MULTI USERS INTERNET BASED TELEOPERATION STATION WITH AUGMENTED REALITY

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SUMMARY

This paper describes a robot arm teleoperation station with visual and sensory feedback. This is a model based station using a 3D graphic interface that allow an operator to plan and control the robot movements with a mouse using visual and sensory information received back from the workspace through Internet. The interactions between the operator and the virtual world through the I/O data provide an immersion sensation and an update of the virtual environment by the real (position) sensory feedbacks. This works shows that it is possible with this station to execute and to supervise in near real time a robot arm.

Keywords: Remote control, Internet, Augmented reality, virtual reality, multiagents.

1. INDRODUCTION

Telerobotics or teleoperation concerns in general unstructured environments that are hazardous, dangerous, uncomfortable, limiting, or costly for humans to be there. However the applications list include today artistic and distance practical learning. The control of the robot should be possible so that human operators can stay outside these dangerous environments. There are many teleoperation modes, depending on the degree of robot autonomy and the human control supervision needs. Usually, some variables or functions are autonomously executed by the robot but are operator supervised and some are directly controlled by the operator when human adaptation and intelligence capabilities are required. A man machine cooperation interface is required as well as good communication tools to overcome long distance real time teleoperation.

The operator becomes a supervisor of the robot execution task and for that purpose he needs all the appropriate data about the remote robot environment in order to be in immersion in that environment. A good solution is to build a virtual reality station (VRS) with augmented reality (AR) capabilities. A VRS allows the operator to predict the task execution before sending a command to the real (remote) robot.

On the other hand, augmented reality allows to follow in near real time the task execution by using Visual and sensory feedbacks. The VRS is represented by the graphic user interface (GUI) who controls the robot and its environment models.

The large use of internet actually, makes it an appropriate mode for the development of teleoperated system communication modes, at least because internet is universal and unable users to access any worldwide network easily and cheaply. In addition to the control itself, this allows to provide pop-up pages within hypertext links easily and intuitively accessed.

However there are many problems to be solved in order to perform internet based teleoperation. The more important are reliability, time delays, and bandwith limitations. Solutions to those problems require many experimental and fundamental research handled by several research laboratories.

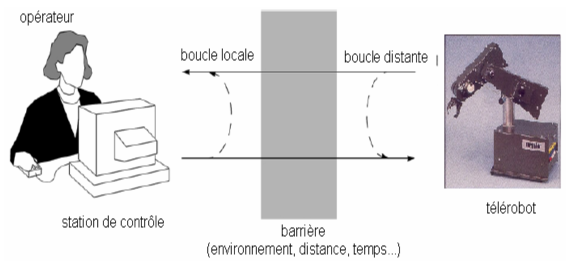

Fig. 1 Synopsis of teleoperation system.

Our contribution is part of a project entitled « teleoperation station through internet » at the "Intelligent systems research laboratory" at USTO.

The robot is the « Mentor » 5 dof arm. The VRS, the network communication module and the web cam visual feedback station is called “Multi users teleoperation station through internet” or (MUTSI), with the tools JAVA, JAVA3D, BUILDER C++ and PHP languages. This station has been presented in [1]. We shall present in this paper the improvements and the developments given since then.

This paper is organised as follows. In Section 2, we provide a short review of telerobotics state of art. In Section 3, the teleoperation station is described. Section 4 presents the experimental and tests results. Work evaluation and concluding remarks are given in Section 5.

2. INTERNET BASED TELEOPERATION STATE OF THE ART [2-12]

Classical teleoperation needs an operator who supervises the robot and its gripper. Nowadays, he can do that through a VR station that will be used as movements commands predictor before the commands are eventually sent to the remote real robot. This is a model-based teleoperation.

The VR station is then a man machine interface (MMI) that allows the operator to interact in near real time with the simulated environments through many sensory devices giving him the sensation of immersion in the virtual environment. Moreover through the superimposition of the real world and the virtual world (augmented reality), the operator can synchronise the two environments evolution when necessary.

