Develop virtual joint laboratory for education like distance engineering system for robotic applications

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Abstract. This paper work with a new system that provides distance learning and online training engineers. The purpose of this paper is to develop and provide web-based system for the handling and control of remote devices via the Internet. Remote devices are currently the industry or mobile robots [13]. For future product development machine in the factory will be included in the system. This article also discusses the current use of virtual reality tools in the fields of science and engineering education. One programming tool in particular, virtual reality modeling language (VRML) is presented in the light of its applications and capabilities in the development of computer visualization tool for education. One contribution of this paper is to present the software tools and examples that can encourage educators to develop a virtual reality model to improve teaching in their discipline. [12] This paper aims to introduce a software platform, called VALIP where users can build, share, and manipulate 3D content in cooperation with the interaction processes in a 3D context, while participating hardware and software devices can be physical and / or logical distributed and connected together via the Internet. VALIP the integration of virtual laboratories to appropriate partners; therefore, allowing access to all laboratories in any of the partners in the project. VALIP provides advanced laboratory for training and research within robotics and production engineering, and thus, provides a great laboratory facilities with only having to invest a limited amount of resources at the local level to the partner site.
1. Introduction
A large number of applications that are based on a platform for distance learning developed in recent years [1], [2]. They made major changes and realize the potential for improving training and robot engineering.

Presented platform in operation, the goal of this application is the design and programming of the remote control. The application of industrial robots that are accessed over the Internet for this purpose, is the program creates which emulates a practical laboratory in which engineering students can confirm the theoretical results by comparing them to the right paths affected by the robot. Students also have the same conditions as in a real lab, because the task and manage real laboratory.

The wide expansion of the World Wide Web and the Internet has created all necessary conditions for the adoption of this powerful means of learning in the common collaboration arena. E-learning can be a way to overcome the geographical isolation and physical distance from the source or learning centers. In these situations, the use of the Internet and connect via Ethernet realistic laboratory receives its full meaning. Robotics is a suitable problem domain, because it essentially requires multidisciplinary knowledge. Robotics covers topics such as mechanical engineering, electronics, control, communications, computer vision, real-time parallel computing and systems design.

- Robotics is very interesting for both children and adults
- Robotics events and contests to motivate the study of technical subjects
- Robotics provides hands-on examples for teaching science, technology and engineering

An increasing number of academic institutions are searching for new methodologies and techniques, teaching that allow students to face real professional situations [3]. This is especially important for interdisciplinary fields such as robotics that require the integration of knowledge from different fields, and a few skills for effective learning. Specifically, the paper combining project-oriented learning, virtual labs and remote labs realistic manageable realized innovative the courses in which students learn the basics of programming industrial robots robot for the competition.

Distance laboratories, houses laboratories and every kind of remote is not exactly new technology. It has previously been done, and some successful results have been received [4], [5]. Much remote laboratory projects after the initialization and a display time, and the process is not included in the paper. In this case, I will try to provide an integrated approach to the study of engineering fields (mechatronics, robotics) remotely without losing the practical hands-on experience at the same time.

In the next section we will introduce VALIP system that provides the basis for all development and implementation of the procedures described in this paper. Subsections 2.1 describes the concept of software components (their behavior and communications) and VIRCA (one of the main software tools that are used to represent virtual environment to the user), respectively. A practical example that describes a common scenario where VALIP system used is shown in Section 3. Finally, Section 4 contains the conclusions of the review and the work presented in this paper.

1.1. VALIP (Virtual Joint Laboratory for Advanced ICT)
The interactive visualization tools operate by accepting input values from users through a graphical user interface developed using a visual language such as Visual Basic, Visual C++, or any other object and graphics oriented language. The main program then creates a VRML file description of the visualization tool and inserts the user supplied values where necessary to create the desired virtual reality display and interactive animation which is then passed to the internet browser for viewing.

