COLLABORATIVE LEARNING AND ENGINEERING WORKSPACES

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Abstract: Research results of improving remote collaboration are presented. The results are based on a new concept of mixed reality. It is capable of to train collaborative work over remote sites. The collaborative environment makes use of the system named deriveSERVER, which has been developed by the Artec Research Center (University of Bremen). It is extended to allow the integration with remote hardware. Remote experiments are used to enhance lessons in SENAI-RS, a vocational education institution in southern Brazil, enabling the development of collaborative projects among students at different sites. Copyright © 2007 IFAC

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1. INTRODUCTION

Collaboration is working together towards a common goal at different times, in different locations, at different companies in different functions. Principles are: support collaboration within the entire working team including external suppliers and partners, support flexible team participation to minimize collocation as a team requirement, benefiting individuals by making their job easier and helping to achieve work-live balances, providing a collaborative environment, allowing the team to tap into their inherent creativity and power of sharing ideas, focusing on people, process, communication and relationships in addition to technology. But now the challenge is to extend this theory to globally distributed enterprises. The benefits of distributed collaboration are: reduced problems of resolution cycle time, increasing productivity and agility, reducing travel to remote sites, enabling more timely and effective interactions, faster design iterations, improving resource management and facilitate innovation.

Collaborative work over remote sites in so called virtual teams is therefore a challenge to developers of information- and communication technology as well as to the involved workforce. Collaboration demands a deep involvement and commitment in a common design, production-process or service; i.e. to work jointly with others on a project, on parts or systems of parts (Erbe, 2005). Information mediated only via vision and sound is insufficient for collaboration. In designing and manufacturing it is often desirable and in maintenance it is necessary to have the parts in your hands. To grasp a part at a remote site requires force (haptic)-feedback in addition to vision and sound.

Engineering education has to consider this development with providing learning environments for students to train collaborative work over distances where face-to-face work is excluded. Müller & Ferreira (2004) reported about remote-lab development of the EU-project MARVEL – a mixed reality learning environment for vocational training in mechatronics. An EU funded project, Rexnet (2006), between European and Latin-American universities, created a network of remote labs.

2. INTERFACE BETWEEN REAL- AND VIRTUAL- WORLDS

In mixed reality concepts distributed environments information flow can cross the border between reality and virtuality in an arbitrary bidirectional way. Reality may be the continuation of virtuality or vice versa. That provides a seamless connection between both worlds. This bridging or mixing of reality and virtuality opens up some new perspectives not only for work environments but also for learning or training environments (Müller, 2005).

2.1 Energy Interfaces (Hyperbonds)

In dynamic systems the system-components are connected through energy- (or power-) transfer. Power is a product of effort (e) and flow (f). Effort e stands for force, pressure, voltage, etc., and flow f stands for velocity, flow of a fluid, current, etc. A dynamic system can be cut off, but at the intersection respective effort and flow have to be provided at either side of the intersection to maintain a dynamic equilibrium. This is the task of an interface: to sense effort and flow at one side of the intersection and generate effort and flow at the other side and vice versa. That can be done with analog values between either sides of a real system that has been cut off. However, the interface has to be controlled to maintain the dynamic equilibrium (Bruns, 2005).

If the real dynamic system should be continued digitally with software running on a computer (virtual dynamic system) the analog sensor-signals have to be converted into digital values for the software side of the interface. The opposite direction requires digital values from the software being converted into analog signals that generate effort and flow at the real dynamic system.
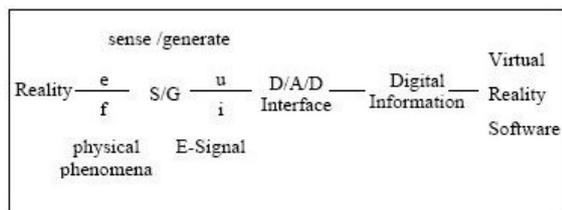

Fig. 1. Components of the energy interface (Hyper-bond).

Figure 1 describes in general the interface between the real world and the virtual world: Effort and flow are sensed (or generated) providing voltage and current (or effort and flow in the opposite), an analog-digital converter provides digital information for the software (or an digital-analog converter converts digital information in analog signals to drive a generating mechanism for effort and flow to the real world).

