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Web-based Control System of a Mobile Manipulator over Internet

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Abstract

This paper explores a web-based remote-control system for a mobile manipulator over the internet. The development of internet technology and increased transmission speed has made it cost effective and convenient for remote control. However, the issue of time delay on the internet poses a challenge to the stability of teleoperation systems. To address this, the paper conducts tests and analysis of time delays, leading to the development of rules and classifications for different types of time delays. The authors propose control strategies and compensation schemes tailored to these time delays and embed three control modes within the system. Additionally, they describe the development of a web-based teleoperation system for a mobile manipulator using J2EE technology.

1 Introduction

An explosion of intelligent devices and systems, such as distributed computer systems, mobile robots, telescopes, and surveillance tools, has been brought about by the Internet's fast growth. Internet robotics, also known as Web-based robotics, is one of these new ideas that has attracted a lot of interest from academics across the world. It presents a wide range of real-world uses, including teletraining, telesurgery, museum guidance, traffic control, space exploration, disaster relief, housework, and medical care, especially in hazardous situations where telerobotic systems are typically used.

This paper explores the development of an Internet-based teleoperation system for a mobile manipulator. A manipulator situated on a mobile platform that provides a large workspace, mobility, and manipulation capabilities is referred to as a mobile manipulator. These attributes make it possible to do a variety of activities, such as moving objects, particularly in dangerous environments.The study proposes compensating solutions based on different delay scenarios, integrates three management modes, and develops classifications and guidelines for managing time delays. To complete this project, a J2EE-based website that allows for remote operation of the mobile manipulator has also been planned and implemented.

2 Overall system architecture

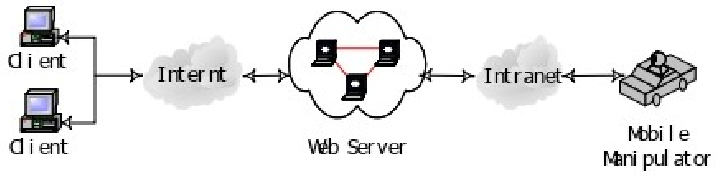

Figure 1. System architecture

As seen in Figure 1, the control system's hardware is made up of client PCs, a Web server, and a mobile manipulator. A client computer is a personal computer that is capable of connecting to the Internet; it does not require the installation of any specific client-side software.

The mobile platform in this figure 2 mobile manipulator system has three wheels. The mobile platform's front two wheels are its driving wheels. The caster, situated at the rear of the mobile platform, is the additional wheel. The mobile platform is positioned above the manipulator, which has four degrees of freedom (DOF). Additionally, ultrasonic sensors allow mobile platforms to avoid obstacles.

Figure 2. The mobile manipulator

The mobile platform has a CCD camera in front of it to capture images of the surroundings. Clients can monitor the robot's condition with the help of the images. The manipulator and the mobile robot are controlled locally by an onboard computer.

Clients can access Web services and the intelligent agent for web-based control through the Web server, which acts as a bridge between the robot and remote operators. The intelligent agent can process information about communication, the Web, clients, and the robot. It can also manage clients and Web control features like control modes and control strategies.

The robot receives commands from the Web server via wireless LAN, while the Web server communicates with the client computer via the Internet.

3 Test and analysis of time delays

It is necessary to understand the characteristics of time delays before developing a control model and choosing a control strategy because time delays have a significant impact on real-time control and the stability of control systems. As a result, tests are conducted on time delays between local and remote sites at various times, and the test findings are examined. The time delay being tested in this case is a round trip time (RTT). Thirty university websites from various provinces were chosen as test sites for RTTs. Every chosen website receives a packet of 32 bits that is sent to it every five seconds at the same time. Data regarding time delays is also recorded every minute. In the interim, RTTs to Sohu, Sina, and Ourgame are also examined for universality due to the large number of visitors to these three websites. Finally, there are three categories of time delays: jitter time delay, relative stable time delay, and stable time delay.

4 Method of control

Unstable control systems can result from delays in time. Certain remote control techniques, like direct control, predict display control, event-based control, supervisory control, and learning control, are applicable in situations where there are time delays. Every control mode has limitations in addition to advantages. It is challenging to fit one control mode for Internet users with varying time delays due to the unpredictability of time delays. Furthermore, precision cannot be guaranteed by a control model that uses time delay compensation. As a result, a control strategy is put forth in which the user's time delay test is used to determine the control mode to be used when the user requests to control the robot. Three control modes—direct control, predict display control, and supervisory control—are integrated into the control system based on the various time delays of the three types.

