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Control of Remote Robots by Means of Cell Phones

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Abstract: Since about two decades, cellular phones coupled to internet and wireless communications are offering many possibilities that can be exploited by classical telerobotics to free human operators from many constraints providing mobility and ubiquitous applications.

This paper presents the design and implementation of an experimental telerobotics system where the human operator supervises and controls remote robots by means of cell phones. To achieve this application, we used Java software namely J2ME platform which is dedicated for programming cell phones and J2SE platform for programming PCs. The adopted software technology of connection between the human operator and the remote robots uses the socket technique with client-server model. The cell phone held by the operator acts as a Client while a PC, situated at the remote robot site, acts as a Server. This application corresponds to Midlet-to-Servlet in Java terminology. Basic simulations and preliminary experiments have been successfully carried out with a three Degrees-of-Freedom (D.O.F) serial robot. These telerobotics systems based on cell phones are effectively offering interesting means to opening new perspectives for mobile and ubiquitous applications.

Keywords: Telerobotics, human-robot interaction, cell phone control, wireless control, remote control, client-server architecture.

1. Introduction

Since about three decades, the evolution of modern technology is offering more and more capabilities to enable mobile interaction and control of remote systems in an easy way anywhere at any time [1-4]. Initially, remote robot control took form during the Second World War by controlling the first robot manipulators dedicated to manipulate radioactive materials in nuclear plants and to achieve repetitive industrial tasks. During this period, the feedback information used to monitor and supervise the task was the direct vision of human operators situated near the operational site. Later on, remote robot control or telerobotics became possible at relatively longer distances with dedicated and specialized wired or wireless connections based on radio waves. For supervising and controlling tasks at long distances, the vision feedback is assured by means of cameras situated at the remote robot site. Soon, this field of telerobotics became very important and involved various kind of robots: arm manipulators, wheeled robots [5], parallel robots [6], etc. It covered also a large number of applications including exploration in hazardous and/or inhabited areas like space, undersea, nuclear plants. However, since the 90's, the availability of multimedia techniques has enriched the development of operator interfaces which represent the core of telerobotics systems. Interaction, control and supervision of telerobotics systems became therefore easier [7-10]. More recently, the involvement of Artificial Intelligence into telerobotics brought unexpected and unprecedented capabilities which are reflected by the addition of more autonomy and flexibility to the telerobotics systems. Consequently, more and new applications have been carried out such as telemedicine, tele-surgery, micro-robotics, social robotics, cooperative robotics, etc. Many complex missions involving various robots of different forms and sizes are actually envisioned [11]. In fact, the standard basic architecture of telerobotics systems is usually constituted of three main parts. The first part is a local site where the human operator is situated and from where usually he/she interacts and supervises the remote robot. The second part is the remote site where the robot is situated in its workspace. The third part is an operator interface which permits communication between the operator on the one hand, and the remote robot and its environment on the other hand. An operator interface is generally constituted of screens projecting the scene of the robot evolving in its workspace and many tools that enable the operator to interact and supervise the task achievement and the robot state. Classically, the local site is fixed and the remote robot can be mobile or spatially fixed according to the robot type under consideration. However, with the recent development of modern wireless communication networks involving Internet; cell phones as handheld devices are becoming to some extent capable of replacing PCs. This capability, if exploited in telerobotics, can give rise to applications implying free displacements of the operator. This is particularly required for human explorers, soldiers, and many others. Indeed, cell phones enable unimaginable means for remote control which can be characterized by the ease of use anywhere and at any time. If the human operators are mobile and the remote robot systems are also mobile; therefore, ubiquitous applications can be designed.

In this context, some studies and applications have been performed covering a large spectrum of domains: education, academic [3] surveillance [12, 13], spying [14], control of mobile robots [4], [15], industrial robots [16], military operations [17], supervision of unmanned vehicles [18], exploratory missions in space and hazardous environments, etc. [4].

In this paper, we intend to present the design and implementation of an experimental telerobotics system in which the human operator can control and supervise remote robots by means of cell phones of the third generation and beyond, using wireless networks.

2. Description of the Telerobotics System Based on Cell Phones

A. Hardware Architecture Design

The hardware architecture of our telerobotics system resembles to classical ones except that the operator can be mobile according to his/her needs. A schematic illustration of the system organization is presented in *Fig. 1*. It is composed of three main parts. The first part concerns the local site where stands the human operator, who can supervise and control by means of the cell phone the remote robot as well as the webcam (on the right side of *Fig.1*). The second one is constituted by the remote worksite (on the right side). It contains a homemade 3 D.O.F robot manipulator of RRR type that holds a gripper on its end-effector. In addition, this site contains a homemade pan-tilt unit that serves to orient a webcam used for selecting views on the robot workspace.

