

# Web-based Local Fuzzy Control of Mobile Manipulators

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**Abstract** - With the development of Internet technology, the web-based teleoperation of mobile manipulators becomes possible. Fuzzy control is to control an object according to the experts' experiences, and its design does not depend on the mathematical model of the control object. It is suitable for the control of the mobile manipulator, which is a complex system. This paper designed a fuzzy control system of the mobile manipulator, and then established a web-based remote control platform by J2EE to achieve the local fuzzy control based on the Internet technique.

**Keywords** - Fuzzy control, Internet, JNI, JSP, EJB

## I. INTRODUCTION

In recent years, due to the application of Internet technology more widely, the web-based teleoperation technology becomes possible. The technology employs the browser/server pattern, allowing a user to visit the server on remote client computer and transfer the control command through the network server to the mobile manipulator to achieve the long range control of the mobile manipulator. Nowadays, various control methods (fuzzy control etc.) are applies to control the mobile manipulator; most of them are local control. How to apply these control methods to control the mobile manipulator via the Internet, this paper carries on a solution.

## II. SOFTWARE USED

In order to develop the teleoperation system with the Java technology, the software, which needs to be installed on the control server of the mobile manipulator, shows as follows:

(1) Java2 development toolkit JDK. JDK is the Java core toolkit, including Java Runtime Environment, Java Tools and Java Fundamental Class. Users can establish any solutions based on the core Java API.

(2) Tomcat, which supports JSP technique [1]. Tomcat is the standard implementation of Java Servlet 2.2 and Java Server Pages 1.1 technology. Tomcat is free software owed by Apache license.

## III. SOFTWARE ARCHITECTURE OF THE CONTROL SYSTEM

As shown in Fig. 1:

**Client Layer:** Web browser software is required (Internet Explorer etc) in a client computer. Generally, like the Microsoft Windows operation system, the browser software is embedded in the OS. The user logs on the mobile manipulator website through the browser, downloads the page from the service layer, registers and then goes on other operations. The user transmits control commands to the server and operates the mobile manipulator after acquiring the control authority.

**Server Layer:** the server layer includes the web server and the application server. The web server provides a HTTP service for the user, and defines the control interface of the remote client computer. The software architecture employs MVC according to the Struts, This architecture makes web pages little coupling and easier to edit and develop. The application server employs J2EEs module technique-EJB to carry out the program design of the control logic.

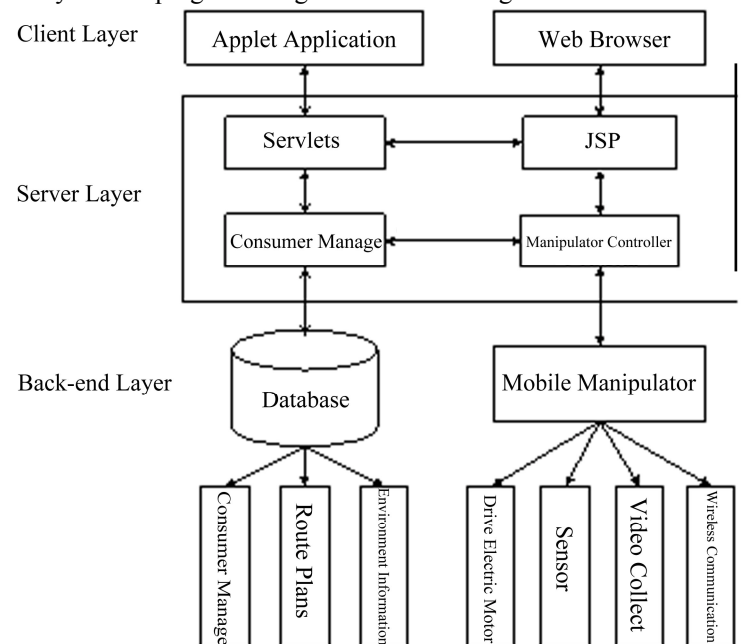


Fig.1 Software Architecture

Back-end Layer: the back-end control system only includes the local control system of the mobile manipulator (the mobile manipulator controller). The Soap technology is employed to achieve the communication between the network server and the mobile manipulator controller.

#### IV. DESIGN AND REALIZATION OF THE SERVER LAYER

The server layer of the mobile manipulator makes use of the Struts MVC model to carry out effective separation between the manifestation part and business logic part [2]. The JSP web pages, as the manifestation part, do not contain any business part cords, only achieving display function. Any Java code is not embedded inside the pages. All these techniques make the software easy developing and maintenance.

