REMOTE HUMAN-ROBOT COOPERATION VIA INTERNET USING WEBOS-BASED TOUCH INTERFACE

Igor Belousov
Technology Solutions Group, Hewlett-Packard, 16A, Bld. 3, Leningradskoe Shosse, Moscow, Russia

Keywords: Human-robot interface, Web-based robotics, Dynamic environments, HP webOS open mobile platform.

Abstract: We consider at this paper the complicated task when the robot manipulator is controlled remotely via the World Wide Web and has to catch the moving object. The robot working environment is non-structured and dynamic. Neither classical teleoperation nor pure robot programming could solve the task of grasping the moving object in such a case. We used the shared autonomy approach to implement the capture task. The operator plans the capture at high level, and the capture is implemented by the robot using vision system. Human-Robot Interface is based on HP webOS Open Mobile Platform using HP Pre or HP TouchPad (tablet computer) as the operator consoles. Using the touch-based control interface and real-time 3D models of the remote robot and working environment make the grasping operation effective, reliable and simple.

1 INTRODUCTION

Achievements at Web-based robot control open new promising application areas for robotic technologies. Web-based tele-maintenance in the industrial settings (Lou and Lee, 1999), tele-surgery (Hannaford, 2008), remote robot control in hazardous environments (Hamel, 2001), remote education in robotics and mechatronics (Tzafestas, 2009) can be mentioned as the examples.

Internet itself is the ideal but challenging environment for experimentation and testing wide class of robotic systems such as teleoperated and distributed systems (Nuno, Basanez and Prado, 2009), networked robots, haptic interfaces. Internet provides natural and mature technology for remote experimentations, but challenges the researchers by such complications as limited bandwidth, unpredictable and variable time delays, losses of data packages, security problems.

To address the issues imposed by Internet we have developed several VR-based methods for effective robot teleoperation (Belousov, 2007). It comprises: (1) an environment for off-line and on-line remote robot programming via the Internet (Belousov and Clapworthy, 2002), and (2) a Java3D-based on-line dynamic virtual representation of the remote robot and its working area (Tan, Clapworthy and Belousov, 2004). These methods allow the time delays inherent in IP networks to be suppressed, and the operator's work to be simplified and accelerated.

Systems for control of the PUMA 560 and CRS A465 manipulators and mobile robot Nomadic XR4000 via the Internet have been developed. Systems were successfully tested under real Internet conditions from different locations in Russia, England, France, South Korea.

Robot teleoperation via the Internet is difficult task due to above mentioned reasons. But it rises to a higher level of complexity when we consider the interaction not only with fixed but also with moving objects. Such dynamic environments are quite difficult to cope with, but at the same time are the most important from practical point of view because the real world systems and environments are dynamic, changing and unstructured.

Due to complexity of this task there are just few articles addressing the problem. In (Kikuchi, Takeo and Kosuge, 1998) the authors used bilateral teleoperation subsystem to grasp a moving object. They considered several conditions limiting the scope of the approach – only 2D motion of the object, permanent and slow speed of the object to grasp, and constant and small time delays.

More general approach was presented in (Belousov, Sazonov and Chebukov, 2005). The Web-based robotic system presented was able to grasp a fast moving object performing arbitrary 3D motion in unstructured environment. Vision system

Belousov I..
REMOTE HUMAN-ROBOT COOPERATION VIA INTERNET USING WEBOS-BASED TOUCH INTERFACE.
DOI: 10.5220/0003649403410344
In *Proceedings of the 8th International Conference on Informatics in Control, Automation and Robotics* (ICINCO-2011), pages 341-344
ISBN: 978-989-8425-75-1

and dynamic model of the object motion were used to define and to predict the motion, and to perform the grasping under supervision by human operator. This approach allowed to develop sophisticated algorithms for collision avoidance for the complex robotic systems such as large space manipulators (Belousov, Esteves, Laumond and Ferre, 2005) and humanoid robots (Yoshida, Esteves, Belousov, Laumond, Sakaguchi and Yokoi, 2008).

The main focus of the current work is improvement of the system for Web-based robot control in dynamic environment via the enhancement of human-robot interaction using the touch-based interface. It is based on HP webOS Open Mobile Platform. The use of the touch-based control interface and real-time 3D models of the remote robot and working environment allows the implementation of the grasping operation in natural way. The operator plans the capture at high level choosing for the robot the intermediate and final goals (clicking on desired positions by a finger at the touch screen with 3D scene model), and the capture robot performs automatically.

Robot manipulator PUMA 560 was used at these experiments (Fig. 1).

Figure 1: Robot Manipulator PUMA 560. Grasping the Rod on Bifilar Suspension.

At the chapter 2 shared autonomy approach for the task of grasping the moving object is presented. Third chapter contains description of the system architecture, data flows as well as touch-based interface and HP webOS platform used. Experiments undertaken are presented at the forth chapter. Chapter 5 concludes the article and describes the future system development.