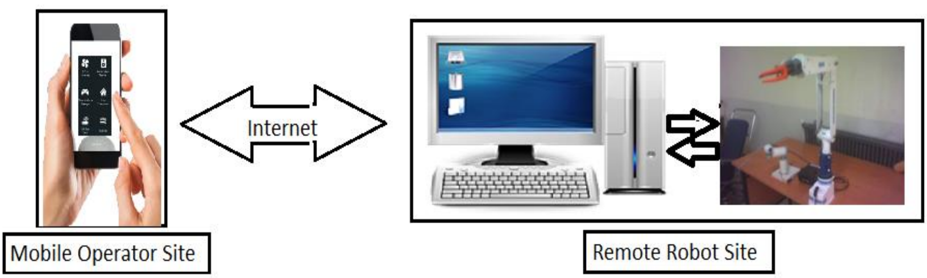

Figure 1: Hardware architecture with operator using cell phone

The third part concerns the communication and control system which enables information exchange and interactions between the human operator and the remote robot and site. The required functions of our system are hosted on the cell phone through a Graphical User Interface (GUI). The GUI permits management of information exchange and visualization of the remote site on the cell phone. It provides functions via panels for remotely controlling the robot manipulator for performing tasks as well as the pan tilt unit for selecting suitable views by the webcam.

The vision feedback to supervise the remote task is assured by video streams sent by the camera and displayed on the screen of the cell phone. Moreover, a virtual robot replicating the wireframe structure of the real robot has been also designed and implemented for simulation purposes based on the cell phone emulator.

B. Software Architecture Design

Our application has been designed for modern cell phones of the third generation and beyond using wireless networks such as WWAN (Wireless Wide Area Network) and thus can take advantage of the access to Internet and multimedia systems. In our telerobotics system, the mobile terminals are connected to the wireless network. Therefore, it was necessary to use specific software for developing mobile phone applications. Consequently, we have used the basic J2ME platform which is a specific platform dedicated to mobile phone applications [19-21].

Applications concerning virtual as well as real robots have been designed by means of this platform. The communication between the mobile phone and the PC at the remote robot site exploits the socket technology according to the well-known Client-Server model. The Client represents the operator's cell phone while the Server is represented by a PC related to the remote site. The dialogue between the Client and the Server is done by exchanging messages. As we have used Java software platforms to implement all our applications; so, we have implemented a MIDlet class for the Client side and the Servlet class for the Server side [22]. A MIDlet is an application that uses the mobile information device profile (MIDP) from the Java Platform Micro Edition (Java ME) environment. Since Java has become one of the most widely used mobile platform, the MIDlet has become the most ubiquitous application of mobile ones. On the other hand, a Servlet is a class that is used to extend the capabilities of servers that host applications accessible by means of a request-response programming model. This Java platform offers also a cell phone emulator on PCs. This is an important facility that enables programming and testing applications designed for cell phones on the PCs.

The GUI has been designed to enable interaction and information exchange between the human operator and the remote site. Technically, the GUI provides the operator with a menu on the cell phone from which he/she can select functions to be performed. It is constituted of some forms that integrate buttons, labels, zones to input data, zones to receive messages, etc. For instance, a specific panel is designed to control the orientation of the webcam by pen clicks or finger touches or by predefined programs. An area is devoted to visualize the video sent by the webcam from the remote site. This enables to supervise the accomplishment of the remote task. Another panel can be used for controlling the robot movement of the serial robot from one configuration to the next. From this panel, the operator can also launch preprogrammed simple pick-and-place tasks.

3. Functional Organization of the Telerobotics System

In this section, we briefly present the functional organization of our telerobotics system. All communications and interaction between these two sites are managed through the structure of client-server model (MIDlet-to-Servlet). Expressed in hardware terms, it means that all communications are performed between the cell phone and the PC. The process of communication between the Midlet and the Servlet works as follows (*Fig. 2*). When the operator needs to interact with the remote site, he/she activates by a pen or a finger touch a button of an appropriate panel on the cell phone; then the Midlet invokes the Servlet. If the Server confirms by a message that it is Idle, then the operator can send the data with the service request.

For security and efficiency purposes, a procedure for error detection by simulation has been implemented [23]. This procedure necessitates a task simulation on the virtual robot before enabling real execution with the remote real robot for avoiding possible errors, non-realizable and singular configurations that can occur with some provided data. In fact, for telerobotics systems using networks such as Internet, the virtual robot is not only implemented on the cell phone at the operator site but also on the PC of the remote site. The simulation on the remote site is optionally available because it can be essentially needed in order to test and estimate the communication quality and possible issues such as micro-interruptions, delays and their random variability that can affect the network under consideration.

In practice, the operator, from the client side, formulates a request to transfer the robot from a current position to another one by sending the appropriate coordinates (x, y, z). The robot movement is simulated first with the virtual robot implemented on the client side. If this simulation fails, then an error is reported to the operator who has to cope with this situation for instance by modifying the data. In case of a successful accomplishment, the data is transmitted for simulation to the server side in order to test and estimate the influence of the network. If the simulation is performed successfully, then the execution of the task with real robot can be performed. During the real execution, a video stream is sent from the server to the client enabling the operator to supervise and control the task execution. After the effective accomplishment of the task, the server has to notify the end of the task to the client.