#### V. DESIGN AND REALIZATION OF THE APPLIED SERVER

In the teleoperation control platform of the mobile manipulator, all business logics are carried out on the application server. That is to say, when any user visits the control website, he must submit his information and send out control instructions to the server. The conversation bean, within the application server, carries on verification to the user information and the control instruction. For the user information, after verifying successfully, sends out a string to the Action class of the web server, which means to pass a verification process. For the instruction information, after verification, the entity bean realizes the consistency of data and sends out the instructions to the mobile manipulator at the same time. Finally, the entity bean interacts with the web server of the mobile manipulator controller.

#### VI. DESIGN AND REALIZATION OF THE DATABASE SYSTEM

The database system is built on Microsoft SQL Server2000. The application program visits the database through the database driver. The Java application visits the database via JDBC (Java Database Connectivity). JDBC is a Java application interfaces that are used to carry out SQL sentence. In the teleoperation platform, the registered users' information, the path planning information and the environment information should be saved and managed. Therefore, three related databases are built up to complete related tasks.

#### VII. REALIZATION OF LOCAL FUZZY CONTROL SYSTEM WITH JNI

##### A. Fuzzy control of the mobile manipulator

A fuzzy controller operates based on the control rules that experts summarized, and its design does not depend on the mathematic model of the controlled object. Therefore, the fuzzy controller is especially suitable for the cases where traditional model-based control does not work well, for instance, no way to build the model, models being uncertain or for severely nonlinear complicated system control [3]. The mobile manipulator with three degree of freedom is employed in this paper, where  $\theta_1$ ,  $\theta_2$  and  $\theta_3$  are three rotation angles of likes. For the mobile manipulator, a fuzzy control system is designed based on the fuzzy control theory, as shown in figure 2:

The model in figure 2 is a mobile manipulator fuzzy control system [4]. Each fuzzy controller controls one joint of the mobile manipulator.  $\theta_{d1}$ ,  $\theta_{d2}$  and  $\theta_{d3}$  are expected positions of each joint of the mobile manipulator.  $\theta_1$ ,  $\theta_2$  and  $\theta_3$  are actual positions of each joint of the mobile manipulator.  $e_1$ ,  $e_2$  and  $e_3$

