

# Remote Control of Industrial Robots via Internet. Procedures and Techniques of Tele-Learning in the Virtual Laboratory Amberg

Prof. Dr. R. Biesenbach, University of Applied Sciences Amberg-Weiden  
Prof. Dr. F. Pautzke, University of Applied Sciences Bochum

The University of Applied Sciences Amberg-Weiden has different activities in Tele-Learning and Virtual Laboratories [1][2][4]. This Paper describes the activities in the virtual robot section of the laboratory "automation and robotics" in Amberg. In a first section we explain the motivation for our "Virtual Equipment", in the second section we give a description of the used hard- and software components. The third section shows by the example of a remote practical training between Ecole Louis de Broglie, France and University of Applied Sciences Amberg, Germany how the virtual laboratory is used in engineering education. At the end we give some experiences and conclusions that we made by practising Tele-Learning by using the "Virtual Robot Equipment".

## 1. Motivation

The Virtual Robot Section enables access to the two industrial robots in the laboratory, that means it is possible to have full operation and programming access via internet to the machines. The section was built to support seminars in robot programming held on the site of our partner-university in Rennes, France. Freely adapted from the **didactical guideline** of Benjamin Franklin:

- **Tell me and I forget**
- **Teach me and I remember**
- **Involve me and I learn**

- the access to the two robots via internet gives the students on the "remote-site" the possibility to verify and test their new knowledge. They become involved.

## 2. Hard- and Software-Equipment

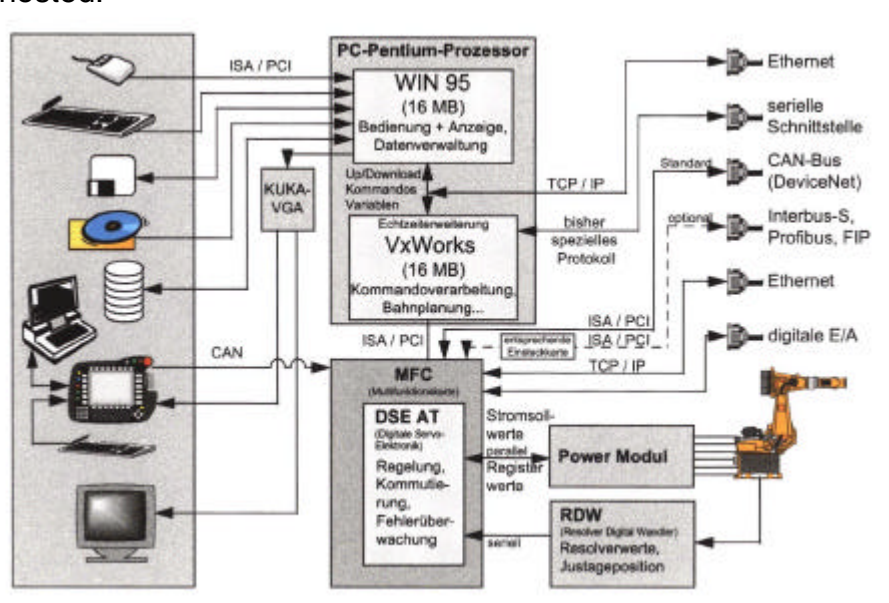
The Virtual Robot Section is part of a conventional automation laboratory. The laboratory facility hosts two KUKA-Robots, a KR15/2 with a payload of 15 kg and a KR45/2 with a payload of 45 kg. Picture 1 shows the KR45/2 Robot. This machine for example has a weight of 875 kg.