Fig 1 shows a common teleoperation station with one operator. The MMI and the operator interactions are possible through I/O organs that receive the operator commands and provide the command results as feedbacks. The interface makes it possible to observe the environment from an arbitrary direction or zoom some parts of the environment. The environment is simulated off-line using dedicated routines (e.g. VRML). The animation must be done in real time wich implies to use 30 images/s. This represents a limitation to the actual VR systems. Otherwise the environment will takes too much time to be displayed and the immersion sensation will be lost.

What ever the improvements in the proposed teleoperation systems, there are hard limitations to be overcome. One of the limitations is the visual information degradation during long distance communication. This why the VR interface is so important as a solution to provide the lost information.

Another problem is the time delay. In classical teleoperation, the user takes a "move-and-wait", tactic that has time delay problems that are unacceptable for tack execution. Bejczy et al suggest use of the « phantom robot » as a solution to this problem. The phantom robot is a predictive graphic robot model witch is superimposed over the live delayed video feed from the remote system. Human intelligence is used to bridge the gaps in knowledge or model discrepancies. This experiment was the start up of the AR concept used in our station.

3. EXPERIMENTAL TELEOPERATION STATION

The robot is the « Mentor » 5 dof robot arm. The VRS, the network communication module and the web cam visual feedback station is called 'MUTSI' with the tools JAVA, JAVA3D, BUILDER C++ and PHP.

3.1 Modelisation

Robot modeling is needed for virtual scene simulation. The models include the transformation models between operational space (that include the terminal organ) and joint space (that includes the robot configuration), that are the direct and the inverse geometric and kinematics models. Systematic and automatic robot modelisation requires appropriate robot morphological description method: the more used is the Dénavit-Hartenberg [13] method.

Graphic modelisation goal is to create an environment model. This model includes two types of data that are the geometric and the topologic data.

The geometric data are about the robot and its environment components. The topologic data define the relationships between the scene components.

Once these models ready, we can implement the graphic user interface (GUI) to be used for scene prediction and dynamics.

3.2 Communication network

Internet use for telerobotics application has the advantage of being cheap. The main problem concern bandwidth limitations and unpredictable time delays during long distance transmission. In order to overcome these problems, we have to improve drastically our system architecture and the man machine interface as we shall show in the following.

We used a client -server architecture with a TCP/IP protocol. All the links between the operator and the work site are implemented using TCP/IP sockets to allow long distance teleoperation through internet.

3.3 Graphical interface

The graphic user interface (GUI) is divided in 4 parts:

1. The scene that represents the superimposition of the 3 robots that are
   - Robot command in wire model representation.
   - Sensory feedbacks in surfacic representation.
   - Real robot image from video feedback in backstage.

2. User interface that allows human operator to interact with the slave site
   - Monitoring in the operational space
   - Monitoring in the joint space
   - Feedbacks of the sensory data

3. Virtual scene control: Four buttons to watch the virtual robots in different positions and two buttons for zooming
4. Pop-ups or chat module

Before starting the animation, one needs to have the HM interface that contains 3D model of the robot to be teleoperated. For scene description language we use JAV3D which is a 3D scene description language. This language allows also interactions with the graphical environment after download

3.4 Description of the build system

The synoptic of the built system is shown in Fig. 2. It is divided into the work site (remote) and the operator site.