This interface, called "energy interface" or Hyperbond, generates or dissipates energy (or power). The power, provided through the real system, has to be dissipated, because the virtual continuation with software needs nearly neglecting power. In the opposite direction, the digital information provided through the software, have to generate the power necessary to connect the real system.

2.2 Application for a discrete time event system

Electro-pneumatic components installed at a real workbench are connected to a virtual workbench with electro-pneumatic components stored in a library. Because the valves can only be open or closed, the cylinders only on or off, one has only discrete events. The energy interface, called Hyper Bond, receives digital information from the virtual workbench and generates air-pressure and air-flow as well as voltage and current for the solenoid valves and cylinders at the real workbench (Fig. 2). In the opposite direction the energy interface senses air-pressure and air-flow as well as electrical signals to convert it into digital signals. No feedback control within the energy interface is necessary.
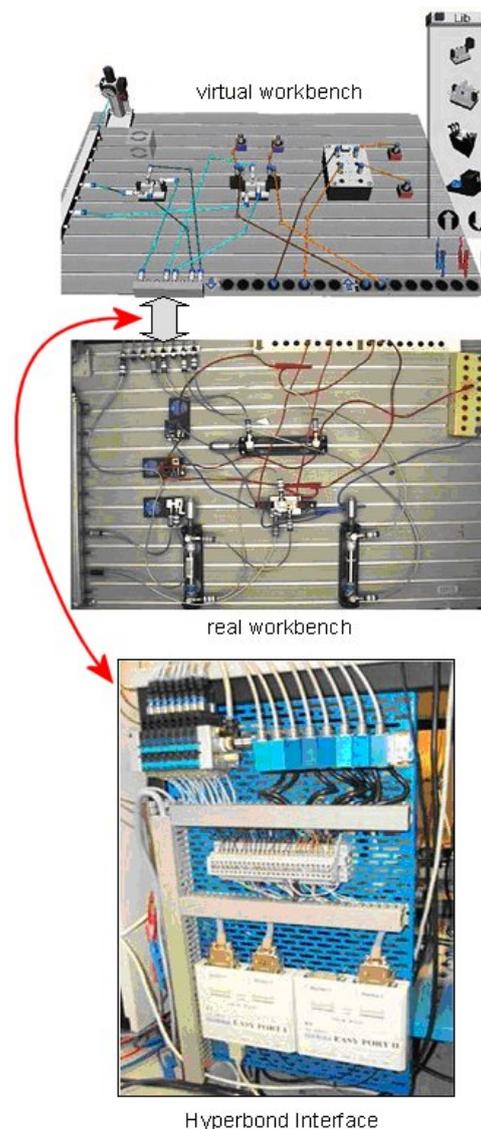

Fig. 2. Real and virtual pneumatic workbench connected with an energy interface (Hyper-bond).

The virtual and real workbench can either be located at a local site or at remote sites connected via the Internet. Also the virtual workbenches may be

distributed at different sites connected via the Internet to the (only one) real workbench. The software of the virtual workbench allows the access of many users at the same time. Therefore students or workers distributed at different locations can together solving tasks at their virtual workbenches and export it to the real workbench for testing their common solution in reality.

3. CAVE AS A WORKSPACE OF REAL AND VIRTUAL WORKBENCHES

The connected workbenches are located in CAVE - like constructions. These consist of scaffolding with canvases where the images of other workspaces with the persons working in it are beamed. The architecture is shown in Fig. 3. Computers connected to a server control the beamers.
The hyper-bond connects the two parts: the real and virtual one. Thus any flow through this kind of object is automatically forwarded to reality or vice versa. Changes in reality are distributed by an updated simulation but also by a camera observing the real hardware. The virtual part of a running session can be stored on the server and reloaded later to continue the work task.
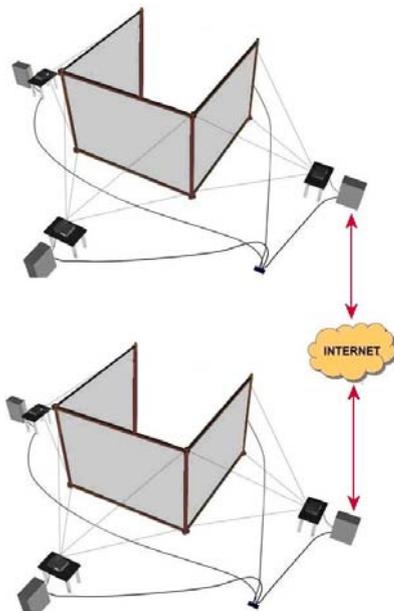