2 SHARED AUTONOMY APPROACH FOR HUMAN-ROBOT INTERACTION IN DYNAMIC ENVIRONMENTS

We consider at this paper the complicated task when the robot manipulator is controlled remotely via the World Wide Web and has to catch the fast moving object. The robot working environment is non-structured and dynamic. Neither classical teleoperation nor pure robot programming could solve the task of grasping the moving object in such a frame. We used the shared autonomy approach to implement the capture task, i.e. the scenario when actions of the human operator and the robot are shared – operator (client side of the system) implements the high-level planning and the robot (remote or server side of the system) performs the requested operations with high precision and accuracy. Such a sharing allowed solving a complicated task of capturing the fast objects which move under the action of natural forces, and the initial conditions of the motion can be arbitrary. Maximum object speed in our experiments was over 1.5 m/sec.

The object used was a rod on a bifilar suspension (Fig. 1). The upper ends of the threads are attached to a fixed beam. The rod can perform complicated free motion in 3 modes.

The vision system (VS) contains two TV cameras placed above the scene and at the side to ensure sufficient visual data to determine the parameters of the real motion of the objects.

The VS determines the coordinates, in the image, of some characteristic points on the object, relative to the camera reference frame. The use of fast image-processing algorithms allows up to 30 sets of measurements per second to be obtained. The data are collected during a time interval and are subjected to statistical processing, taking into account the mathematical model of the object motion. This gives the initial conditions of the motion of the object and allows the motion to be predicted for several seconds ahead. The result of the prediction is the precise time and the required position of the robot at which the desired operation with the object should be performed.

3 SYSTEM ARCHITECTURE

In the last few years Web technologies demonstrated the significant evolution. The most important trends are standardisation based on HTML5 and CSS, revolutionary improvements (run-time speed, standartisation, cross-platform support) of Javascript, move of the technology to mobile/ personal world with such amazing options as 3G/4G fast Internet connection everywhere anytime and touch-based interfaces on tablets and smartphones. We decided to use all these advances and to develop next generation of the system for Web-based robot control in dynamic environment using these technologies.

HP webOS – open Linux-based operating system for mobile devices, - has been chosen (Allen, 2009). It uses standard HTML5, CSS and Javascript for applications development and provides good opportunities for developers of remote teleoperated robotics systems. Open operating systems with real-time possibilities are extremely important for developing robot control systems (Manchini and Frontoni, 2009) and HP webOS is a good choice for remote robot control from the mobile devices.

Other advantage of webOS is in its native multitasking. The user experience is optimized for launching and managing multiple applications at once. HP webOS is designed around multitasking and makes it simple to run background applications, to switch between applications, and to easily handle interruptions and events (Zammetti, 2009). These features were used for the development of the client part of the system.

The system contains 3 main parts – robot, server and client. The robot part consists of the robot manipulator and the robot controller. The server part contains the server computer and TV cameras. We have used Palm Pre smartphones and HP TouchPad tablet as the client control devices. All the client software is realised with open technologies javascript and OpenGL ES. We used HP webOS SDK 2.1 (Pre 2), and SDK 3.0 for TouchPad.

The robot controller was connected to the server computer via RS232 serial interface. Communication between the server and client parts was performed using TCP/IP packages.

The software of the robot part of the system provides communication with the server part (bi-directional data exchange) and control of the robot itself. It has been realised using VAL-type language.

The server part of the system contains the software modules for the data exchange with both the robot and the client parts, and a module for TV-image processing.

The software of the client part consists of modules for communication with the server, a module for robot control, and the modules for visualisation of the robot and working environment – 3D graphic representation and TV images.

Important part of the client side is a human-robot interface. The functional description is presented at Chapter 4, but here it is important to emphasize that it is build using HP webOS UI and provides rich touch-based user experience in a simple and logical way. It supports multi-touch and multiple gestures such as tapping, flicking, swipe, dragging, scrolling and others. This makes operator’s work comfortable and natural.

4 EXPERIMENTS

We tested the above algorithms and control environment to grasp the rod by the PUMA manipulator when operator was located far away from the robot and controlled it via the low-bandwidth Internet connection.

At the start of the control program, the rod is placed in the equilibrium position. A remote operator can define the initial motion of the rod by choosing in the on-line webOS-based Virtual Environment (VE) any point on the rod surface picking the point with the finger; robot hits that point with a random speed to provide random character of the oscillations. Operator observes the rod motion in the VE and chooses in the VE the desired grasping point and instant to begin the grasping operation. Chosen values are transmitted to the sever (i.e. robot) site and control program automatically: 1) predicts the capture instant and position of the manipulator gripper for that time, 2) controls the capture, 3) checks the capture implementation, and 4) decides to repeat capture in the event of failure. Operator continues to observe the rod oscillations and grasping process in VE and can stop the control program and re-plan grasping scenario if needed.

Operator used HP Pre 2/3 webOS-based smartphones and HP TouchPad to control the remote robot and the control interface is presented at Fig. 2. Window with 3D models of the robot and the environment is located at the right-hand side of the picture. Since only several numbers should be transmitted from the server to visualise the rod, scene redraw was performed almost at real time scale even for a low bandwidth connection. Components of the robot control interface are placed at the left-hand part of the picture.