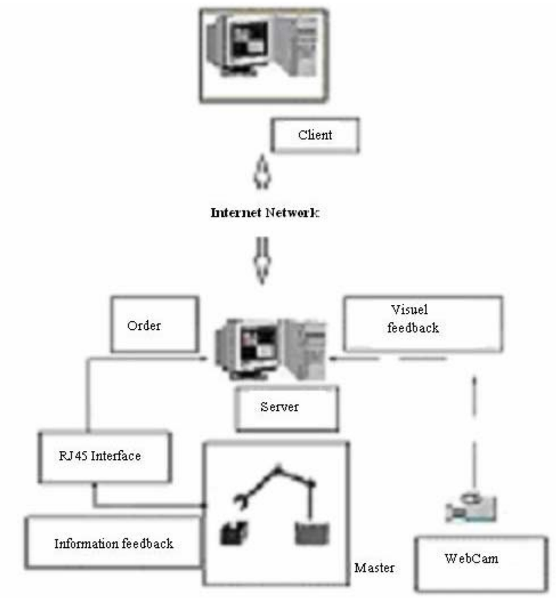

Fig. 2 Functional representation of the robot internet teleoperation system.

The remote site contains the 5dof Mentor robot arm. The client-server communication module wrote in JAVA allows the communication with the operator site and the robot command. It also provides sensors feedbacks from the real robot. It includes vision module that provides permanently through two methods the webcam images.

The master site can be any web connected pc with JVM virtual machine navigator. The page that includes JAVA applet, JAVA3D file that corresponds to the scene and the visual webcam feedback is downloaded by the operator by using its URL.

3.5 Robot teleoperation network

To teleoperate the robot, one has first to launch the server components and then the client components.

3.5.1 Server components

In order the server to accept the client connexion, it has to launch

- The server program in JAVA which takes in charge the data exchange with the client, the robot command with the instructions, and the sensors feedbacks.
- The Web server that host the HTML page that contains the user interface to be downloaded by the operator.
- The web cam program that allows image capture of the robot and its environment.

The remote site representation is given in Fig. 3

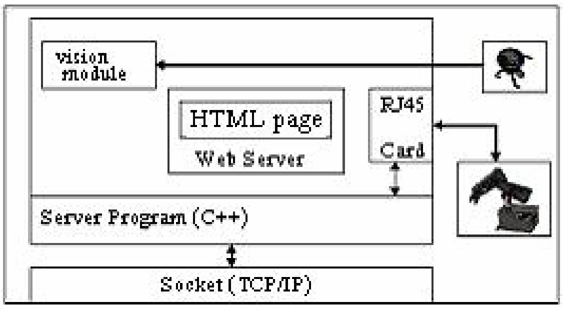

Fig. 3 Remote site (server).

3.5.2 Client components

The client has to download the HTML page that contains the following components

- The scene that represents the superimposed real and virtual robots
- The applet for communication between the server, the operator and the JAVA3D environment
- Visual feedback through the web cam

A master site representation is given in Fig. 4.

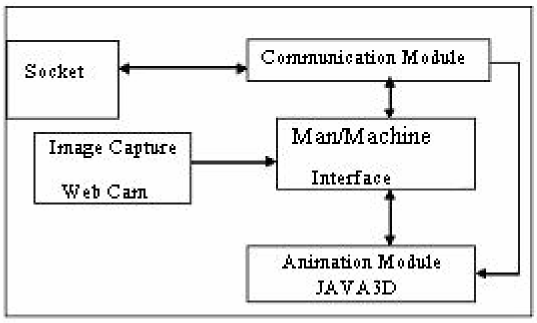

Fig. 4 Master site (operator site).

4. RESULTS

The server is represented by a simple interface, that provide to the administrator to activate the clients standing and the possibility to stop the server.

The robot command and control via internet is possible using any computer with browser to access the HTML page hosted in the following web server URL:
http://193.194.88.13/Mentor/commande12.html Fig 6.

To have access to the MMI, one has first to register:

- If the operator has a password, he can have directly access to the command page
- If the operator is new, he has first to fill a registration procedure that include the name, surname, and proposed password. These informations are saved in the Server system.