VALIP is an acronym which stands for Virtual Joint Laboratory for Advanced ICT (Information and Communication Technology) in Production. In more readable terms, it represents a common place where all collaborators can communicate and exchange information. It represents a virtual copy of the real world and real environment, e.g. laboratory or production environment with machines, robots and other industrial equipment, allowing the collaborators to remotely access the resources that would otherwise be unavailable to them.

Joint virtual laboratory – creating infrastructure for administration, maintenance and functioning of the program revolving around joint laboratories – including acquiring equipment for two laboratories
(remote sensing and remote controlling), joint software purchasing and development; integrating laboratories into teaching and research activities at UBL.

VALIP uses a range of tools to accomplish this goal and it consists of software and hardware devices that all communicate together in order to display required information to the participants and allow them to interact with the environment, directly affecting the real world state through virtual workspace. 3D visualization can be supplemented by video-camera streaming over the Internet, providing in-depth information and a complete picture about the state of the environment.

VALIP provides an advanced laboratory for education and research within robotics and production engineering, and thus, offers access to huge laboratory facilities with only needing to invest a limited amount of resources locally at the partner’s location.

The important part of this virtual reality is the safety of the robots, equipment and personnel. The primary idea is to have a program that will communicate with safety PLC on one side, and virtual reality generator on other side. This program will represent one of the main components in VALIP system.

When the safety light beams are blocked, PLC will stop the robot and send a signal to designated component in VALIP system which will further inform the whole system about the new state of the cell. Virtual reality generator will reflect this information to visual presentation of the cell. The reverse communication will also be possible. Person who is remotely operating the cell will be able to send commands to the PLC to power the robots or the conveyors, through user interface rendered in virtual reality.[9], [10], [11] The visualization of this program is represented in the Figure 1.

![Figure 1](image.png)

**Figure 1.** Control workstation with multiple screens, displaying VirCA application window, virtual reality windows, and real laboratory

2. **Object components**

   Inside of VALIP environment, every physical or logical object is represented by software component which describes the object and their two most important aspects:
The behavior of the object, taking into account its internal behavior and the response to actions from other objects connected to it, and

The ports or connectors through which the object communicates with other objects in the system.

Since all objects (machines, robots, sensors, logical processes, etc.) in the real world exchange the information between them, it is crucial that their virtual representation has the same ability. This is accomplished by implementing custom ports to software components, based on how they interact with the environment in the real world, through OpenRTM-aist [6], a software platform for development of component-based robotic systems. The components can be developed in several programming languages, most notably C++ and Python.

![Control workstation with multiple screens, displaying VirCA application window, virtual reality windows, and real laboratory](image)

**Figure 2.** Control workstation with multiple screens, displaying VirCA application window, virtual reality windows, and real laboratory

The communication between the components is established through one of the following port types, which can be based on either CORBA or ICE implementation [1]:

- **Data Port** – used for continuous exchange of information between the components (CORBA based),
- **Service Port** – used for interface-based communication defined by IDL (Interface Description File) (CORBA based), and
- **Ice Port** – used for interface-based communication defined by Slice (Specification Language for Ice) port (Ice based).

In addition, each port can either act exclusively as a provider or a consumer. This means that in order for components to have a two-way communication between them, each of them has to have a set of provider/consumer ports. The example for component layout and their connections will be presented in section 3.

If you would like to register a picture into VirCA you have to place a new node in the "scene" file of the room and have to create a new "material" file in textures folder.
Add this node to the scene file of the room:

```xml
<node name="Pic1">
  <position x="349" y="150" z="0" />
  <scale x="2" y="2" z="2" />
  <rotation w="1" x="0" y="0" z="0" />
  <plane name="Pic1"
    castShadows="false"
    receiveShadows="true"
    distance="0"
    width="40"
    height="65"
    xSegments="1"
    ySegments="1"
    numTexCoordSets="1"
    uTile="1"
    vTile="1"
    material="04pic01"
    normals="true"
    movablePlane="true">
    <normal x="-1" y="0" z="0" />
    <upVector x="0" y="0" z="-1" />
  </plane>
</node>
```