Robot Controllers: Both machines are controlled by two KUKA specific robot controllers, the KRC1 and KRC2. Typical for KUKA controllers is an industrial PC running the WINDOWS 95 operating system with the realtime extension VxWorks on a single processor board [5]. From the Hardware Point of View the kernel of the controller is a PC motherboard with a Pentium or Celeron processor (on our machines an Intel Celeron at



Picture 1: KUKA KR45/2 Robot

433 MHz) and 64 MB RAM. On this processor the operating systems WINDOWS 95 and VxWorks are running simultaneously. The real time operating system VxWorks takes all time-critical processes like continuous path control and sensor integration, while under WIN95 the operating, display and data management is done. Both operating systems are triggered by a single chip, called RealTimeAccelerator which is hosted on a MultiFunctionBoard (MFC). This chip assigns by occurrence of interrupts the higher priority always to the realtime operating system VxWorks. On this MFC-board also the digital servo-electronic for the drives as well as the position control loop is hosted.



Picture 2: Structure of the KUKA-Industrial Robot Controller KRC1[5]

The MFC-board also manages the communication of the control elements of the operator panel using CAN. Picture 2 shows the structure and components of the KUKA KRC1 controller. For network communication the MFC-board is equipped with an Ethernet interface (TCP/IP protocol, RJ45 terminal).

Die operation of the robot is made with a special operating device, the KCP (KukaControlPanel). This KCP includes all elements (except the main power switch) which are needed to operate and program the robot. The KCP features an 8" TFT-Display, move- and release buttons as well as a 6D-Mouse for fast teaching of movements.



KUKA-Control-Panel [6]

Internet Connection: The modular and open system of the KUKA-Robot-Controller supports the necessary internet connection for the "Virtual Robot Function". The necessary IP-address for internet linking is taken from the DHCP-Server and is adjusted for both machines to fixed numbers. The electrical terminal is realised with RJ45 and TP- wiring to the University-LAN. The graphical operator interface of the KCP runs under a Windows application. For putting this application into the internet, the original manufacturer software had to be extended. For this purpose a server has to be installed on the robot controller. This server can be accessed from an external place by using a suited client. Using a server supporting remote framebuffer protocol,

the complete user interface of the KCP can be transmitted to a external client. For the Virtual Robot Project we use VNC by AT&T (VNC stands Virtual Network Computing). The remote framebuffer protocol is a protocol for sending graphics to be displayed on a remote display[7]. This remote display is a client, running somewhere in the LAN or internet. As client software we use a standard browser like Netscape. It works also with MS Internet Explorer. With this set-up, experiments on remote robot control can be run from every location in the world wide web by having access to the graphical KCP operator interface. To get remote control to the machines for example you can also use programs like NetSupport PC-Duo by Vector Networks Inc. The PC-Duo remote control is GDI intercept based, uses a mirror driver and has much more options for industrial remote maintenance. As VNC is freeware and it meets all our requirements for the virtual robot project we chose this program. We installed VNC as a service, that means the rfb-server will be started automatically every time you switch on the robot controller. This simplifies very much running a remote practical training, - because the teacher on the (far away) remote site stays independent from the class in the laboratory.

Safety Aspects: At present time, remote access to the robots is possible in the programming and test mode as well as in the automatic operation mode. Because automatic operating speed is up to 100 times faster than in the testing mode, safety installations have to be active in automatic operation mode. To fulfil the safety requirements, the work spaces of the robots are monitored by programmable optical laser scanners. Every approach to the machines causes an immediate safety shutdown. By safety reasons this shutdown can only be reset by laboratory personal. For the same safety reasons the programming device of the laser scanner has no remote function.

Communication: Communication between the simultaneous working teams is realised using shared word pads and internet voice communication. For optical visualisation during the experiment two webcams are installed in the robotic laboratory in Amberg. The first is used for visualisation of the robot movements and the second one is needed to create a "visual relationship" between the two groups. A third camera is installed at the remote site laboratory. The visual contact between the two work groups pointed out to be important to keep motivation and concentration in both groups.

### **3. Experiences with the Virtual Robot Equipment**

In 2001 different remote sessions were held, for example with the University of Applied Sciences Bochum [3] and the Ecole de Broglie [2], using the virtual laboratory in Amberg. In April/May 2002 the new "remote robot facility" was used for a robotic seminar at Ecole de Broglie in Rennes. The robotic seminar was accompanied by a simultaneous group work session between students in Amberg and Rennes. On both sites virtual laboratories had to be installed.