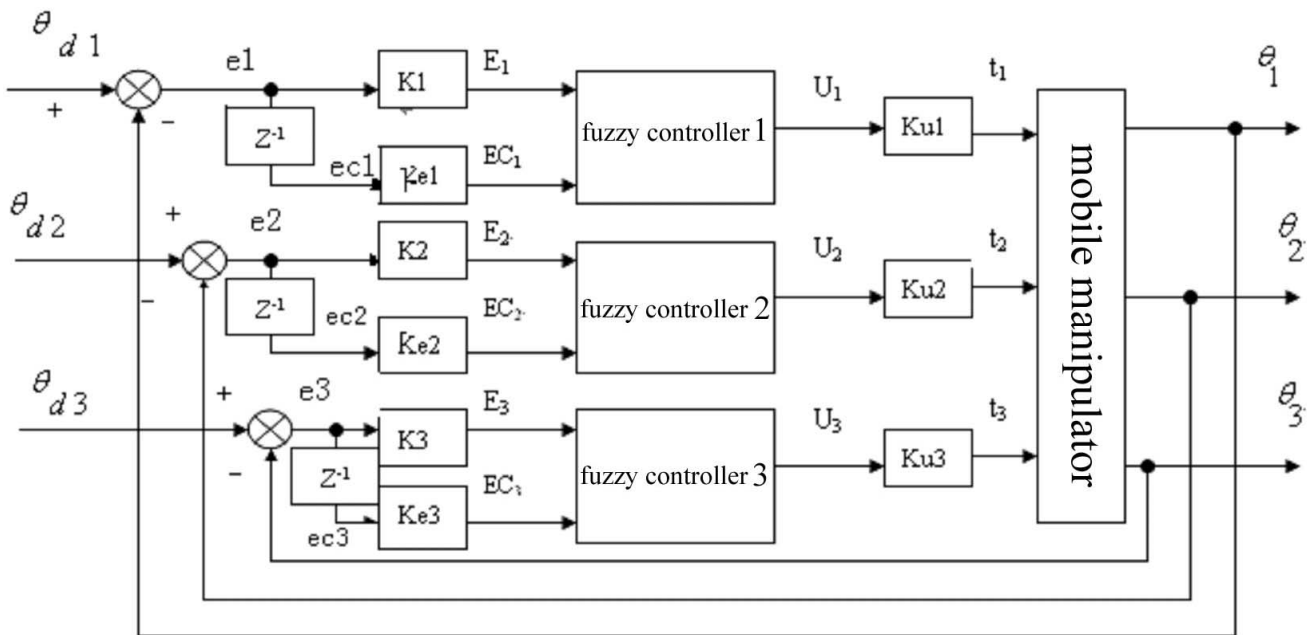


Fig.2 the Fuzzy Control System of the Mobile Manipulator

are position errors of each joint of the mobile manipulator.  $ec_1$ ,  $ec_2$  and  $ec_3$  are differentiations of  $e_1$ ,  $e_2$  and  $e_3$ .  $K_1$ ,  $K_2$ ,  $K_3$ ,  $Ke_1$ ,  $Ke_2$  and  $Ke_3$  are the quantization factors. To convert the universe of discourse of  $e_1$ ,  $e_2$ ,  $e_3$ ,  $ec_1$ ,  $ec_2$  and  $ec_3$  to the input universe of discourse of the fuzzy controller,  $E_1$  and  $Ec_1$  are the input of the fuzzy controller 1,  $E_2$  and  $Ec_2$  are the input of the fuzzy controller 2, and  $E_3$ ,  $Ec_3$  are the input of the fuzzy controller 3, after conversion.  $U_1$ ,  $U_2$  and  $U_3$  are the output of three fuzzy controllers, called proportion factors. To convert the outputs of fuzzy controller to actual universe of discourse results in the torsion  $t_1$  of the joint 1, torsion  $t_2$  of the joint 2, and torsion  $t_3$  of the joint 3.

### B. Realization of the call of local fuzzy control based on JNI

The local control module is developed by the VC++ language. Since the network application based on JAVA cannot call the VC++ programs directly, JAVA native interface (JNI) technology can solve this problem. Through JNI, the JAVA codes which run in the internal VM (Virtual Machine) can be mutually called by the programs and procedures compiled by languages such as C, C++ and assembler language. Figure 3 describes the fundamental structure of JNI.

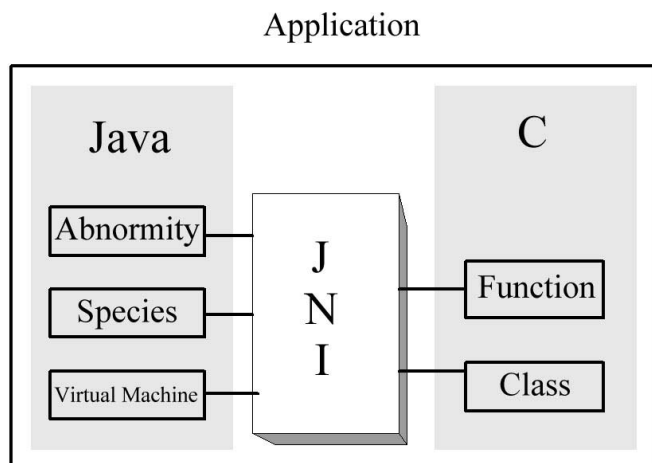


Fig.3 the Fundamental Structure of JNI

### C. Realization Process

(1) Using Matlab, according to the fuzzy control system shown in figure 2, build up the *FuzzyControl.m* file, and imitate.

(2) Using the interface between Matlab and VC++, VC++ programs call the *FuzzyControl.m* file, to build the *FuzzyControl()* function.

(3) Compile JAVA code.

In one of the directory, such as D:/ of your computer, compile a JAVA program, named as *ArmNative.java* [5]. Define the motion control method and the dynamic link library called by JNI.

```
public class ArmNative{
    static {
        System.loadLibrary("ArmControl");
    }
}
```

```
}
public native void FuzzyControl();
}
```

### (4) Compile JAVA code

Execute javac *ArmNative.java* under DOS environment. An *ArmNative.class* file is generated in the same directory. Create a new folder in the directory, and copy *ArmNative.class* file to the new folder. (This folder will be a package called by JSP)

### (5) Create C/C++ head document

In dos command window, input javah control.*ArmNative*, after enter Return button and compile successfully, and then a *control\_ArmNative.h* file is created. This file is a head document of the VC++ programs.

### (6) Create dynamic link library

Build a new project named *ArmControl* in VC, and then compile a source file. Part source codes are shown as follows:

```
class ControlArm
{
public:
    void FuzzyControl();
    void GTInitial();
    void InputCfg();
    void AxisInitial();
    void error(int rtn);
public:
    ControlArm();
};
```

Compile all projects. If all projects are right, the program will be able to create the dynamic link library *ArmControl.dll* file.

## VIII. EXPERIMENT RESULTS AND CONCLUSION

This paper establishes the mobile manipulator control website, as shown in Fig. 4 (next page). By setting up the client layer, the web service layer, and the local control method of the back-end system, the combination of web-based control and local control is achieved, and the mobile manipulator can be controlled using the local control method on the client computer.

