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A DISTRIBUTED LABORATORY FOR AUTOMATIC CONTROL AND ROBOTICS EDUCATION

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Abstract: Traditional classroom education approach gives students only few opportunities to experiment the subject matter by themselves, which is in fact the best approach to learning. As a consequence, teachers have increasingly turned to real-world experimentation, which is based on laboratory-scale processes. There are many cases when real-world experiments are too expensive to buy, and this is the case in most Central European Universities. This paper presents a distributed laboratory for automatic control and robotics education based on telepresence, the sense of being present at a distant location. Different experiments and set-ups are presented.

Keywords: telepresence, intelligent control, autonomous robots.

1. INTRODUCTION

At a dawn of a new information era, major changes in education require new approaches and methodologies. It is now critical to maximize the effectiveness of technology for learning. The main challenge is how to use the advantages of digital communication technologies, and multimedia systems, and how to integrate them with the traditional education.

The aim of this paper is to present a distributed laboratory for automatic control and robotics education. Its main idea is to use telepresence as an efficient vehicle for flexible learning. This paper presents simple and more complex laboratory experiments that help students to understand the basic concepts of automatic control and robotics. The paper is organized as follows. Section 2 describes our distributed laboratory while section 3 describes local experiments that are available for the students. Section 4 presents some possibilities to use telepresence for education, that is to run the laboratory experiments from a remote location. Section 5 gives some conclusions and directions for further research.

2. DLAB- A DISTRIBUTED LABORATORY FOR AUTOMATIC CONTROL AND ROBOTICS

Virtual laboratories are attracting more and more researchers and educators. A virtual laboratory is a heterogeneous, distributed problem solving environment that enables a group of researchers located around the world to work together on a common set of projects [1]. It deserves its name if the respective applications are supported by virtual reality software and hardware. If not, it is better to name that laboratory just "distributed". The key components of such a laboratory are:

- Powerful computer servers;
- Dynamic and distributed data bases with application specific information;
- Different equipments and instruments that are connected to the network, e.g. sensors, actuators, controllers etc.;
- Collaboration tools, such as chat, MUDs, tele-immersion;
- Software tools (modelling, simulation, visualisation etc.);
- Advanced network technologies and services, such as bandwidth reservation services.

A Distributed LABoratory (DLAB) for automatic control and robotics has been opened at "POLITEHNICA" University of Bucharest since November 2000. It is distributed in the sense that it uses computers, robots and pilot plants that are located in 3 different usual laboratories. DLAB is virtual in the sense that a remote user gets an impression of unity behind all these distributed resources. DLAB is used mainly for teaching robotics and automatic control, but some applications allow the integration of a research dimension. As the main paradigm, it uses telepresence which means a virtual presence at a remote location that is served by information and communication technologies. By using a wide range of technologies that can be classified as audio, data, video and virtual environments, a human user can get a sense of being present at that remote location. When multiple users are virtually present at the same remote location one can speak of collective telepresence.

DLAB has three Khepera autonomous robots and one Koala robot. The Khepera robot is a miniature mobile robot with functionality similar to that of larger robots used in research and education. It allows real world testing of algorithms developed in simulation for trajectory planning, obstacle avoidance, pre-processing of sensory information, and hypotheses on behaviour processing. The Koala robot is a mid-size robot designed for real-world applications. Bigger than Khepera, more powerful, and capable of carrying larger accessories, Koala has the functionality necessary for use in practical applications, rides on 6 wheels for indoor all-terrain operation, and sports stylish bodywork for attractive demonstrations [2].

Of course, the Internet is an ideal candidate for telepresence systems and there are already some remote control laboratories in use. In [3] it is presented a general framework for implementing and deploying remote experimentation solutions. Java and LabView implementations are considered and compared. The application taken into account is the teleoperation of an inverted pendulum which seems to be a favourite application for teleoperation via Internet [4]. However, even industrial pilot plants are being considered as candidates for remote control [5].