The laboratory in Amberg hosts the two robots, two webcams, video projector and screen, and two PC running voicemail and a shared word pad. All machines are behind the firewall.



Picture 4: Students of the Engineering School Luis de Broglie, Rennes during a simultaneous practical training with mechanical engineering students at University of Applied Sciences Amberg.

The laboratory in Rennes was equipped with nine PCs, one webcam, video projector and screen, voicemail and shared wordpad. All machines are behind the firewall

Sequences of the seminar: The seminar is divided into two blocks. Each block is build from different didactical units. The first block is a conventional seminar in robotics. The students learn about the structure of an industrial robot, safety guidelines, operating of the machines and how to program them. During this phase of the seminar the Virtual Robot is used by the lecturer to demonstrate how the robot can be moved in manual operation mode. After that demonstration the students have the chance to practise this with the "Virtual Robots". The correct movement in different co-ordinate systems of the robot can be watch via webcam. In the following units the students learn how to program the machines in operator and expert modes. Each instruction unit is directly accompanied by a practical training unit with the "Virtual Robot". During this first seminar block no person is present in the laboratory in Amberg. All interaction and movements are done from the remote site.

The second block of the seminar is a simultaneous practical training. Here, the two groups work together solving a programming task, testing the routines on the robots and bring them in to automatic operation. For this task, both groups get a clear defined conceptual formulation. During this phase both, the remote control of the robots and the communication applications are needed. Both groups work together, communicating via voicemail, shared wordpad and webcam. The role of the lecturer now is different. On the one hand he is still the teacher, who supports the remote site group, on the other hand he becomes a director who has to lead both groups in the right direction and correct wrong ways at an early state in order to get the seminar goal reached in a limited timeframe.

Some conclusions for effective use of Virtual Environment: The conclusions given below are related to the virtual environment described above and should not be generalised.

1. *The use of virtual equipment opens a wide range of new possibilities in education.* Like the example given above demonstrates, the necessary practical exercises can be given without having the necessary hardware on the site.
2. *Virtual equipment has to be 100 % reliable.* Every failure reduces acceptance by students and teachers.
3. *Virtual equipment has to be fast in action/interaction.* Spoiled by fast home and office computers the user does not accept slow virtual equipment.
4. *Matched communication means are important.* Simultaneous work groups team up over a wide distance need matched communication.
5. *Use of virtual equipment allows the teacher to involve the students.* A better teaching/learning environment can be created by the use of virtual equipment.

#### Literature:

- [1] The emerging role of eLearning at Universities of Applied Sciences in Germany: Status and prospects from the Business Management Faculties point of view, W. Renninger, University of Applied Sciences Amberg-Weiden, 2002 Annual EDEN Conference
- [2] Programmation a distance d'automates industriels, R. Biesenbach, Ecole Louis de Broglie, Rennes, 2001
- [3] IT-Automation, Ferninstandhaltung über Internet, R. Biesenbach, F. Pautzke, High-Tech-Tag Bayern 2001, Amberg/Bochum, 2001
- [4] SAP-Training in a virtual Environment, W. Renninger, University of Applied Sciences Amberg-Weiden, B. Bärnreuther, University of Applied Sciences Hof, SAP International Curriculum Congress 2000
- [5] Steuerungstechnik für Industrieroboter, G. Schneider, KUKA Roboter GmbH, Augsburg, 1999
- [6] InTouch-Anbindung über OPC an Roboter-Steuerung, G. Schneider, K. Peteler, Applikationsbericht Wonderware GmbH, München, KUKA Roboter GmbH, Augsburg, 1999
- [7] The RFB Protocol, T. Richardson, K. R. Wood, ORL, Cambridge 1998
- [8] Virtuelles Lernen - Aufbau und Durchführung internetbasierter Kurse, W. Renninger, FH Amberg-Weiden, H. Wunderatsch, FH Hof, Meile, 1998