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## REFERENCES

- [1] Sun Wei-qin, Li Hong-cheng. Detailed Technology Explanation of Tomcat and Java Web. Beijing: Publishing House of Electronics Industry. 2005-07
- [2] Ramesh Nagappan . Robert Skoczylas . RimaPatel Striganesh . Java Web Serve exploitation. 2004-11
- [3] Zhu Jing. Principle of Fuzzy Control Theory and System. Beijing: China Machine Press. 2005-08.

- [4] Li Na. Research on the Motion Planning and Control of Mobile Manipulator: M.S. Thesis. Tianjin: Tianjin University of Technology. 2006-04
- [5] Feng Da-bin. Research for Web Based Teleoperation on Mobile Robot: M.S. Thesis. Tianjin: Tianjin University of Technology. 2004-04

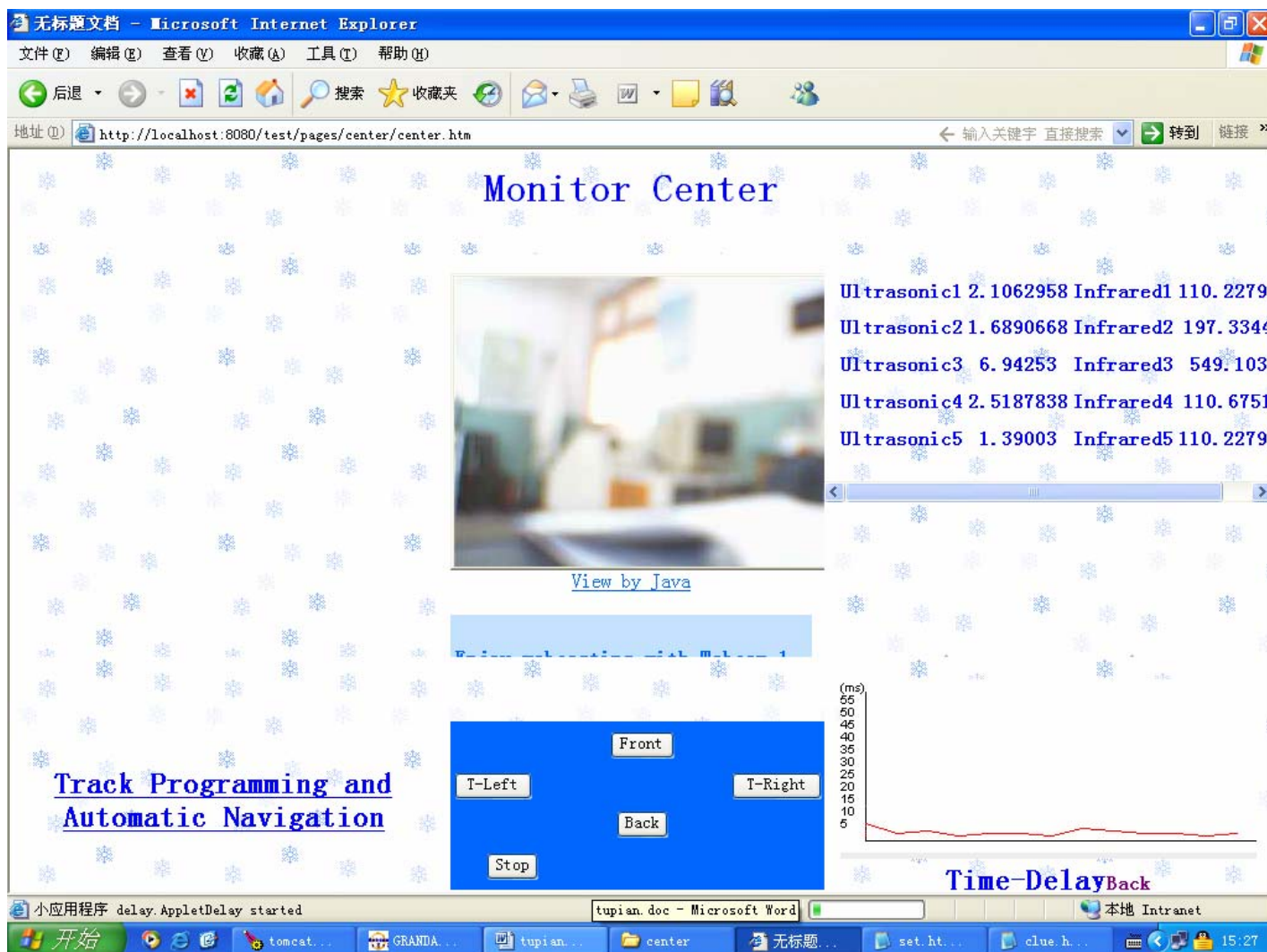


Fig.4 Interface of the Control Centre