Fig. 3. Sketch of CAVE's (scaffolding with canvases, beamers and computers).

Figures 4 and 5 show the arrangements used for the test cases. The common virtual workbench and the real workbench (via video projection) are available via the Internet and visible at an enlarged screen or are beamed at canvases fixed at the scaffolding.
A student or a group of students are operating at the real workbench and are communicating with students at the distributed virtual workbenches thereby using internet telephony. If the students at the virtual workbenches claim for additional or other components at the real workbench the students there have to respond respectively.
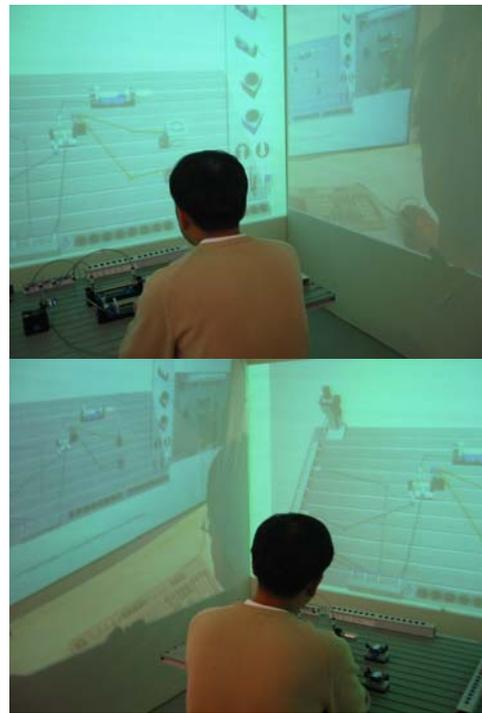

Fig. 4. Workspace with the real workbench, the virtual one in front and the remote counterparts screened on the left and right canvases.

Fig. 5. Two remote workspaces connected with the remote workbench.

4. APPLICATION IN A COMMON PROJECT: ARTEC (GERMANY) AND SENAI (BRAZIL)

SENAI-RS as an important technical education institution in Brazil, interested in new techniques recently developed in mechatronics education, established cooperation with the Artec Research Center (Bremen) and the Federal University of Rio Grande do Sul to develop a mixed reality application with electro pneumatic devices used in industry.

The basic idea of the project was to extend the deriveSERVER (Bruns and Erbe, 2004) developed at Artec Research Center (Bremen) to the educational needs of SENAI Mechatronics Technology Center.

4.1. DeriveSERVER Description

The deriveSERVER is a system that provides remote access to a virtual reality environment (based on 3D virtual models) and also a real experiment. DeriveSERVER stands for distributed real and virtual learning environment for mechatronics and tele-service.

The used experiment in the remote and virtual laboratory was a traditional electro pneumatics workbench used in mechatronics with cylinders, valves with pushbuttons, solenoid valves and much more, providing a simple discrete control.

The system was not designed (developed) to treat analog signals, so analog devices are not used, therefore only discrete control is possible with Boolean variables. Solenoid valves can be driven by electrical current, making electrical control possible as typically used in electro pneumatics systems.
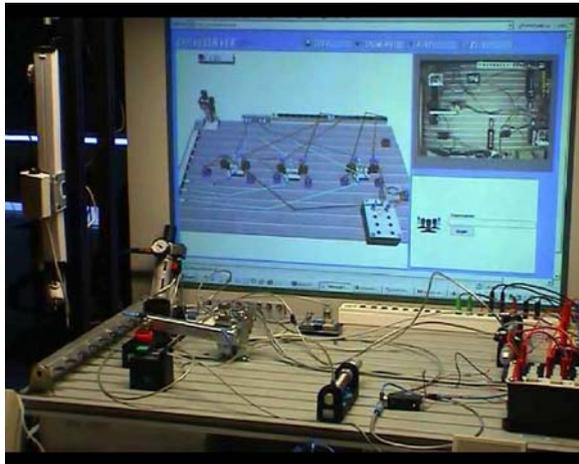

Fig. 6. Local tests mixed reality installation.

