REMOTE OPERATION OF THE ROBOTS THROUGH THE NETWORK

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Abstract *The remote operation of the robots or of any actuator, in general, is a useful action in many cases: heavy operation environments (underwater, inaccessible areas for humans, nuclear reactors), for operation on the battlefield or for sharing the unique or expensive resources. This paper presents a method of remote operation and a computer program that relies on the existence of the computer network. The network may be private, Intranet or Internet, without being influenced by the transmission media: cable, radio or optical fiber. The presented method allows the transmission of the information in both directions: data and images from the robot to the operator as well as operator's commands to the robot. This duplex transmission equally allows manual (the operator generates the command) and automatic control. The possible software solutions and the problems of the remote operation are presented.*
The method was applied for two robots in our laboratory: a 5 degree of freedom robot arm and a 3 wheel mobile robot. For testing it, the robot was remotely operated in Intranet, then in Internet (Bucureşti, Craiova, Greece etc.).

Introduction

This paper presents a class of applications of remote operation and remote perception, generally named telepresence and teleoperation. The fundamentals of these applications rely on the transmission of the information, through the computer network. Telepresence consists of transmitting sensory information to the operator and making him feel as acting in the environment where the sensors are. This means that the operator receives sufficient information about the remote equipment and the environment, displayed in a sufficiently natural way, that he feels physically present at the remote site [1]. The feedback consists of images, sounds, tactile and force information. Teleoperation consists of transmitting the commands of the operator to the remote equipment even when the sensory feedback (usually only visual) is delayed or is missing (the operator establishes the reference for the remote control loops only).

The geographical distance between operator and remote equipment is not important for the application structure but has an important influence on the dynamic properties of the system, because it determines the transmission delays. Typical applications of telepresence and teleoperation are:

- the remote equipment (may be a mobile robot) acts in a hostile environment, dangerous for the human operator, such as nuclear reactors, war zones, etc.;
- the equipment collects information from inaccessible areas (narrow spaces) or far from the available operator (as in the case of remote surgery);
- the remote equipment needs to be reconfigured, according to changes in the environment or to changes in its objectives. This kind of applications includes the robots that do not receive direct commands from the operator, but are occasionally reloaded with a new program;
- the equipment is available in a small number of exemplars (could be even unique) and has to be operated by more users from different geographical areas (such as in scientific or remote education experiments).

The connection between the operator and the remote equipment, proposed in this paper, is based on the computer network. The client-server technology is used to drive the information transfer and to manage the access to this information. Both telepresence and teleoperation are enabled by the usual capabilities of a computer network.

In the case of robots acting in battlefields or other hostile areas, there is a particular interest for remote operation, in order to use the abilities of the operator without endangering his life. There is a general advantage of the remote operation through the computer network; this is the possibility of operating at any distance from the operator due to the worldwide spread of the internet. Supplementary, the military applications could take advantage of the transmission system to the robot (wire, optical fiber, radio – including satellite), that already exists.

Chapter I – Structure of the remote operation system

The system performing all the actions implied by telepresence and teleoperation has to contain (Fig.1):

- the remotely operated equipment, that contains suitable sensors and actuators, able to execute the received commands. The sensors provide information about the evolution of the environment and the degree of accomplishment of the commands. The information is managed by a computer that usually may be connected to internet or a similar network;
- the computer used by the operator. This one may contain suitable input and output devices, such as joystick, voice processor, head mounted display, haptic device (for example, glove collecting position information and providing force and tactile feedback);
- the network, that may contain intermediate links (computers) between the two correspondents;
- the transmission media, implying wires, optical fiber, radio transmission (rarely infrared or acoustic). The radio transmission may be the base of a wireless network or may link the equipment situated at any distance. Supplementary, transmission through public networks has to solve security and cipher problems;
- dedicated software for the application on both sides.