4.1 Direct control mode

Users can operate the robot in direct control mode when they request to operate the mobile manipulator, provided that the RTTs they detect fall within the stable time delay. In this mode, the user can direct the mobile manipulator by giving it simple commands like "move forward," "turn right," "stop," and so forth. Without any intelligence, the robot will carry out the directive. In this mode, there should not be many time delays. The robot's camera captures images in real time, which users can use to control the device.

4.2 Predict display control

The system enables the user to control the robot using the predict display control mode during a relatively stable time delay. In the "predict display" mode, the control system incorporates virtual reality technology to simulate a time delay and forecast the robot's behavior. Received remote information might not accurately reflect the current remote situation due to time delays. In order to lessen the impact of time delays, Smith predictors are made to maintain synchronization between the real state of the robot and their predictive display. The user monitors a virtual real scene that shows the robot's current state, and the operator makes decisions about how to operate the robot based on this observation. The operator site does not display the camera's real-time image.

4.3 Supervisory control

The operator will enter supervisory mode if the RTTs being tested fall within the jitter time delay's scope. The supervisory mode of the operator out of control system closed loop only allows the remote robot to receive task-level commands; the autonomous control loop of the robot completes the concrete task. In other words, although the remote robot is intelligent, it only engages with humans when it comes across circumstances that it is unable to manage. Supervisory control is necessary for Internet applications with significant uncertain time delays because of Internet time delays and robot safety concerns. It is possible to increase a robot's capability by utilizing many of the established experiences that demonstrate local intelligence in robots, such as path planning, object recognition, self-referencing, and collision avoidance.

4.4 Selection of control mode

Based on the time delays tested, a client's control mode is selected. Time delay detector checks the RTTs between the client site and the Web server site when a client requests to operate the robot. The client will switch to a control mode that is adaptive to the kind of time delay, based on the RTTs that were tested. Figure 3 depicts the control strategy's flow.

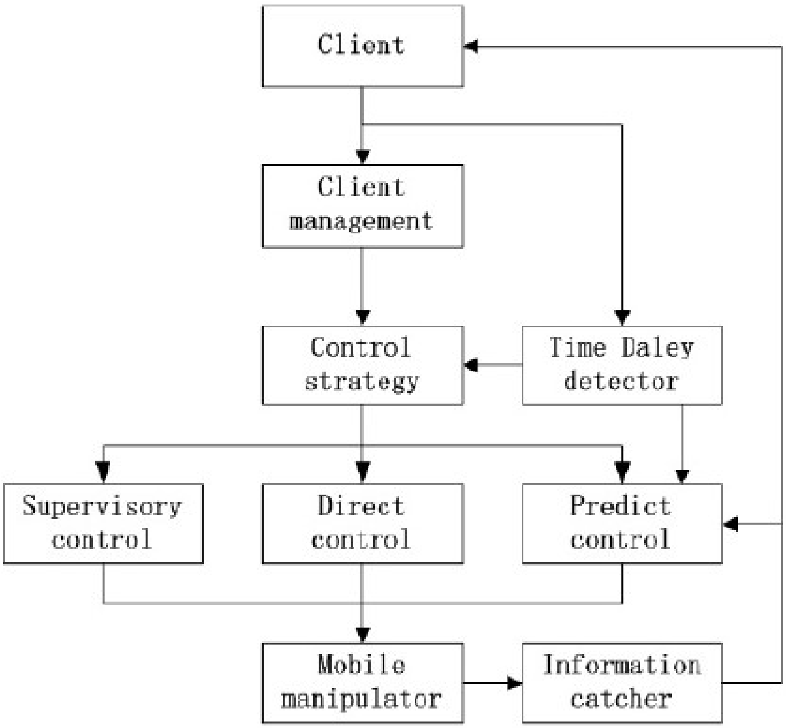

Figure 3. Flow of control strategy

5 Web-based system based on J2EE

Control system applications are created in a Java 2 Platform Enterprise Edition (J2EE) environment. Java is the foundation of the J2EE architecture; it is independent of operating systems and is purely an object-oriented programming language that works well with modularized design.

A method based on components for designing, assembling, and deploying enterprise applications is provided by the architecture of J2EE, a Web-oriented enterprise application development environment. The Web-based control system's stable and dependable demands can be better met by the Web-based control system built on the J2EE environment.Within the overall deployment, each layer carries distinct responsibilities, and each layer may contain additional components. Figure 4 displays the application with four tiers.