DLAB applications can be classified as local and remote applications. Local means that the students take the experiments while they are located in any of the 3 laboratories, and remote means that the student run the experiments from a remote location. All that is needed in this case is a computer with an Internet connection.

3. DLAB LOCAL APPLICATIONS

3.1 Braitenberg vehicles

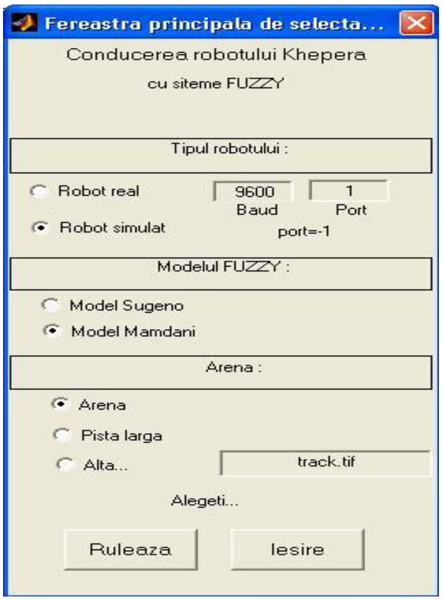
The student has the possibility to test simple Braitenberg vehicles [6] that are artificial creatures which are still extremely simple, but show fear, aggression, love, and affection combined with a wandering eye. The following Braitenberg vehicles can be tested on real Khepera robots and in simulation [7]:

1. aggresive robot: the robot detects obstacles, either static or moving, and moves straightforward to them;
2. loving robot: it “likes” a light source (or an obstacle) staying close to it;
3. coward robot: it “dislikes” light sources or obstacles and runs away from them;
4. explorer robot: it “likes” the nearby source (or obstacle), but keeps an eye open for other, perhaps stronger sources.

The second step for the user is to simulate 2 robots. The user can specify a pre-defined behavior for each robot. For example, the first robot could be aggresive, while the second could be coward (in Braitenberg’s terms). So, one can simulate the well known prey-predator problem (or the cat-mouse problem). The control algorithms are written in Matlab, Java and LabView.

3.2 Intelligent control techniques

The advanced student is able to test intelligent control methodologies, such as fuzzy logic and neural networks, both on real robots and in simulation [7]. Fuzzy control applications are described elsewhere [8] and a front panel of this application is given in fig. 1. Applications of genetic algorithms to tune fuzzy logic control systems for the Khepera robots are described in [9].



Conducerea robotului Khepera
cu siteme FUZZY

Tipul robotului :
○ Robot real — 9600 Baud — 1 Port
● Robot simulat — port=-1

Modelul FUZZY :
○ Model Sugeno
● Model Mamdani

Arena :
● Arena
○ Pista larga
○ Alta... — track.tif
Alegeti...

Khepera Control Center

Comunication Setup
COM: -1
BPS: 19200

Application Setup
Time: 500
☐ Train
File Name: custapp

Aries Titus Grigore
UPB 2001

Fig. 1 Fuzzy control window

Fig. 2 Neural control

Advanced control engineering and cognitive science students are able to test intelligent controllers that are based on neural networks. Simple neural networks structures and training algorithms were tested for different tasks, such as wall following and obstacle avoidance. First of all, a joystick is used to manually control the robot. During this training session, all the data (from sensors and actuators) is collected and further used for training the neural network. The simplest neural network that is used has only two layers, with 8 input neurons (there are 8 infrared sensors) and 2 output neurons (there are 2 wheels). For more difficult tasks, a supplementary hidden layer can be added. For training the net, one can use different versions of the usual back-propagation algorithm. In fig. 2, one can see a front panel of such a neural network based robot controller.

In both cases, the user is able to control as many real robots as many serial ports are. The fuzzy controllers and the neural controllers can be further refined and tested in different real conditions. So, the student can understand the basic principles of fuzzy logic control and neural networks. Both applications are written in Matlab.

4. REMOTE ROBOTICS EXPERIMENTS

Another set of applications addresses the problem of control of autonomous robots from a telepresence point of view. That means that any user can control the robots from a remote location.