According to the Fig. 7 the mixed reality interface is available in the Internet displaying the real video capture and the virtual workbench using the Internet Explorer (IE) web browser from Microsoft, Java Runtime Engine from Sun Microsystems and the Cortona VRML client plug-in for IE. The dash-dot line displays the path covered by the virtual-real signal.

This software and hardware architecture provides a reliable system capable to simulate (virtual workbench) and use real equipment to improve education in basic pneumatics (also mechatronics), system automation and system process development.

5. SENAI INDUSTRIAL TRAINING

5.1 Training Structure

The SENAI Mechatronics Technology Center in Caxias do Sul, Brazil (SENAI-Mecatrônica, 2006), offers technical school for young students that are
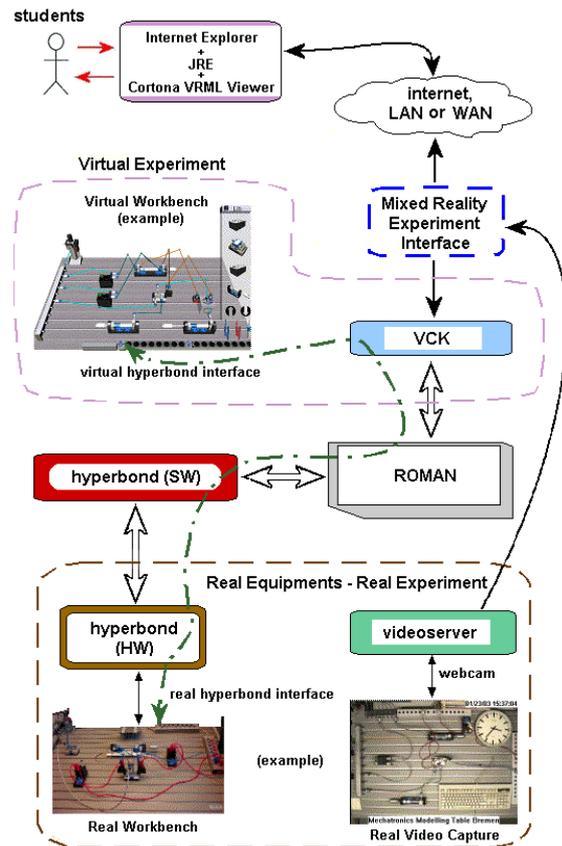

Fig. 7. Derive SERVER interaction architecture.

interested in becoming a technician in mechatronics. The study classes are used to teach most of the technician basics, like: Technical Drawing, Electricity and Electronics Principles, Computation and Programming, Hydraulics and Pneumatics, Control Systems and Devices, Management Principles and also basic technical English language.

5.2 E-learning Courses at SENAI

The entire SENAI-RS institution uses at least 3 different custom e-Learning platforms to give students a collaborative environment, common space sharing and teacher feedback. The first one is TELEDUC, a software developed by the University of Campinas (Unicamp - Brazil), under free license. TELEDUC has been subject of research for the past six years (Otsuka and da Rocha, 2002). The second is WebEnsino (Ilog, 2006), developed and commercially offered by ILOG – Brazil, licensed to SENAI-RS. The third one is the MOODLE platform (MOODLE, 2006), used recently under free license (GPL) in this project.

All courses, elaborated by the SENAI educational personnel, follow the competence-based model aimed at professional skills that are coherent with the contemporary market and productive world demands. Therefore, the courses follow a specific methodology, called the Challenge Methodology (SENAI-DN, 2002), which has his main development approaches in the PBL (Problem Based Learning; SENAI-DN, 2002) and in the Problematization Methodology (Berbel, 1999).

