Virtual Electrical Engineering Lab – An Integrated Environment for On-line Education in Electrical Engineering

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Abstract

This paper addresses the problem of remote collaboration in global electrical engineering student projects. The problem has several facets, including the arrangement of virtual engineering laboratory workspaces, the computational support for remote conducting of experimental work, communications, work styles, technology integration, utilisation of digital media in engineering projects and learner embodiment in the environment. We approach this problem combining synergistically the concept of collaborative virtual environment, virtual instrumentation and shared digital representation of the electrical engineering design. Proposed environment incorporates data mining technologies for analysing collaboration data and bringing new insights on the learning activities in on-line learning environments.

Introduction

Advanced educational strategies in teaching, learning, and research are developed and integrated with advanced information, computer, and communication technologies (ICT) to bring on real time interactions, and, consequently, supporting new teaching, learning and research scenarios. Sharing information and experience and the concept of partnership and community development between educators and learners are becoming increasingly critical to engineering education. In engineering faculties, online-teaching and research complement the existing face-to-face educational methods. However, the current perception among the engineering disciplines is that distributed multimedia information technology and groupware are not suitable for those engineering subjects, which require technology intensive hands on experience [1, 4, 7, 9]. Contrary to the design area, where the pioneering works in virtual design studios [16] gained some knowledge in computer-mediated remote collaboration in design, there is a lack of knowledge and understanding of how engineering students team up in virtual environments where interaction is mediated by shared distributed multimedia computer resources. The experimental study of remote collaboration in concurrent engineering, presented in [19] concluded that the socio/organisational aspects overwhelm technological issues. However, socio/organisational issues are implicitly influenced by the integration and synergism of the components that constitute the virtual environment and embodiments that represent objects from the physical world, including the embodiments of humans [6].

The research presented in [13] showed that online engineering subjects could be developed and run successfully in an interactive Internet-mediated learning environment. Authors also examined virtual communities and virtual instruments as techniques for improving students learning in an online engineering subject (see [14, 15].

The idea of integrated virtual working environment was introduced in [17[i]], in the context of a virtual design studio (VDS). The authors presented a high-level view of the VDS concept as an extension of conventional studios. Pioneering the research of Web-mediated VDS, Maher, Simoff and Cicognani [16] revisited and extended the concept of a virtual design studio and, in general, collaborative virtual design environment. The results of a nearly a decade of research, presented in [16], provide guidelines towards different scenarios of a virtual design studio, the enabling technologies and the design of the studio environment.

This paper develops the virtual design studio approach in the area of electrical engineering education. The paper presents the architecture and technological support of a *virtual electrical engineering lab* (VEEL) in terms of shared representation, virtual lab space organization, and integration with communication technologies. The architecture of the lab is derived by an analogy from the virtual design studios. It includes means for collecting and analysing data, which can bring insights on how teams of electrical engineering students collaborate in a virtual laboratory and assist on the improvement of VEEL architecture.

The virtual lab architecture

An analogy between the virtual design studios and virtual electrical engineering lab is based on the view that similar to the studios in the design field, electrical engineering laboratories, now equipped with extensive computing facilities, are a place where engineering professionals and students interact and discuss projects, conduct laboratory experiments, organise and structure the project data, transfer and share various representations, develop and publish project documentation. In all of these activities, information and communication can be handled in electronic form. Recent developments in virtual instrumentation and corresponding applications, have shown that conventional experiments and engineering projects can be presented as an *active digital media* [20], which includes custom-written virtual instrumentation (VI) [5, 8, 10]. The idea of a shared representation in a virtual electrical engineering laboratory is illustrated in Figure 1. The digital media representation is itself the model that simulates the behaviour of a system, developed in a project.

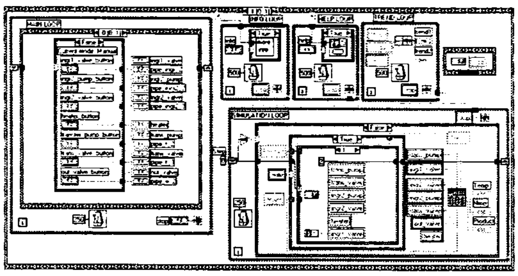


Figure 1. Elements of shared representation based on active media approach (in this case a model of a simple mixer process monitoring and control system).

The virtual working space for the engineering students can be organised in numerous ways. An ontology of the virtual lab takes into consideration the classes of components that make up the lab - a virtual place where practical experiments are conducted, hence, a place equipped with various instruments. The place amalgamates communication and information sharing technologies in a way, transparent for participants. Neglecting this integration can lead to devastating misuse and waste of technology. As a result, instead of taking the advantage of the virtual environment, engineering students can "bounce" off the virtual lab, having no idea how to organise and operate the environment, how to conduct the lab work and collaborate with other students on engineering tasks.

