Mixed Reality Learning and Working Environments - The MARVEL approach

Dieter Müller

1. Introduction

Mechatronics is becoming an important subject in engineering education and vocational training. Accordingly, there is a growing need for innovative learning concepts, capable of supporting the necessary education and training platforms. Integrated learning arrangements where e-learning with simulations and remote laboratories is combined with experiential learning in real laboratories and at workplaces, can play an important role in future engineering education and vocational training. The current generation of e-learning environments does not provide an integrated solution (comprising pedagogical, technical, and organizational aspects) able to meet these requirements in vocational training yet. Cultural differences and similarities concerning learning and collaboration styles may be devised, but were not sufficiently integrated yet into curricula, courseware and teaching methods.

The European project "Virtual Laboratory in Mechatronics: Access to Remote and Virtual E-Learning" (MARVEL) deals with the above mentioned requirements. The objective of this paper is to discuss some key ideas of the MARVEL project. First I outline the background of MARVEL, followed by a brief discussion of its pedagogical concept. Then I will introduce our approach to a mixed reality learning space which compromises a three-dimensional taxonomy of learning media, places and activities. Before concluding, I will discuss a few examples of learning scenarios which may illustrate the proposed approach in practice.

2. The MARVEL project

MARVEL is an education and training project funded by the European Leonardo da Vinci programme. The project focuses on a learning arrangement consisting of a didactical concept, web-based solutions and e-learning modules allowing remote work with virtual laboratories, workshops and real working-places in the field of mechatronics (Müller & Ferreira 2003). The main target groups of MARVEL are students in vocational training and employees of companies where learning is integrated into the daily activities. The main teaching subjects are system control, maintenance, process monitoring, automation technology of networked mechatronic plants, and machinery. The general idea behind MARVEL is to provide a real time learning environment that merges real and virtual, as well as local and remote laboratories and distributed workshops, in different partner institutions. Thus the project has an organisational development goal, which is the co-ordination of learning facilities in different institutions and countries to form a transnational learning network of remote laboratories and distributed workshops. Currently the MARVEL project consists of seven member institutions as shown in table 1.

As a prototype working example, the MARVEL project will develop a pedagogical concept (learning concepts and user scenarios); a technical concept (standards for remote techniques and guidelines for actual and virtual workshops and laboratory assignments) and teaching modules together with supporting learning aids and examination materials. Particularly advanced will be the tele-cooperation tools and demonstration models built by industry and partners' experience.

Remote laboratories and distributed workshops	Type	Institution & Location
Solar Heating Plant and Laboratory at Delmenhorst Colleges	Remote accessible full-scale solar plant	Technical College II Delmenhorst - Germany
HTI Solar energy e-Learning Laboratory	Remote accessible pilot solar lab	Higher Technical Institute Nicosia - Cyprus
Robot Training Lab at ZENON	Robot training with facilities for remote tutoring	Zenon S.A. Robotics & Informatics, Athens - Greece
Remote Workshop at West Lothian College	Suite of remote experiments	West Lothian College Livingston/West Lothian - Scotland
FEUP's Remote Lab for Electronics	Electronic workbench and remote lab	University of Porto, Faculdade de Engenharia, Porto - Portugal
deriveServer at artecLab	Mixed reality web service for mechatronics	University of Bremen, Research Centre artecLab, Bremen - Germany
Remote Mechatronics at Haute Ecole Valaisanne	Course modules in remote engineering	Haute Ecole Valaisanne Sion - Switzerland

Table 1: The MARVEL network of remote labs and distributed workshop facilities

The MARVEL project evaluates and makes available working examples of remotely accessible practical environments, including e-learning and student assessment materials for various application fields and use cases. In relation to real work tasks, the training of non-technical skills such as teamwork, the ability to communicate in foreign languages, intercultural competence and customer orientation, will be an important goal in the MARVEL learning scenarios. Working with remote experiments, collaboration in distributed teams and communication in a foreign language with students from a partner college may help to develop and train these soft skills.