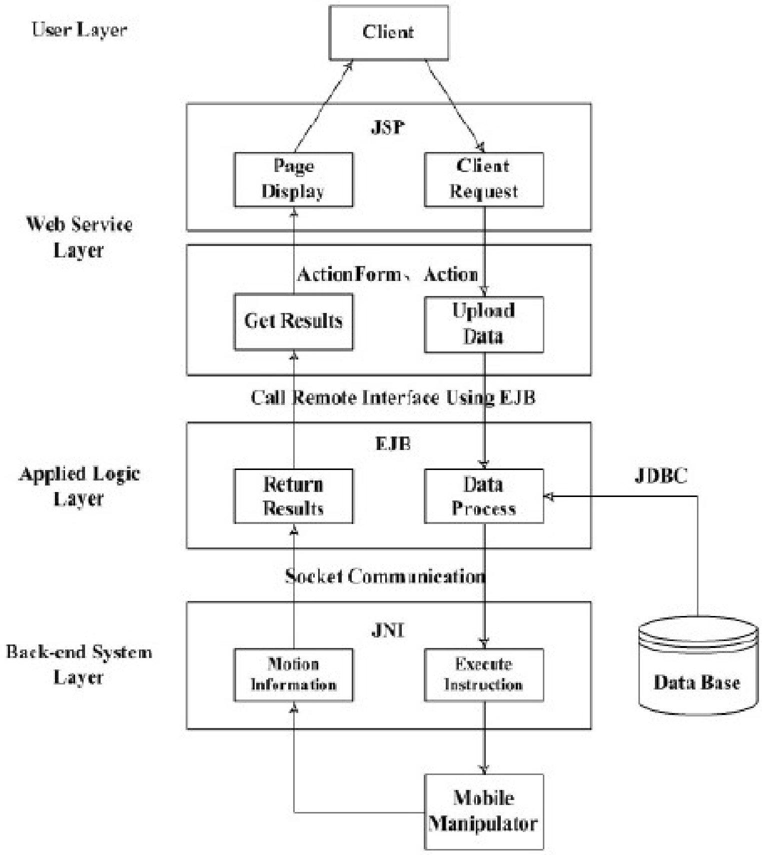

Figure 4. Four -tier application

5.1 User layer

Client computers, which house universal browsers like Internet Explorer, Netscape, and others, house the user layer. The foundational software for Internet communication that uses the TCP/IP protocol is the universal browser. Similar to how Internet Explorer is built into the Windows operating system, a universal browser is typically installed on a client computer concurrently with the installation of an operating system. Users of the web can access the robot website with any universal browser and download webpages that are written using JavaScript or JSPs from the web service layer. The web user can log in to the control interface by using the webpage. The user can give control commands to the mobile manipulator after they have 398 control authority. In the meantime, they can acquire information on the robot's condition and its surroundings.

5.2 Web Service Layer

Users can access HTTP service using the Web service layer. This layer defines the main interface, user logon interface, and control interface to enable user-robot interaction. Model-View-Controller (MVC) software architecture built on Struts is used to accomplish loose coupling between control logic and WebPages. The MVC-based design can facilitate cooperative development and maintenance.

5.3 Applied Logic Layer

The intelligent agent in the applied logic layer carries out the client management, data processing, and Internet-based control logic for the mobile manipulator, among other functions. Components that address control logic and other issues form the foundation of the program. Servlets and Enterprise Java Beans (EJB), which comprise Session Beans and Entity Beans, are the components that are discussed in this work.

5.4 Back-end System Layer

The robot controller, a mobile manipulator's local control system, and a database containing information about users and the robot are components of the back-end system layer. The database is accessed via Java Database Connection (JDBC). Sockets are used to enable communication between the robot controller and the Web server.

6 Summary and Conclusion

This work develops a Web-based teleoperation system over the Internet for a mobile manipulator. Time delays are examined and categorized based on RTT tests conducted online. A suggested control approach automatically selects one of three control modes according to varying time delays. A Web-based teleoperation application for the mobile manipulator is conceived and developed using JEE and MVC. Ultimately, a system test demonstrates that the control system allows additional Web users to teleoperate the mobile manipulator via the Internet in addition to ensuring control stability.

7 Acknowledgement

This work is partially supported by the Tianjin High Education Technology Developing Fund (2006BA10), the international Science and Technology Collaboration Project (2006DFA12410) and Tianjin Nature Science Fund (07JCZDJC09300).

8 References

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