The arrangement of the virtual lab comprises the following key issues:

- Metaphor(s) and models for communication and collaboration in the environment; for representation and embodiment of human and software agents that assist the completion of the engineering tasks; for embodiment and representation of the virtual instruments in the collaborative environment.
- An agreement about the instrumentation support, information archiving and documentation sharing, including a central location for accessing the latest documentation of the experiments or project; a set of file formats for exchanging documents within the lab; a set of tools that model, draw, analyse, document the circuits under investigation and simulation, using approved formats.

The virtual lab is expected to be a common environment both for individual and collaborative activities. The idea is supported by the research in CSCW, which suggests that when working, the individual adopts at least two roles: personal manager and worker [11]. As personal manager, the individual plans, coordinates and schedules the activities in the future. As worker, the individual performs various tasks, in order to achieve the goals set during the personal management phase. We will investigate two different approaches to running a virtual lab, based on two concepts: the "desktop", supported by groupware technology[ii] and the "world", supported by virtual world technology[iii]. We will use these two concepts as metaphors of reference, that is, conceptual frameworks, which represent, by comparison with the physical world, a way of managing the virtual lab. Because electrical engineering project development and experimental activities are communication-intensive tasks, it is critical to understand that the VEEL environment is more than just a collection of tools and personal computer "desktops" – it is a technological scenario with components, integrated to a certain degree. The VEEL environment can be viewed also as an environment that supports a virtual community – the community of students and educators. Those aspects of the environment may not directly be addressed in its functionality specifications [12], for example, the aesthetics and comfort of the environment space.

The central problem in virtual engineering environments is providing students with meaningful and relevant practical experiences. The approach, taken in VEEL, integrates computer-based techniques to interface the students with the physical world. In the laboratory applications, from the technical point of view, all the engineering problems deal with some physical quantities such as temperature, voltage, pressure, speed, position, current, force, torque, etc. A computer equipped with suitable interface circuits data acquisition systems and software can give a visual look to these quantities and process the acquired data. In VEEL these experiences are made available to remote area participants (or participants in another node) via an Internet link. Figure 2 illustrates the common features of a computer-assisted real time experimental module. Depending on the target aim, the experimental systems may contain all or some section of the block diagram shown in the figure.

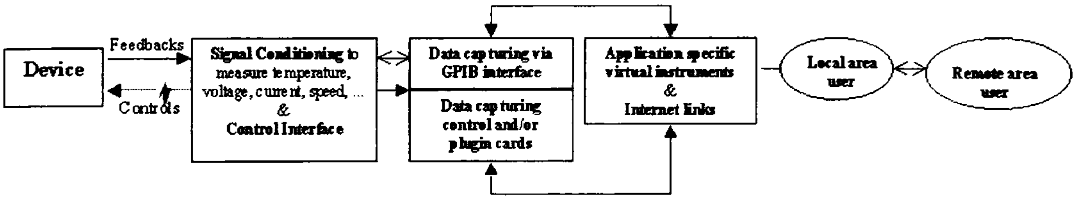


Figure 2. The general block diagram of a computer-based laboratory system.

The instrumentation support of VEEL is based on programmable and customisable virtual instruments, in particular, on LabView[iv]-based applications. The experimental process and outcomes can be delivered remotely without having multiple copies of the experimental arrangement. Additional scientific visualisations and advanced analysis can also be added in the form of virtual instruments with minimum cost, which is limited or not possible in the conventional laboratory practice. Moreover, the VEEL which combines of virtual instrumentation and virtual worlds, offers an environment for participatory design, where students can participate in the modifications of the virtual lab environment (within the constraints of the physical controllers) and can try the results of their changes immediately. Participatory design allows to adapt and evolve the laboratory environment as part of the learning process.

The LabView technology allows the creation of application-specific templates to reduce the production time and overall effort in the design of the laboratory environment for identical subjects. The interface provided by LabView mimics the interface of "real" instruments. LabView is also used in the design of interactive labs and other learning materials, including video components, animated diagrams of system operation, interactive short tests and other learning gadgets.