2. Experiential learning in a mixed reality learning space

In our approach we try to combine simulation training, remote lab experimentation and learning-by-doing on real-life systems, to reduce knowledge transfer problems between virtual and real systems (Müller 2001). The MARVEL project follows an innovative paradigm in engineering education and vocational training by supporting local and distributed learning based on merging *virtual* and *real* labs and workshop facilities. Mixing tangible objects of real work spaces with the digital representation of information spaces, is an approach that witnessed an increasing interest during the last decade. This concept – also known as *Mixed Reality* – provides an interesting idea which comes close to our requirements.

2.1 Mixed Reality

The term Mixed Reality (MR) was first used by Milgram and Kishino (1994) to describe Virtual Reality related technologies that involve the merging of real and virtual worlds. A central element of MR is to provide user-friendly human-computer interfaces, by which, real physical and virtual digital spaces may be overlaid in space and time. Milgram and Kishino introduced the concept of MR as a spectrum that extends from real to virtual experiences, with Augmented Reality (AR) and Augmented Virtuality (AV) bridging the two. AR and VR are the two significant subsets lying within the MR spectrum of the Reality-Virtuality continuum.

The first works about Mixed Reality where strongly influenced by the research on head-mounted displays, 3D-stereo vision, large-screen projections and holographic displays. Accordingly, the research was focussed on visual aspects of human-computer-interface design. Later on, Milgram and Colquhoun (1999) enhanced their concept towards a three-dimensional taxonomy to integrate also aspects of user perceptions and perspectives. This taxonomy offers various ways in which virtual and real aspects of MR can be realized. Another taxonomy for shared spaces with Mixed-Reality boundaries was published by Benford et al. (1998).

2.2 Mixed Reality learning space

In our research at *artecLab* we have expertise with the *technical* design of various prototypes for mixed reality based environments for engineering and technical training (Bruns/Erbe 2004, Faust 2003). In relation to the MARVEL project our research is less focused on technical issues of MR and more on the question of how to organize and arrange learning spaces for distributed learning and working along the reality-virtuality continuum. Thus the approach in MARVEL, which is presented in this paper, describes an *organisational* concept, in terms of learning scenarios and their implementation into learning and/or working processes. It is based on the idea of a mixed reality learning space that spans the reality-virtual continuum and integrates the local and remote as well as different learning modes. Figure 1 illustrates the dimensions of the mixed reality learning space and shows the range of choices available and the possible interaction among the various technological alternatives.
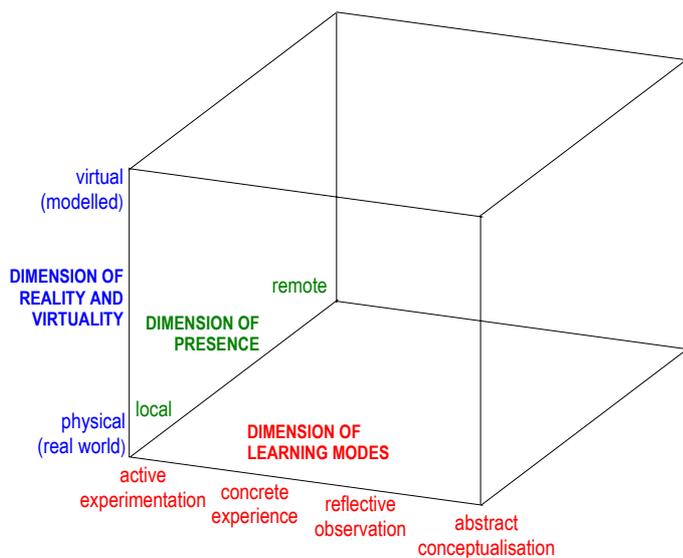

Figure 1: Mixed Reality Learning Space

There are three motivations behind this taxonomy. First it allows to explore the didactical impact of virtual as well as real (physical) learning media and tools in the learning process. Second, such a taxonomy may identify which learning activity requires which tools. Third, producing a clear taxonomy helps to build a rich learning environment, which has the capability to support different learning modes and styles. To illustrate the practical use of this taxonomy, the three dimensions will be explained more in detail:

1. Dimension of reality and virtuality: The dimension of reality and virtuality (reality-virtuality continuum) concerns the extent to which a learning media/tool is either totally virtual or is based on the physical world. This spans the extremes from fully virtual environments (e.g. virtual lab, computer-based simulation, digital worlds) to wholly physical environments (e.g. work-based learning, on-site training).