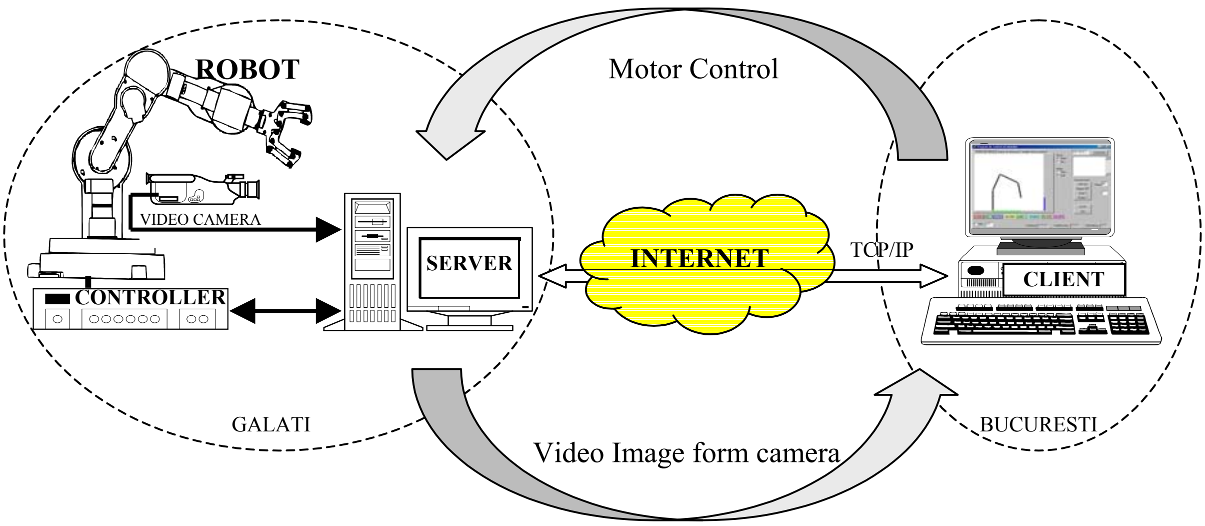

Figure 1: The structure of the remote operation system

The processor of the remote equipment (the robot) is not significantly loaded by the communication task. The most part of the computing time is required by the local control loops and other tasks, such as processing the sensor information. The sensors may concern internal variables (such as wheel movement, forces, inclination, speed) or environment ones (distance to obstacles, image of the surroundings, sound, infrared, etc.).
The transmission system does not influence the contents of the data exchanged by the correspondents. However this system is involved in two issues: the security of the operation and the quality of the control. The latter is affected by the transmission delays which may produce the failure of the control actions. This is why fast equipments require dedicated transmission lines, while the slow ones may be operated through internet, even if this network produces unknown and variable delays. The same slow network is suitable in the cases where teleoperation consists of occasionally updating the control software on the robot.

The software running on the two computers can be implemented in several ways, provided that it manages the communication problems. For the case of robots acting in difficult or hostile environments the only acceptable solution is that one using dedicated software running on both sides. The other software solutions (using a general web browser) are good for applications that are not time-critical and transfer small amount of data. Excepting the specific devices the structures of the teleoperation and telepresence systems do not differ, so the software solutions are similar for these applications.

Chapter II – Implementation

The structure presented above was used to set-up a teleoperation experiment at the University of Galati. The main parts are those contained in Figure 1. The robot arm has 5 degrees of freedom and a gripper. It contains the position sensors and the power supplies and accepts the commands through the serial link. The corresponding computer manages the communication with the robot and the digital camera. The computer of the operator may be everywhere in the world, provided that it is connected to internet. This structure is suitable for operating the robots in hostile or inaccessible environments, but can be adapted for other purposes, also.

The software is original and was written using the client-server technology. According to the specific terms, the client is the operator's computer, whereas the computer linked to the robot is the server. The server application does the following operations:

- reads the position of the robot and sends commands through the serial port;
- acquires image from the video camera and compress it;
- performs communication with the client using the TCP/IP protocol. The data sent to the client are: image, position and state of the robot. The received data are the commands;
- shows a visual interface, useful for setting the image quality parameters, for chatting with the remote operator, for opening and closing the connection;
- initializes the camera and the robot, the image format and the connection with the client. These operations are done only once, at the beginning of the experiment. After deciding the final parameters, the server software is set in such a way that it needs no human intervention more.