4.1 Java systems

First of all, a Java based system was designed to allow the user to remotely test some Braitenberg like algorithms. The user has the option to remotely test simple robot commands (turn left, back, forward etc.). Secondly, the remote user has the option to select from four possible behaviors (aggressive, loving, coward, explorer) and to remotely test each behaviour. A video window is always displayed on the screen, giving the user an idea of how looks that particular behaviour. The Braitenberg-like control algorithms, which simply relate the motors of the robot to the sensors, are written in Java [8]. This experiment is used by students in automatic control and by students in cognitive science, as well.

4.2 LabView based systems

LabView based applications are very powerful and easier to develop in a graphical oriented environment. A simple and free LabView player is available on the net. The remote student can control one robot (see the client in fig. 3). This robot may be or may be not a member of a team of two robots that are connected to the same remote server. The user can also control both robots at the same time (see the client in fig. 4). Further details are given in [10]. One can test for each robot a simple obstacle avoidance rule-based algorithms and 4 Braitenberg control algorithms (the same as above) having a continuous visual feedback. The system works fine and it is the first remote collective robotics experiment described so far.

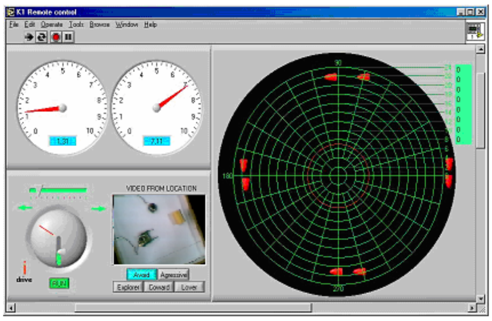
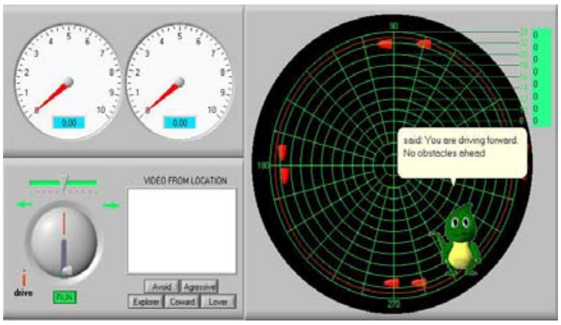


Fig. 3. Telepresence client (1 robot)

Fig. 4. Telepresence client (2 robots)

The remote control experiment described above can have an increased pedagogical impact by using software agents. The first experiments of this kind are described in [11]. The approach that is currently used in DLAB is based on the Microsoft® Agent technology and a first idea was to use conversational agents is aiming to help students to understand the experiment before it starts. This is why a conversational software agent is integrated using Visual Basic Script into the DLAB's web page [9]. When the relevant page is open the agent appears and gives basic information about the experiments that can be taken (fig. 5).

Fig. 5 Off-line software assistant



said: You are driving forward.
No obstacles ahead

Fig. 6 On-line software assistant

The second way of integrating conversational agents is to use them on-line. That means that one agent is integrated into the telepresence client (fig. 6) and gives the user a feedback of his actions ("you are driving too fast", "there is a close obstacle to the right" etc.) and even can stop the robot in emergency cases.

5. CONCLUSIONS AND FUTURE WORK

The tele-access to remote experiments and learning environments will drastically reduce the infrastructure requirements of experimental equipment for practical work in training engineers. The main contribution of this paper is that it proposes an integrated way of teaching basic automatic control and robotics using a distributed laboratory. Local and remote experiments are available for students. For further developments, new experiments and pilot plants (such as a servomotor and 3-

dimensional crane) will be integrated for remote use. Both classical and advanced (intelligent) control solutions will be proposed and compared in terms of benefits, and drawbacks. Finally, DLAB will be integrated into a global network of remote control laboratories named Globe@Lab.

Security problems related to this kind or remote experiments and access to autonomous robots represent a delicate problem which need further research. Until now, the remote access to the robots has to be pre-scheduled with the instructor.

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