6. COLLABORATIVE TASK SOLVING IN REAL AND VIRTUAL WORKBENCHES

The task is to develop and test an e-pneumatic control circuit for automatic welding operations: work pieces are fed and clamped; the welding operations are activated (Figure 8). When the welding is finished the clamps open and the work pieces are ejected. Within this scenario three groups of students at different locations are involved to perform the following tasks: developing the control virtually, testing it at a real workbench. To solve this task collaboratively work spaces are linked through the Internet. The virtual workbench can be accessed via the Internet so that students or engineers at remote locations are able to solve the task collaboratively. The students at the real workbench can also manipulate the components at the virtual workbench, and all can communicate visual and via internet telephony.
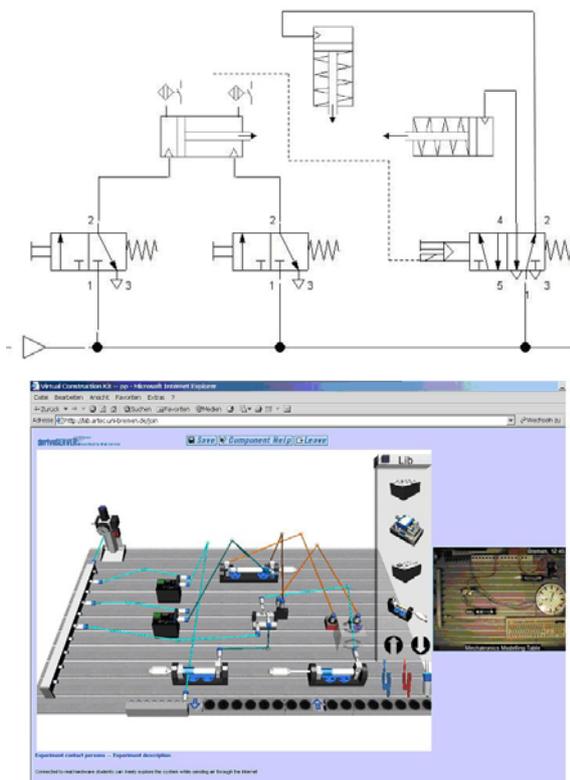

Fig. 8. Electro-pneumatic control of a welding operation; virtual and real workbench.

When a solution of the control tasks is found at the virtual workbench the solution can be partly or completely exported via the hyper-bond interface to the real workbench.

7. RESULTS

Special courses in the e-learning system MOODLE were developed to help student perform and understand the theory involved in the mixed reality experiments. Educational material was carefully designed to embrace Portuguese and English languages. The selection of the language is controlled in the MOODLE system. The deriveSERVER system was integrated in the MOODLE interface so that students can learn and interact collaboratively in a common virtual environment (VLE). The VLE contains didactic materials divided into 4 major courses:

- Devices Manual
- Use of the deriveSERVER system
- Experiments Guide
- Basic Electro Pneumatics

The first course contains all documentation of the electro pneumatic devices involved in the experiments separated into sensors, actuators and other devices. The second course contains didactic material (step by step tutorial) used to teach students to perform experiments using the deriveSERVER. The experiment guide course is used to control the sequence of experiments (in the deriveSERVER) that the student should do accordingly to his performance. The last course, but the most important, contain all theory material of basic pneumatics commonly used by teachers and technical instructors in SENAI Mechatronics classes.

The hyper-bond software (SW) interface was modified to support, additional to FESTO EasyPort hardware (HW), OPC (OPC Foundation, 2006) communication, and parallel/serial port HW communication.

Thanks to the client-server architecture (communication sockets) of the hyper-bond to the experiment manager (ROMAN), students can use local hardware attached to simple parallel PC port to interact with the experiment.

The Fig. 9 illustrates hardware interactivity and his communication interfaces. The discontinued arrows show the enhancements in the system interactivity. Students can manipulate all the interfaces in a single experiment locally or remotely.

The virtual pneumatics workbench (VCK interface), accessible through the internet web browser, links the hyper-bond I/O to any and every software or hardware attached to the system.

