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TELEROBOTIC TECHNOLOGIES IN E-LEARNING

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Today, e-learning methods and techniques are commonly used. In the Internet age they mainly employ different standard forms of the transfer of text and audio-video streams.

However, there are disciplines where the education process cannot be realized by means of the standard e-learning technologies, e.g. physics, chemistry or other practical educational courses. The education process requires on-site presence, e.g. in specialist labs.

The telerobotic technologies can allow e-learning for the courses including practical training. We have adapted a few types of the robotic manipulators to can use them for e-learning. Herein, we also present control systems and software developed by us for this idea. The presented works include the most sophisticated haptic equippment also.

Keywords: E-learning, Distance education, Telepresence, Robotics, TeleRobotics, Cartesian Robots, Haptic technology

1. Introduction

E-learning is the term that has a very broad meaning. In especially, it means the use of various multimedia techniques for distance education. The knowledge can be transferred by text, audio, images, animation, and streaming video. Currently, such processes of education are based on Information and Communication Technologies (ICT) [1]. For example, Web sites that contain a variety of didactic courses are the simplest and most common form of e-learnig [2].

The advantages of e-Learning are evident. Knowledge can be transferred at any place, at any time, worldwide. Whoever is taking part in an e-learning course can learn at his own pace in the most appropriate and convenient location. Even the exams and other tests may be carried out via network – most often by Internet. Today, you can so easily imagine that a student can complete his studies and had never be at university.

However, there are learning areas that need a physical on-site presence - for example: physics, chemistry and engineering science. Students in these fields need to practice in different laboratories. Of course there are hybrid (blended) courses for such studies. In this cases, the teaching course is divided into two parts. One of them is the e-learning course and the second part that is hands-on training. The solution is not always optimal.

In recent years, it is observed drastically decrease of interest in learning physics, chemistry and so on. This applies to courses ranging from basic to advanced. In a few years, it may have not enough specialists in many fields of industry and science. To solve this problem, the special didactic projects should be implemented for those who want to study in these areas. From economic point of view, the maintenance of the specialist teaching staff and laboratories in most schools is not cost-effective for such small groups of students. The perfect solution is to support the teaching by e-learning methods. There are a lot of ways for such teaching. Of course, every student can complete an e-learning course before joining a hands-on training. The practical training can be done in specialist learning centers. Of course such training requires the presence in these centers - it is rather unthinkable for students of primary and secondary schools. Today, there are technical possibilities to eliminate the need for the physical presence in many laboratories for practical exercises. In recent years, many tools useful for telepresence [3] have been developed [4] – for example, webcams are widely available. They deliver audio video streams in real time. Many of them can be remotely controlled by a common web browsers. In short, there is ready hardware and software to watch something that is happening somewhere far away. So the existing audio-video tools for the passive telepresence allow the users to feel as if they were present in remote location. Importantly, these elements are commonly used. They are very popular and commercially available and low-cost also.

To achieve effect of active telepresence, the adequate telerobotic tools are needed.

They are needed to cause different events and manipulate various objects in remote location.

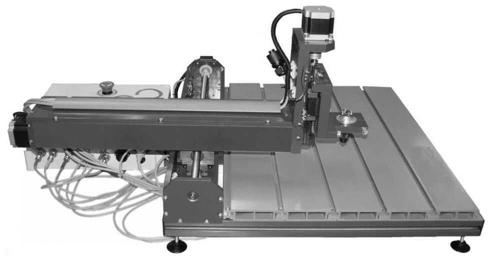
Below, there are described our works on telerobotic technologies dedicated to create tele-laboratories that can be used in e-learning. We have developed special software system to test different types of robots, including the most sophisticated haptic equipment also.

2. Analysis of type of robotic manipulators for e-learning

We have done analysis of types of robots in terms of their usefulness in e-learning applications. Generally, robots are electro mechanical devices (most often controlled by computer system) that can perform various physical tasks [5]. There are currently known software robots also. They can be used to replace teachers in performing some repetitive functions. Of course they may find very wide and different use in e-learning but it is not a subject of interest in this work.