In every example, the configuration of specified displays is based on the real circumstances of the environment, where VirCA should be visualized. The origin of the coordinate system, in which the displays should be determined, is the user’s actual point of view. That is the point where the user will watch the display(s) from. Axes of the coordinate system are defined by the conventions of the Ogre3D engine. Namely the X dimension means the width (or horizontal axis) on the display, the Y refers to the height (or vertical axis) on the display, and the Z dimension means the depth on the display, in the way, that the negative direction of the axis points towards the display.

![Figure 3. COORDSYS.](image_url)
2.1. VIRCA - Virtual environment

VALIP uses software package VirCA[23] as its primary tool for presenting the information to the user [2] [7]. VirCA is an acronym and stands for Virtual Collaboration Arena. It is a software application which renders a 3D environment inside of which virtual reality can be presented to end users. Collaborators can interact with the objects displayed in application window and inspect the current state of the virtual world (which, as already mentioned, represents the copy of the real world) in real-time [3].

![VIRCA room](image)

**Figure 4.** VIRCA room.

The content inside of virtual workspace is defined by components that are connected to VirCA component. These components constantly send information about their virtual representation allowing VirCA to render their 3D models or other graphical details inside of virtual world.

The user is able to interact with the components through VirCA application window or by using dedicated control components. Sample tasks include turning on the conveyor belt or instructing the robot to pick up an object.

The Virtual Collaboration Arena is a modular built and component based, distributed, interactive virtual reality manager system for connecting virtual and real rooms, displaying and manipulating the devices in them, realizing collaboration that way.

[20] The VirCA system - as virtual reality manager system - handles on the one hand physical, on the other hand communication rooms in order to realize distributed, interactive collaboration. To the virtual room different real rooms can be connected, providing the relation to the reality that way. In the virtual reality, there are representations of virtual and real devices as well as static and dynamic virtual objects, to which last physics simulation can be applied. The user can display the virtual room with any kind of display devices and manipulate it with any kind of input devices, e.g. drag'n'drop dynamic virtual objects. The virtual and real devices can refresh their representations through so-called trackers and can retrieve information from the virtual room through virtual sensors.

[21] In the communication room, the devices can share their own knowledge, which can be some kind of information, service or ability. Hereby the devices in the room can use the knowledge of each other, realizing the knowledge plug n play that way between intelligent entities. So the knowledge implemented once need not be implemented again for the given application, but as a component, it is available on the internet, can be reused. The user can access the abilities of the single devices through
a standard interface, the so-called commander, while the devices can be controlled from the communication room through a standard interface as well, the so-called controller.

[18] The novelty of the VirCA system is on the other hand the connection of virtual and real physical rooms. The user can see - with real 3D as well - and manipulate the different, from each other physically far devices together, on a standard surface, so VirCA provides information integration. With the help of the virtual objects, the cooperation of such real devices far from each other can be tested without the development of a simulator, but with greater precision, the transport or purchase of which would be expensive otherwise, so VirCA is an efficient test environment. [19] The sensors created in the virtual room can be virtual representations of existing, but very expensive, or even not existing (future sensors) sensors, which operate transparent for the devices, identical to the real sensors, so VirCA enables fast development.

![Figure 5. VIRCA room with Robot.](image)

One of the two VirCA has to be the slave and the other has to be the master. You can set it in the rtc.conf file - just change the value (true or false) of this row:

VirCA.IsMaster: true

If you set true then your VirCA is a master, if you set false your VirCA is a slave.