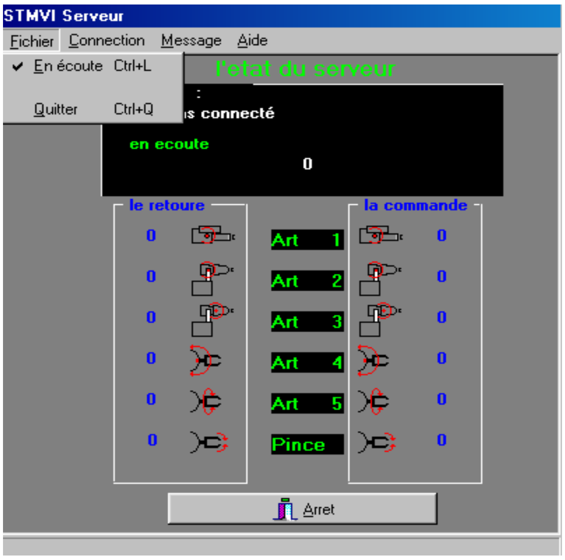

Fig. 5 MUTSI server interface

The implemented teleoperation station is multiagents. Several clients can have access to MMI, but only one of them can execute the command and the others will be supervisors. The clients management is done using PHP language that allows to manage a data base with clients data and their position in the queuing list. Once the user is identified, he has access to a selection page to select the command mode:

- Superimposition of the virtual image (command), the real image (sensors feedbacks) and the web cam image Fig. 6.
- Superimposition of the virtual image (command), and the real image (sensors feedbacks) but with the web cam image isolated Fig. 7.
- Superimposition of the virtual image (command) and the web cam image Fig.8.

In this case, the robot commands are sent to the robot itself through the internet and to the virtual environment (virtual robot). At the MMI left, we can see the command values and the robot sensors feedbacks. They are used to animate the graphical representation of the real robot. The client can then follow in near real time the robot evolution through the implemented graphic interface. The other tool is the visual feedback that can enhance the interface capabilities. It allows to continue the teleoperation even in case of time delay, communication cut, or to avoid collision.

A pop-up module gives the possibility to send messages to the server and then to communicate with the administrator in order to succeed the robot teleoperation. As illustrations of the implemented station capabilities, we could test many tasks including path following in the two joint and the operational spaces as well as a working sequency identical to industrial sequences that can be online programmed.

These experiments had shown the ability of our station to perform teleoperation through internet using MM interface with VR and AR capabilities.

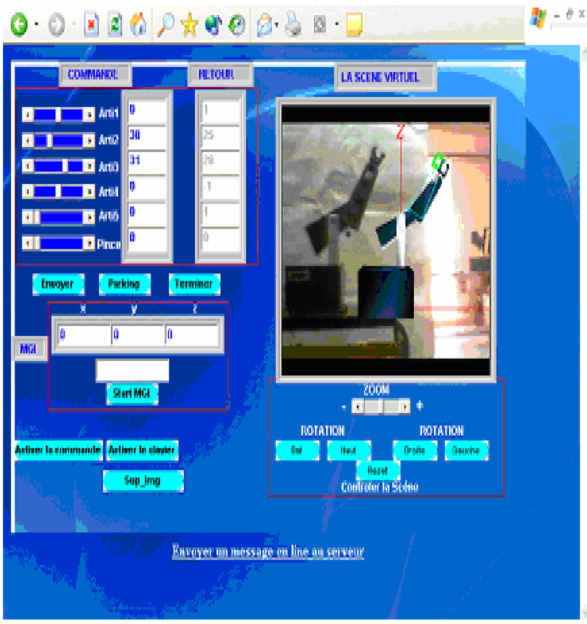

Fig. 6 The graphic users interface displayed on web page.