Fundamentally, the physical robots consist of an electro-mechanical manipulators and computer systems. to drive the manipulators. The computer system controls the manipulator and can do so in two ways: autonomous or in manual mode. Basically, for the e-learning tasks, the manual mode is useful. Of course, the system must be adapted to use the manual mode from any distance through network.

Classical robotic arm



Cartesian manipulator

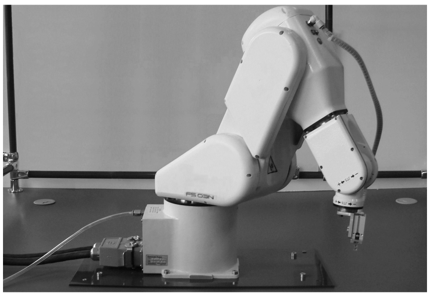
Figure 1. The static robotic manipulators

There are a lot of various constructions of the robotic manipulators [6, 7] – e.g. mobile machines, humanoid robots, static robotic arms and Cartesian robots and many, many others. It seems that only the last two of these groups of manipulators (see the Figure 1) can be most useful in tele workshops.

3. Classical robotic arms

A robotic arm is a type of the manipulator with similar functions to a human arm. The human arm ends a hand with fingers. The end of the robotic arm is called the end effector. A gripper can be the end effector and then it is analogous to the human hand. Thus, it seems natural that the construction is optimal to replace student hand in remote location. There is a great choice of different constructions of the robotic arms ranging from industrial equipment and ending on the gadgets for robotic fans – see the Figure 2. We tested both robotic arms presented on the figure 2.

It is worth noting that the mentioned robotic gadgets are very cheap and they are often equipped with electronics to control them by computers. Some of them have a metal structure but despite all their capabilities are very limited - maximum load and coverage are very small. Moreover, many of them do not have position sensors but often enough to visually determine the position of the end effector. In summary, the mentioned disadvantages make that the equipment can be helpful only for building models of tele laboratories, in especially for testing software.



Industrial robotic arm

Small arm - toy for robotic fans

Figure 2. The radically different models of robot arms

The considered models of the robots are very easy to adapt for controlling their from a distance by network. The simplest way is the use of so called Remote Desktop Protocol (RDP) that is embedded in many computer operating systems, including the well-known 32-bit and 64-bit versions of WINDOWS – see the Figure 3.

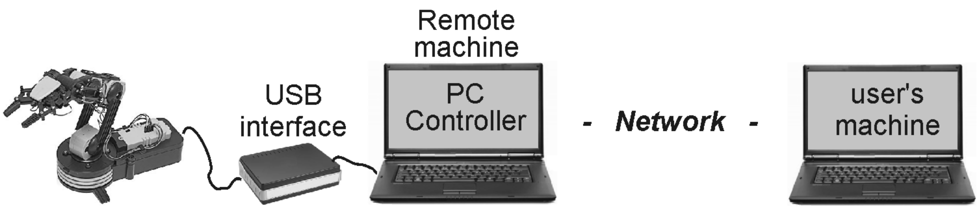


Figure 3. The scheme of remote controlling for simple small models of robots

The tested industrial arm has a lifting capacity up to 3 kg and a coverage of about 0.6 meters. The device is very effective and very efficient and long life equipment that can fully replace the human hand in a large number of activities. Of course the arm is equipped with position sensors with high accuracy better than 0.1 mm. The arm is controlled by a special autonomous controller which practically is a computer equipped with standard ports and a network card. However, the computer is not ready for direct implementation of a tele-control system. The special computer software of the controller frees users from problem of solving the inverse kinematics equation [x]. Normally, it is needed for calculating all joint angle values of the manipulator to set its arm in desired position. In this case, only values of the linear position and the angular orientation of the end effector should be sent to the controller. It is done by serial port RS-232 – see the Figure 4. The data is sent from the proxy computer that has the TCP server installed (based on Transmission Control Protocol). The special TCP server has been designed by us. It ensures exchanging data between network and the computer serial port. The server software has been designed for WINDOWS platforms.

User computers (client machines) can be a full-fledged WINDOWS computers or any other devices with TCP Client software (e.g. mobile phones or tablets and so on).