8. CONCLUSIONS

The presented mixed reality concept support collaborative learning in remote labs and distributed workspaces. In addition, the bidirectional tele-cooperation functionality allows extended enterprises to use the Internet for collaborative engineering. Also with new plant equipment being more complex and requiring more complex maintenance, the training requirements for workforce and engineers increases. The presented environment will allow groups of employees at remote locations to take part at the same training using the same equipment (either virtual or real). The students or workers are able to work in a collaborative way to solve problems and explore problems to be solved. This kind of interaction provides a systematic support for student, skilled workers and engineers. The environment can be used as an appropriate and cost effective tool to support collaborative engineering.
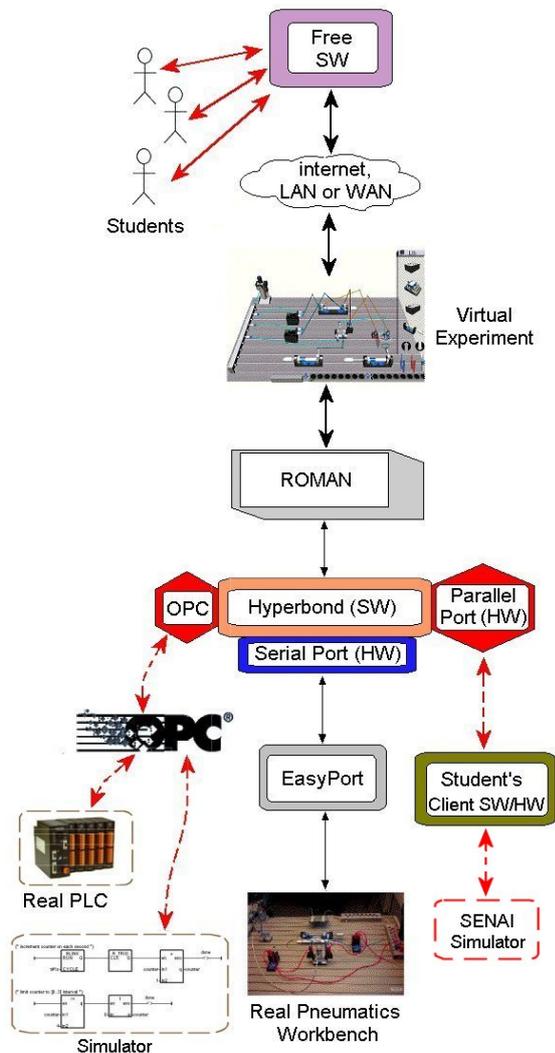
Fig. 9. Hyper-bond new communication interfaces.

The system allows integration of different remote equipments or simulators providing a common The system allows integration of different remote equipments or simulators providing a common environment to remote collaboration of remote experiments. This is especially important to cost effective remote experimentation, since among remote experimentation partners, real hardware must not be duplicated acquired.

The Fig. 10 depicts the current SENAI installation of the enhanced systems that is slightly different from those displayed in the Fig. 6 from the installations of the Artec Research Center (University of Bremen). Several actuators are placed on the real workbench to be controlled and automated via the virtual workbench displayed on the plasma TV.
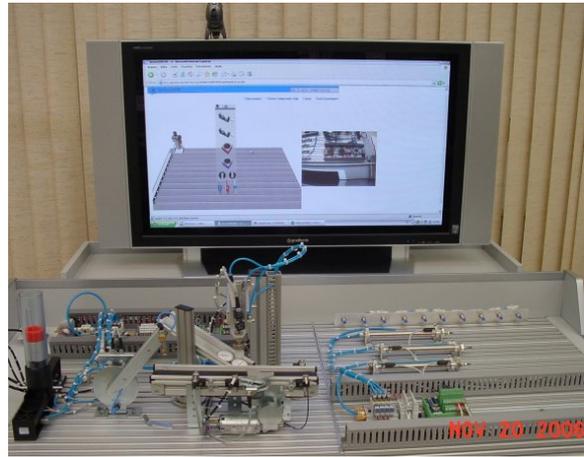

Fig. 10. SENAI Caxias deriveSERVER installation.

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