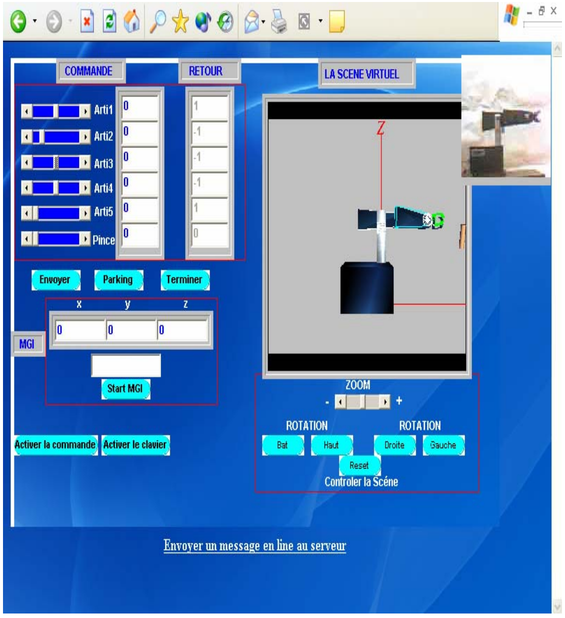

Fig. 7 The graphic users interface displayed on web page.

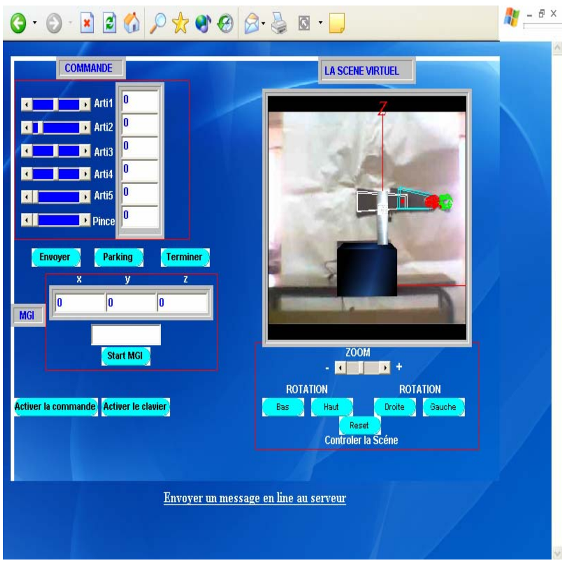

Fig. 8 The graphic users interface displayed on web page.

5. CONCLUSION

We have presented ''MUTSI''; an internet teleoperation station which shows that even with unpredictable time delays of the net, the teleoperation is possible when using intelligently the capabilities of Virtual Reality, Augmented Reality and teleprogramming.

This station gives the possibility to any operator linked to the internet to interact with the remote robot.

We are working to improve more the MM interface, to be able to deal in a better way with the time delay, especially in complex tasks, such as in practical training.

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BIOGRAPHIES

Lahouari Kaddour-El Boudadi was born on 07.02.1967. He received the Eng. Degree in Electronics from the University of Sciences and Technology of Oran (USTO, Algeria) in 1990, and the Magister degree from the University of Sciences and Technology of Oran (USTO, Algeria) in 1995; his thesis title was " Commande dynamique d'un robot à 6 d.d.L". Since 2000 he is working as a teacher with the departement of electronics. His interest is in man-machine interface, telerobotics.

Nasr-Eddine Berrached was born in 1954 in Tlemcen, Algeria. He received the Eng. Degree in Electronics from the University of Sciences and Technology of Oran (USTO, Algeria) in 1978, and the Dr. Eng. Degree from the University of Sciences and Technology of Lille (USTL, France) in 1982. He also received the Dr. of Eng. Degree in Computer Science from the Tokyo Institute of Technology (TIT, Japan) in 1992, and the Dr. "d'Etat" degree in Electronics from USTO in 1994. He joined USTO in 1982, where he is professor at the Department of Electronics. From 1986 he was leading the Laboratory of Robotics, and from 2000 he is leading the Research Laboratory in Intelligent Systems of the same university. His interests include man-machine interfaces, telerobotics, machine vision, pattern recognition, and inverse problems.