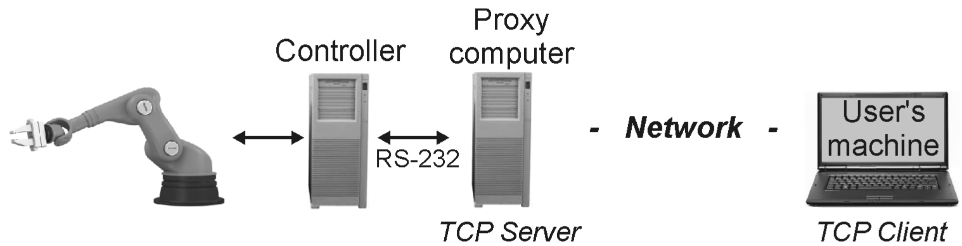


Figure 4. The scheme of remote controlling for the industrial arm

Despite the many advantages, this is by far the most expensive equipment tested in this work.

There is another problem, that is however symptomatic for all family of robotic arms regardless whether they are industrial devices or robotic gadgets. There is a risk that users can perform operations that could damage something in the tele laboratory. Ideally, it would be protected the tele-manipulator system against such adverse activities. However, it is difficult to effectively limit the scope of operations performed by such manipulators. It is relatively easy to limit the workspace for the end effector but there are other operations that can be undesired (e.g. wrong angular orientation in a given point in space, and so on). Thus, the utility of such manipulators for e-learning is debatable and if possible it should be use the other robotic tools.

4. Haptic tools

In the systems presented above, their users can control the tele-manipulators by standard input devices as a keyboard, a touch screen or a computer mouse. The results of their actions may watch through audio-video streams obtained from a remote location. It is good if a software interface is friendly and it is possible to instinctively control different operations taking place far away from us. Generally, this is not the most intuitive way for controlling performed operations.

It would be ideal if intuitive interfaces for the robotic arms could be based on natural possibilities of a human hand. An linear and angular position of the hand should clearly define appropriate position of the robot. Also it is desirable to sense touch. This can be useful to be able to feel the resistance when the hand is moved too fast in relation to the possibility of the manipulator. Also we should feel resistance when the end effector is on the border of the allowed area of operation. Moreover, the manipulator operates in 3D space so intuitive control devices have just such spatial properties.

To realize such intuitively interface, the commercially available input device has been used. It is called "Phantom Omni® Haptic Device" – see the Photo 5. This device is a practical example of the use of haptic technology [8-10] – it is a tactile feedback technology which would allow a user to feel stimuli from the remote environment.

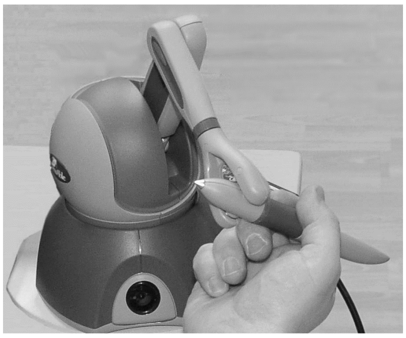


Figure 5. The PHANTOM Omni® haptic device

The implemented tool is equipped with the special stylus that features 6-DOF positional sensing in the cuboid space (Width = 160 mm, High = 120 mm, Depth = 70 mm). The stylus tip is gimbaled and it is able to detect Yaw, Pitch, Roll and angles with about ± 5% linearity. Moreover the haptic provides the sense of touch (tactile) by generating force feedback up to maximum value about 3,3 N. It is enough to employ the device as the instrument for the operator to control the manipulator.

This haptic device has been implemented in our works not only for the intuitive controlling. It can be also useful for testing the hardness of materials or to give sense of touch of objects placed in distant locations. For example the softness of various materials can be tested if the manipulator is equipped with proper force sensors (standard components in robotics). In especially this system can be built from the pair of the presented haptic devices (one haptic is used as the manipulator). All the tasks can be performed using the computer system as shown on the Figure 6.

In the simplest terms the system works as follow. The linear and angular coordinates are read out cyclically from the haptic controller by the user computer. They are transferred to a manipulator controller (computer) via network. There the data are analyzed also taking into account the dynamic of the operator's gestures. Now, the manipulator is controlled accordingly to the results of the analysis. The computer controller returns the data determining the amount of force to be generated on the user's hand.