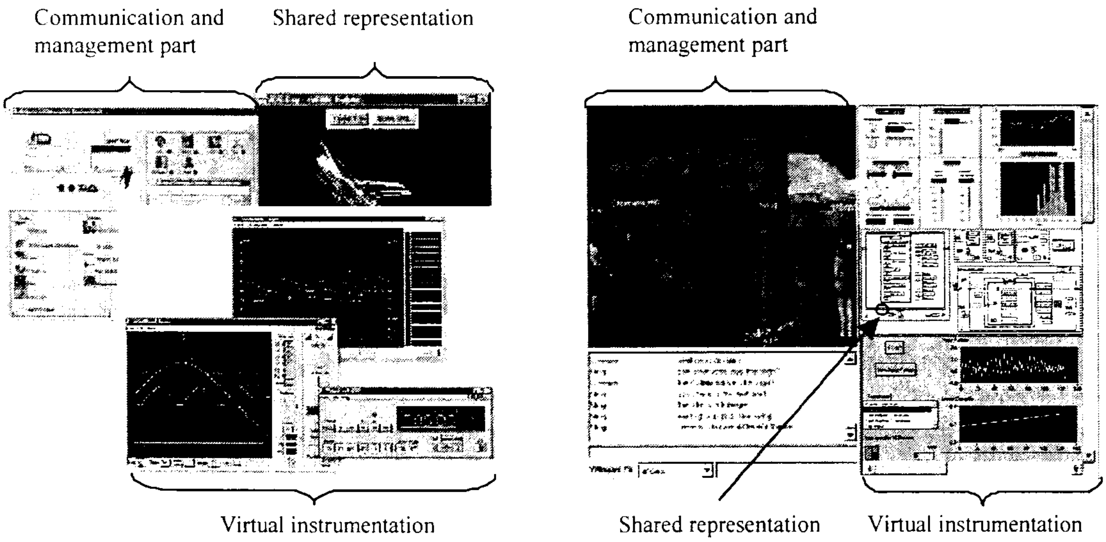
Figure 3 illustrates an implementation of the two metaphors and corresponding scenarios. The desktop metaphor in Figure 3a includes the communication and collaboration tools running within the shared environment. In this example, the shared environment is based on NCSA Habanero (habanero.ncsa.uiuc.edu/habanero/). The LabView tools are integrated through simple hablets and run outside the collaborative environment.

The virtual world place metaphor, shown in Figure 3b, is organised in terms of 3D place, where students go to do their labs, and where they can communicate and collaborate during the practical work. Tools and people are embedded in that place's supporting software. A VEEL that runs as a place should be thought of as a physical laboratory, where engineers find all the instrumentation, models and information needed to complete various tasks. The virtual instruments in this case are integrated as "things" (or agents) inside the virtual world (though their displays may be in a separate frame, as s hown in Figure 3.

Integrating data mining technology in VEEL

The design of the data record which keeps a record of the actions within the environment and the design of the virtual environment that supports VEEL are seen as complementary and parallel activities, affording the opportunity to control data collection to a greater extent. The data sets include also the communication data (transcripts of synchronous communication, threads on discussion boards) and the data recorded at the sites of the remote participants.

The methodology is based on the framework, shown in Figure 4 and described in details in [3]. The framework embeds knowledge discovery in collaborative virtual environments. It guides the design of the learning environment in a way to provide the data necessary for mining and analysis of collaboration, allowing to feed extracted knowledge (for example, a topology of the engineering workspace) back into the redesign of the learning environments. VEEL so far is based on "off-the-shelf" collaborative environments, thus the data collection is limited to the integration of environment log (activities data) with the corresponding communication transcripts (communication data), and the content of the shared and documented work files. The log files are approached with some of the available web data mining techniques [2] and the corresponding system WUM[v]. Communication data is analysed with techniques presented in [18].



a. "desktop" VEEL b. virtual world VEEL

Figure 3. Two different approaches to running a virtual lab.

Conclusions and further research

The paper presented the approach towards the development of a virtual environment for electrical engineering education. The virtual workspace can become the basis for on-line environments for engineering education. VEEL architecture can be adapted for on-line laboratories for supporting "learning-by-doing" strategies in other areas of engineering. This will require the provision of the necessary interfaces with the physical devices and the corresponding virtual instruments, when the corresponding workspace in the virtual world that supports such lab may remain unchanged.

Unfortunately, the graphical representation of controls and data makes it difficult for an individual with a visual impairment to independently operate laboratory instruments. There are several projects, which investigate alternative interfaces to virtual instruments specifically designed for individuals with visual impairments. They usually offer alternative navigation techniques combined with audio feedback. The design and integration of such components into the VEEL environment is an important direction for further work.

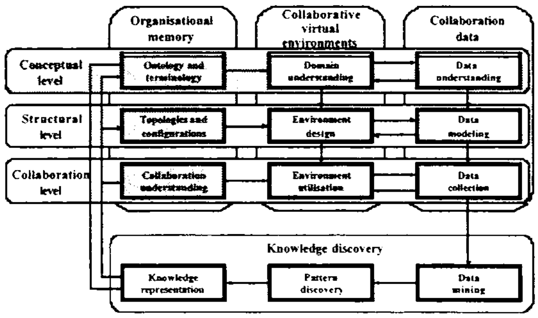


Figure 4. Framework for integrating data mining in the design and application of collaborative virtual environments and knowledge extraction from them

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[i] See pages 441-462.

[ii] E.g, Groove (www.groove.com) and eRoom (e2.eroom.com).

[iii] E.g. Active Worlds technology (www.activeworlds.com) and Adobe Atmosphere (www.adobe.com/products/atmosphere/main.html).

[iv] LabView is a product of National Instruments (www.ni.com).

[v] Web Utilisation Miner, http://wum.wiwi.hu-berlin.de/