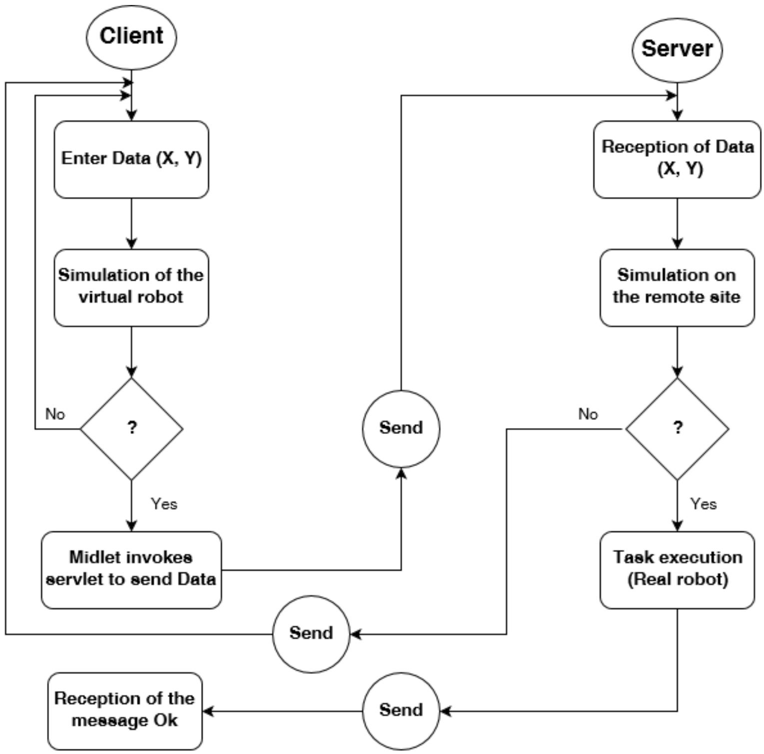

Figure 2: Functional organization scheme of the Midlet-to-Servlet communication

4. Some Simulations and Experiments

Many simulations have been performed by the virtual robot in order to test some elementary commands such as move left, move right, move up, etc. The same commands have been performed with the real robot. Some simple pick-and-place tasks have been also carried out by our virtual and real robots. On the other hand, different actions concerning the pan-tilt unit for orienting the camera have been also performed. *Fig. 3* shows images representing the elements that have served to perform our experiments. We can recognize from the left side to the right side: a panel showing the virtual robot used for simulation on the cell phone screen at the operator's site (*Fig. 3a*); the robot in the remote environment (*Fig. 3b*); and the pan-tilt unit holding the webcam at the remote site (*Fig. 3c*).

a.) Virtual robot b.) Serial robot c.) PTU

Figure 3: Some elements used in the experiments

Some tasks have been simulated on the virtual robot of the operator's cell phone. Other simulations have also been performed on the PC at the remote site enabling to test the quality of the communications such as the instability caused by time delays, possible micro interruption on the network and any other issues. Experiments with the real robot have been carried out only at relatively short distances in our laboratory (a few meters). The effect of the very short delays which is about milliseconds has no significant influence on the robot control compared to its effect experienced with our classical telerobotics system at distances of about 600 km. The delay is sensed particularly with manual control by joysticks or continuous finger touch on sliders of the GUI, especially if actions are complex and performed in a fast way with respect to relatively long delays.

Moreover, our experiments have tested commands generated by pen clicks and by impulse contact by finger touches on the cell phone screen. Since these types of commands correspond to preprogrammed short movements of the remote robot; so, they were not sensitive to delays. It reveals as in other works that interactive discrete commands enable to avoid instability and difficulty of control compared to manual control where the operator is engaged continuously to direct the remote task.

5. Conclusions and Future Work

The goal of this study was the testing of some command modes for telerobotics systems based on cell phones for providing free mobility to human operators. The adopted communication technique used the client-server model. In this model, on the one side, the operator's cell phone acts as a client while, on the other side, the PC at the remote robot site acts as a server. The technology adopted used Java platforms J2ME and J2SE corresponding to a Midlet-Servlet communication technique. This technology proves to be very easy to implement and very flexible to adapt to such telerobotics systems. The basic simulations and experiments carried out with our telerobotics system based on cell phone are offering new capabilities and opportunities for ubiquitous telerobotics applications.

As future works, there are some command modes that deserve to be tested on our telerobotics system based on cell phones. These command modes have been previously designed, implemented and successfully tested on different robots developed in our laboratory and described in the papers [24], [25]. These concerned command modes are namely interactive programming based on the graphical-user-interfaces, voice-based, pointing-on-image-based, and gesture-based [25].

Moreover, the cell-phone-based architecture can also be adapted and extended to many other robotic structures such as mobile robots, parallel robots, cable-based robots, etc.

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