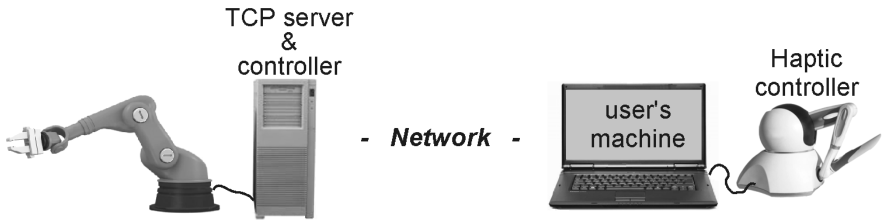


Figure 6. The architecture of the haptic system

It should be noted that the haptic controllers may be used also to control virtual objects. Thus, it is possible to create virtual e-learning laboratories from which we receive not only audible and visual stimuli but also touch stimuli.

The main disadvantage of such methods for controlling a remote operation is that they require from users to possess the haptic devices and the haptic equipment is very expensive.

5. Cartesian manipulators

Cartesian manipulators are very often encountered machines in small business and large industry. The robots based on these manipulators are also called linear robots since their end effectors can move linearly along three mutually perpendicular axes [11]. One of the most popular applications for the manipulators are computer numerical control (CNC) machines. These machines are relatively very cheap. Also the required electronics to these machine is very simple. There are many standard commercially available components dedicated for the purpose. Usually, the step motors are used to move the end effector. The motors are controlled by electronic drivers interfaced with a PC computer. Through very many years the CNC machines were interfaced with computers by so called a parallel port – often also called LPT (Line Print Terminal). The typical control system for the CNC machine is shown on the Figure 7.

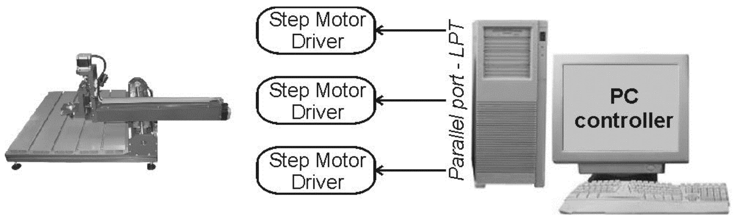
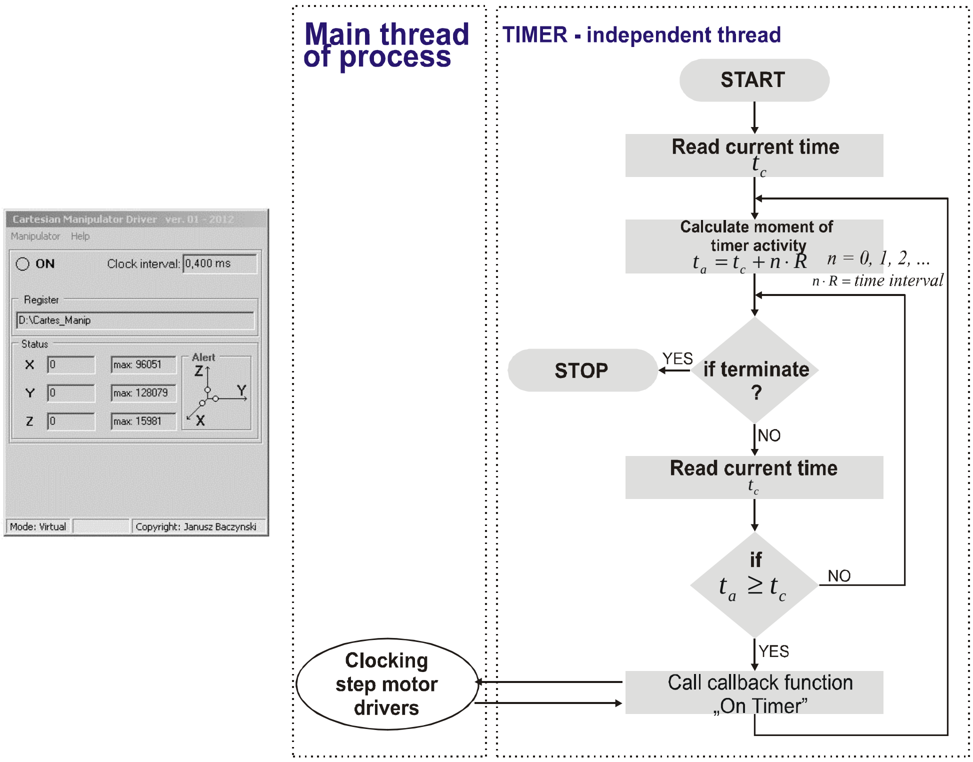