The client performs the following:

- displays the visual interface to the operator (figure 2), containing the image, the position, the state of the robot, two schematic projections of the robot (for mouse-generated commands), buttons (for on-off commands) and the window for chat with the server (chat is used during the tuning stage only);

- reads the commands of the operator, generated by mouse or by keyboard, and computes the specific commands that have to be transmitted to the robot;
- uses the TCP/IP protocol to manage the communication with the server, through the network. The communication transfers the commands in one sense and the position, the state of the robot and the image – for the other sense;
- initiates the connection to the server, only at the beginning.

The described system was tested through intranet, then through internet (Bucharest, Craiova, Greece). Even if the transmission speed was low, it did not visibly affect the operation, because of the small dimension of the command and position data. However, the image was transmitted with a low refresh rate, because of the speed of the network, resulting in a flickering aspect. About the possibility of errors, the TCP/IP protocol is safe, it didn't allow transmission errors that could determine wrong commands.

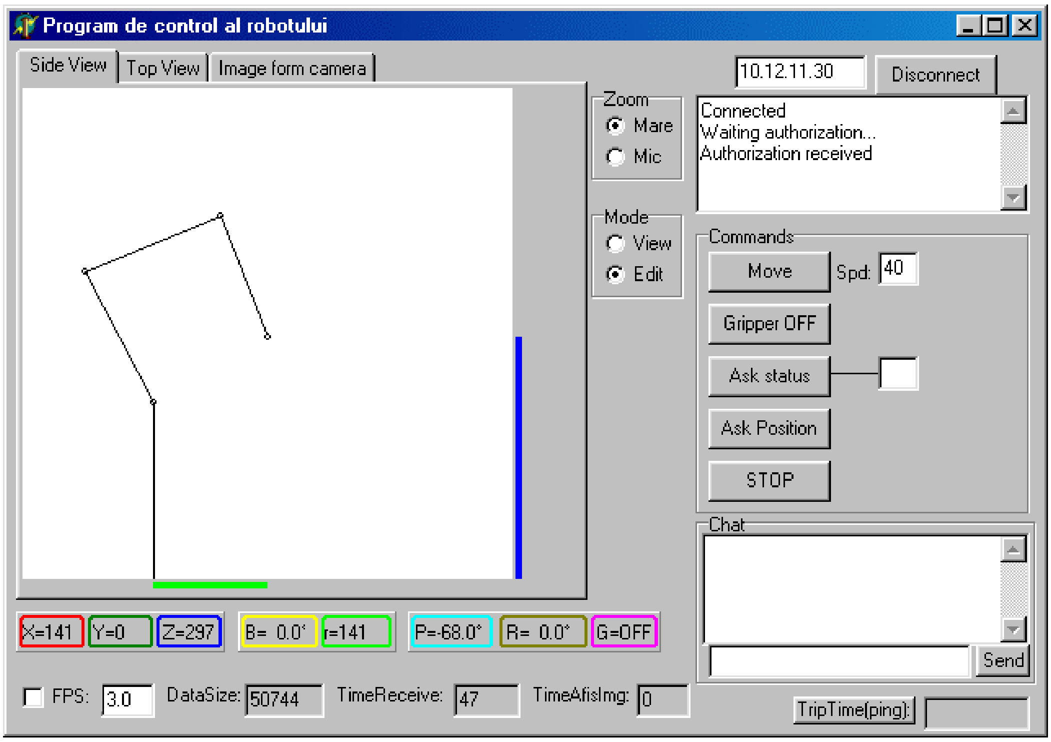

Figure 2: The visual interface to the operator

Conclusions

The experiment of teleoperation, carried out in the laboratory, on the robotic arm and the mobile robot, is a starting point for studying the teleoperation and telepresence applications. It functioned satisfactory, but showed the problems produced by the transfer speed.

In the future, the structure of the system can be improved, mainly by adding an extra camera and by changing the coding method for the transmitted images (streaming). An other necessary improvement concernes the security issue, that is not yet implemented in the first variant of the experiment.

References:
[1] Sheridan, T. B., "Telerobotics, Automation and Human Supervisory Control", The MIT press, 1992