developed an experimental architecture for web-based control of an autonomous robot. The autonomous robot provides further proof that "autonomy mitigates the effects of low bandwidth and unreliable communication" [1]. We conclude that the web interface has made the human interaction with the robot more convenient and flexible. We see a significant potential in expanding this research to similar remote control applications.

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Biographies

Tarek M. Sobh, Ph.D., P.E. Professor Tarek M. Sobh received the Ph.D. and M.S. degrees in Computer and Information Science from the School of Engineering, University of Pennsylvania in 1991 and 1989, respectively, and the B.Sc. in Engineering degree with honors in Computer Science and Automatic Control from the Faculty of Engineering, Alexandria University, in 1988. He is currently the Dean of the School of Engineering at the University of Bridgeport, Connecticut; the Founding Director of the Interdisciplinary Robotics, Intelligent Sensing, and Control (RISC) laboratory and a Professor of Computer Science, Computer Engineering, Mechanical Engineering and Electrical Engineering.

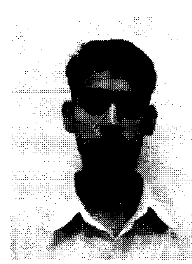
He was the Interim Chairman of Computer Science and Computer Engineering and the Director of External Engineering Programs at the University of Bridgeport. He was an Associate Professor of Computer Science and Computer Engineering at the University of Bridgeport from 1995 -- 1999, a Research Assistant Professor of Computer Science at the Department of Computer Science, University of Utah from 1992 -- 1995, and a Research Fellow at the General Robotics and Active Sensory Perception (GRASP) Laboratory of the University of Pennsylvania from 1989 -- 1991. He was the Chairman of the Discrete Event and Hybrid Systems Technical Committee of the IEEE Robotics and Automation Society from 1992- 1999, and the Chairman of the Prototyping Technical Committee of the IEEE Robotics and Automation Society from 1999-2001. His background is in the fields of computer science and engineering, control theory, robotics, automation, manufacturing, AI, computer vision and signal processing.

Dr. Sobh current research interests include reverse engineering and industrial inspection, CAD/CAM, active sensing/imaging under uncertainty, robots and electromechanical systems prototyping, sensor-based distributed control schemes, unifying tolerances across sensing, design, and manufacturing, hybrid and discrete event control, modeling, and applications, and mobile robotic manipulation. He has published over 100 journal and conference papers, and book chapters in these and other areas. Dr. Sobh edited or co-edited issues of several international research Journals in these areas. He has been on the program committees of several international conferences and has chaired and organized several conferences, sessions, workshops, and tracks in Robotics, Automation, and Sensing meetings and has made many presentations, invited talks, invited lectures and colloquia, seminars, and panel participations, at research meetings, University departments, research centers, and companies.

Dr. Sobh is active in consulting and providing service to many industrial organizations and companies. He has consulted for many companies in the U.S., Switzerland, India, Malaysia, Dubai, and Egypt, to support projects in robotics, automation, manufacturing, sensing, numerical analysis, and control. He has also worked at Philips Laboratories in New York, and a number of companies in Egypt.

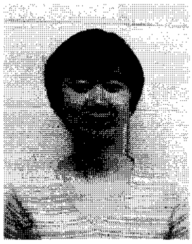
Dr. Sobh has been awarded many grants to pursue his work in robotics, automation, manufacturing, and sensing. Dr. Sobh is a Licensed Professional Electrical Engineer (P.E.), a Certified Manufacturing Engineer (CMfgE) by the Society of Manufacturing Engineers, a Certified Professional Manager (C.M.) by the Institute of Certified Professional Managers at James Madison University, a Certified Reliability Engineer (C.R.E.) by the American Society for Quality Control, a member of Tau Beta Pi (The Engineering Honor Society), Sigma Xi (The Scientific Research Society), Phi Beta Delta (The International Honor Society), and Upsilon Pi Epsilon (The Computing Honor Society). Dr. Sobh was the recipient of the Best Research Award by the World Automation Congress in 1998.

Dr. Sobh is a member or senior member of several professional organizations including; ACM, IEEE, IEEE Computer Society, IEEE Robotics and Automation Society, IEEE Computer Society Technical Committee on Pattern Analysis and Machine Intelligence (PAMI), the International Society for Optical Engineering (SPIE), the National Society of Professional Engineers (NSPE), the New York Academy of Sciences, the American Society of Engineering Education (ASEE), the American Society of Quality (ASQ), the American Association for the Advancement of Science (AAAS), Society of Manufacturing Engineers (SME), and a founding member of the Society for Industrial Computing.



Rajeev Sanyal Rajeev Sanyal completed his B.E. in Electrical Engineering from Mumbai University, India. He is currently pursuing his Master's degree in Electrical Engineering at the University of Bridgeport and working as a Research Assistant at the RISC lab.

Rajeev Sanyal's major research interests are speech recognition, artificial intelligence, mobile robotics, and machine perception.



Bei Wang Bei Wang is a senior at University of Bridgeport, pursuing a B.S in computer science and a B.S. in mathematics. She is a member of IEEE, ACM, Phi Kappa Phi (The Honor Society) and Upsilon Pi Epsilon (The Computing Honor Society). She is also the president of Upsilon Pi Epsilon university chapter and Vice-president of Phi Kappa Phi university chapter.

Bei Wang is a 2002 Upsilon Pi Epsilon Microsoft Scholarship Award recipient and 2002 Sigma Xi Grant-in-Aid of Research Recipient. She also receives Full tuition Academic Scholarship from University of Bridgeport. She is nominated for inclusion in the 2003 edition of WHO'S WHO AMONG STUDENTS IN AMERICAN UNIVERSITIES AND COLLEGES.

Bei Wang's major research interests are Artificial Intelligence/Robotics, Computational Biology and Algorithm Research.