Figure 7. The control hardware of the CNC machine

The step motors drivers must be clocked by pulses with frequencies up to several or dozen kHz. Therefore, the PC controllers (common PC computer) that generate the clocked pulses are often equipped with real time operating systems. It is the good solution when the use of the PC controller is limited only to control the manipulator movement.



The screenshot The simplified flow chart of the timer

Figure 8. The application “Cartesian Manipulator Driver “

In this case all other operations are performed on other computer machines that are linked with the PC controller. For the tele operation applications the computer with multitasking operating system is much more convenient. We have used the PC controller with the system WINDOWS XP and have developed special multi-threaded application to control the manipulator. It has named “Cartesian Manipulator Driver” – see the Figure 8. In this application we have employed the system mechanism called the high-resolution performance counter - in the PC used by us, the resolution of this counter is equal to 279 nsec. In this way we have achieved the possibility of clocking step motor drivers with frequency up to 10 kHz.

The Cartesian Manipulator Driver consists of two threads. One of them is a timer – Fig. 8. The main thread is used to display the current position on the manipulator end effector and for so called “arm solution” – solution of equations of motion of the manipulator [12]. The two thread structure allow the calculation of all parameters needed for the manipulator movement without slowing down clocking the stepper motor drivers.

The following architecture of the tele control system for e-learning applications of the Cartesian manipulators has been devised – see the Figure 9. The prototypes of all software components has been realized and practical tested. The described system has been tested on the local network (LAN) and the Internet. All tests were very successful and showed that the Cartesian manipulators can be easily controlled from any distance. Moreover we have designed the special mechanism to limit the range of movement of the manipulators. It is useful to protect the telelaboratories against irresponsible users.

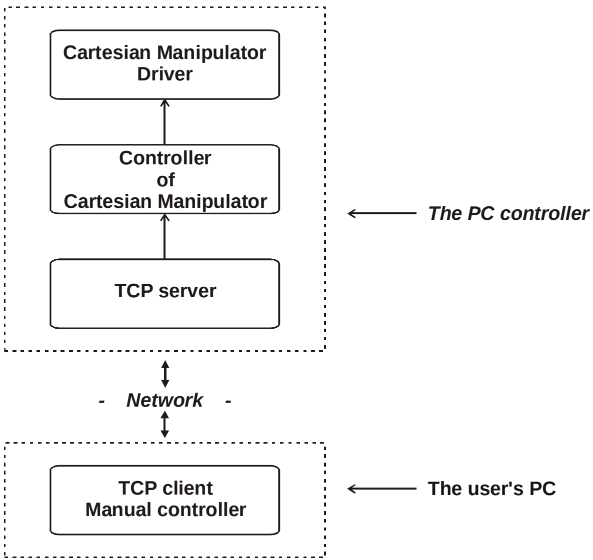


Figure 9. The architecture of the tele control system for the Cartesian manipulators

6. Conclusions

The aim of this work was to analyze the different types of the robotic manipulators in terms of their suitability for e-learning. The two selected types have been tested in practice by special developed software. Addition, the haptic controllers was tested and for this purpose the special software has been developed also. The system has been tried successfully on a small group of computer science students at Faculty of Physics and Applied Informatics of University of Lodz..

The classical "robotic arms" are most efficient and effective. However the equipment has two very essential disadvantages:

- very high price of these manipulators,
- it is difficult to protect the remote environment against the undesired operations.

The haptic controllers greatly improve the intuitive control from a distance. However, they are expensive and each user of the tele laboratory would have to have the equipment.

The Cartesian manipulators are most optimal devices for remote operations. They are relatively cheap – even about ten times cheaper than industrial robotic arms. They are easy to protect them against unwanted operations performed by the users of the tele laboratories.

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