**Note:** If you use VirCA and start the slave VirCA then you have to choose a slave number of it between 0 – 3.

![Figure 6. VIRCA basic screen.](image)
3. Practical example

Practical example of VALIP-based system is demonstrated by performing a remote operation on robotic cell located at Narvik University College (NUC). The task described represents a basic functionality of the robotic cell and contains procedures which are implemented in any other task robots commonly perform in industrial environments. Almost all other types of robotic assignments are constructed upon simple instructions of robot movement, gripper actuation (analogously welding control) and sensor reading, all of which are included in the steps of this task.[8]

For the sake of simplicity, the cell consists of a single robot with the gripper attached to it, one conveyor belt equipped with sensors and a simple table. The robot task consists of the following steps:

- picking up the object from specific position on the table,
- placing the object on the conveyor belt,
- waiting for the object to trigger one of the detection sensors located on conveyor belt,
- positioning the robot at object pickup location,
- waiting for the object to approach the position,
- picking up the object,
- Placing the object back at the original pickup position on the table.

![Component layout and connections between them.](image)

The system consists of multiple software components which are run on three computers. Server computer is located at NUC and provides a name server to which all of the components connect and communicate through. [17] Robot computer is also located at NUC and is directly connected to KUKA robot. Finally, client computer is located at UBL and is used to display virtual reality to remote users. Each of the components is described below.

- Karat. Used for robot control, this component is run on a dedicated robot computer. This computer is directly connected to the robot and also connected to the server computer via separate LAN network or Internet connection. The components allow VALIP to communicate to robot and exchange data with it.
- Kuka3. Used for providing VirCA with the information about robot position and orientation, allowing it to render robot model. This component is run on server computer.
- SchunkPSH32Vis. Used for providing VirCA with the information about gripper position and orientation, allowing it to render gripper model. This component is run on server computer. It is designed as a separate component to allow gripper to be easily replaced with different model (with its own visualization component).
- QtKUKA. Used to provide additional GUI to allow further control by the user. While it is also possible to control the task directly through VirCA, this GUI presents more advanced options to the user, making the whole user experience more intuitive. This component is run at client computer, allowing for remote operation.
VirCA. Software tool used to render the environment and component models as a virtual reality. This component is run at client computer, allowing for remote operation. All components are connected to each other, exchanging the information between them. The connections are established using System Editor, yet another software tool, located at server computer. Ice ports are marked in blue color and are mainly used for visual information exchange between visualization components and VirCA. CORBA Data ports are marked in green color and are used for continuous feed of information between components. Red colored CORBA data ports are used for IDL-based control interfaces.

Since the robot is already programmed for this task, the process is being monitored through VirCA from Laboratory for Intelligent Systems at University of Banja Luka (UBL) which is equipped with required hardware and software. More importantly, the whole task can be manually started, positions and other parameters modified and process controlled from this location, more than 2.600 km away from the physical robotic cell (or any other location world-wide, for that matter).

4. Conclusion
In this article, has been presented real-time controlled Laboratory through the Internet. The main value of the system is that it helps the student to perform practice experiments remotely. With the virtual lab developed, students can learn robotic concepts such as direct/inverse cinematic, path planning, dynamics and programming. The user interface is very user-friendly, and the graphical simulation very realistic.

[14] The remote capabilities of the application allow users to experiment with real equipment through the Internet. Finally, the system presented collects a lot of interesting virtual and remote features (complete robot simulation, robot dynamics, remote power and robot control, augmented reality, etc.); the use of this new technology facilitates a reduction in the impact of the growing number of students on the familiar constraints of laboratory time and cost.

[15] This kind of virtual laboratory allows the teacher and the students of an on-line course through the Internet to use shared simulations in order to experiment practical concepts in a coordinated way [8]. Also, if we built Virtual Joint Laboratory, then we are the part of ISPACE. The iSpace Laboratory Network is a worldwide scientific non-profit network of professors, researchers and laboratories engaging in active research in the intelligent space-related

This paper was focused on describing VALIP as a feasible solution that fills in the gaps that are present in conventional methods of control and monitoring. [16] VALIP represents highly modular and customizable product, and offers tools that allow end users to easily integrate components of robotic cells, production lines and other similar environments, allowing personnel to remotely interact with them.
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