System has been tested from different remote locations and proved to be an efficient and reliable – grasping was performed in 100% cases.

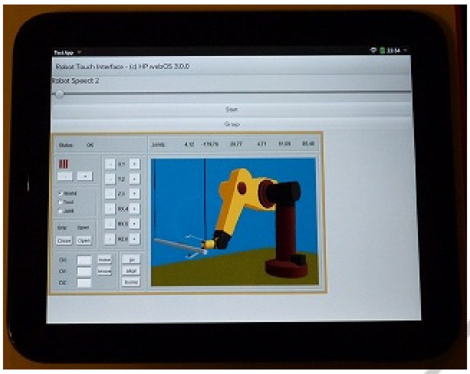

Figure 2: Operator's Control Interface on HP TouchPad as the control device.

5 CONCLUSIONS

Complicated task of grasping the moving object by a robot manipulator when controlling the robot via the Internet has been solved. Use of the shared autonomy approach (when operator forms initial motion of the rod and plans grasping operation, and robot performs final operation automatically) allowed to suppress communication delay, and also to use in appropriate proportion operator's skills in planning high-level operations and robot accuracy.

HP webOS-based HP Pre 2/Pre 3 smartphones and TouchPad tablet were used as the control devices by the operator for remote robot control. And the operator used natural gesture manipulations on the live 3D model of the scene for high-level planning of the grasp operations.

Methods developed could be applied to the wide class of the remotely controlled systems with the delays in control loop.

Future work will be focused on adding the modules for automatic obstacle avoidance, remote programming of the robot in touch human-operator interface and use of WebGL language (3D extension for Javascript, http://www.khronos.org/webgl/) for 3D visualisation of the robot and its working environment at HP webOS devices.

REFERENCES

Lou, R., Lee, J., 1999. Tele-Control of Rapid Prototyping Machine Via Internet for Automated Tele Manufacturing. In *IEEE International Conference on Robotics & Automation ICRA'99, Detroit (USA), May 1999, pp.2203-2208.*

Kikuchi, J., Takeo, K., Kosuge, K. 1998. Teleoperation system via computer network for dynamic environment. In *IEEE International Conference on Robotics & Automation ICRA'98, Leuven (Belgium), May 1998, pp. 3534-3539.*

Bakers, P., Tso, K., 2000. Internet-based Operations for the Mars Polar Lander Mission, In *IEEE International Conference on Robotics & Automation ICRA'2000, San Francisco (USA), April 2000, pp.2025-2032.*

Hamel, W., 2001. Observations concerning Internet-based teleoperations for hazardous environments. In *IEEE International Conference on Robotics & Automation ICRA'2001, Seoul (Korea), May 2001, pp. 638-643.*

Hannaford, B., 2008. Telesurgery via Internet, Workshop "New Vistas and Challenges in Telerobotics", In *IEEE International Conference on Robotics and Automation, Pasadena (USA), May 2008.*

Tzafestas, S., 2009, *Web-based Control and Robotics Education*, Springer, 296 p.

Nuno, E., Basanez, L., Prada, M., 2009. Asymptotic Stability of Teleoperators With Variable Time-Delays, In *IEEE International Conference on Robotics and Automation, Kobe (Japan), May 2009.*

Manchini, A., Frontoni, E., 2009. RoboBuntu: A Linux Distribution for Mobile Robotics. In *IEEE International Conference on Robotics and Automation, Kobe (Japan), May 2009.*

Belousov, I., Clapworthy, G., 2002. Remote programming and Java3D visualisation for Internet robotics, SPIE's *International Technical Group Newsletter*, Vol. 11, No. 1, February 2002.

Tan, J., Clapworthy, G., Belousov, I., 2004. The Integration of a Virtual Environment and 3D Modelling Tools in a Networked Robot System, International Journal of Image and Graphics, World Scientific Publishing Company, Sept. 2004, pp. 1-20.

Belousov, I., Sazonov, V., Chebukov, S., 2005. Web-based Teleoperation of the Robot Interacting with Fast Moving Objects, *In IEEE International Conference on Robotics and Automation ICRA'05, Barcelona (Spain), April 2005.*

Belousov, I., Esteves, C., Laumond, J.-P., Ferre, E. 2005. Motion planning for the large space manipulators with complicated dynamics. In *IEEE/RSJ International Conference on Intelligent Robots and Systems IROS'2005, Edmonton (Canada), August 2005, pp. 3713-3719.*

Belousov, I., 2007. Sidebar – Java3D for Web-based Robot Control, Invited Article in "Advances in Telerobotics", Volume 30, 2007, Springer-Verlag.

Yoshida, E., Esteves, C., Belousov, I., Laumond, J.-P., Sakaguchi, T., Yokoi, R., 2008. Planning 3D Collision-Free Dynamic Robotic Motion Through Iterative Reshaping, *IEEE Transaction on Robotics, Vol.24, N°5, October, 2008, pp.1186-1198.*

Allen, M., 2009, Palm webOS, O'Reilly, 2009, 432 p.

Zammetti, F., 2009. Practical Palm Pre webOS Projects, Apress, 2009, 400 p.