2. Dimension of presence: The dimension of presence concerns the extent to which a learner or a group of learners is acting in their local space 'the sense of being there' or interacting from remote. This spans face-to-face on the one side and distance education on the other. Face-to-face learning still plays a major role in education and training. The advantages of classroom learning, because of the direct contact, both in and out of class, can engage students in thinking and interaction through questioning, discussion, small-group presentation, role play, and case studies. In practices, the advantages of face-to-face and distance learning methods might complement each other.

3. Dimension of learning modes: This dimension covers different learning modes. In line with the theory of experiential learning (Kolb 1984), which is the educational concept behind MARVEL, there are several underlining modes that characterize a learning activity: action, experience, reflection, and conceptualisation (Wolf 2002). As the learning process is not identical for all people,

3

different learning styles can be distinguished as well. Preference for one or more modes over others indicates a preferred learning style. But learning styles are also context-dependent. Depending on the learning task, the experience with the learning subject, and the point in time when learning takes place "different individuals will adopt different learning styles for the same materials, and a single individual may change learning styles from one occasion to another" (Hammond 1993, p. 55). Consequently, an appropriate environment that accommodates various learning styles is essential for effective learning (Pimentel 1999).

3. Learning scenarios

The learning scenarios considered in MARVEL address various mechatronic systems and use cases, but will concentrate initially on process control, robotic systems and computer integrated manufacturing and electronics. A brief characterisation of these learning scenarios is presented in the table below.

Learning scenarios		Settings and course trials
1	Distributed process monitoring, control and maintenance of a solar plant	Classroom-only and various types of mixed classroom-workplace learning settings, including remote experiments and teaching sessions with teams from partner colleges in more than one country.
2	Configuration and programming of a robot with support by a tele-tutor	
3	Distributed diagnosis and maintenance of a modular production system	
4	Exercises in remote engineering and mechatronics	
5	Remote experiments in electronic circuit design	

Table 2: MARVEL learning scenarios

Various experiments have already been evaluated in a local setting with students (Müller & Ferreira 2003). Distributed learning settings will also be evaluated, where students will access virtual and physical laboratories and workbenches from a remote partner institution. A teacher, assuming the role of a tele-tutor, will support these learning sessions via Internet. In further course trials distributed learning groups will collaborate via Internet and solve a typical maintenance task, requiring them to program and/or configure a real mechatronic system. For safety reasons, their ability to modify parameters remotely is limited, and the learning task will be supervised by an instructor at each site. As a complementary action to distributed settings, teachers will hold a joint teaching session with the partner colleges, using their local lab facilities. In addition we will introduce the *deriveServer*, a distributed and collaborative e-learning platform, which integrates real and virtual, local and remote media for mechatronics under one common interface.

The *deriveServer* is a direct outcome of the European project "Distributed Real and Virtual Learning Environment for Mechatronics and Tele-service" (DERIVE). The system is based on the Hyperbond-technology (Bruns 2001), providing means to freely combine real and virtual worlds (see Figure 2). With the *deriveServer* local and remote learners can work together on different levels of abstraction ranging from real objects, three dimensional virtual worlds, up to symbolic representations. The environment supports 'bridges' between the real and virtual world with integrated simulations. A key feature of the system is the function of freely replacing virtual parts by real ones and vice versa (Faust/Bruns 2003). With a special kind of coupling between the computer and real hardware it is possible to build hybrid systems which are a mixture of real and virtual parts. The main component is a virtual construction kit for assembling virtual mechatronic systems. By dragging and dropping objects from a library onto the working area new elements are added to the system. Each object has a number of connectors which can be linked to other. And if the status of the real system changes the virtual simulation model reacts accordingly: modifications in the real world lead to an update of the virtual system.
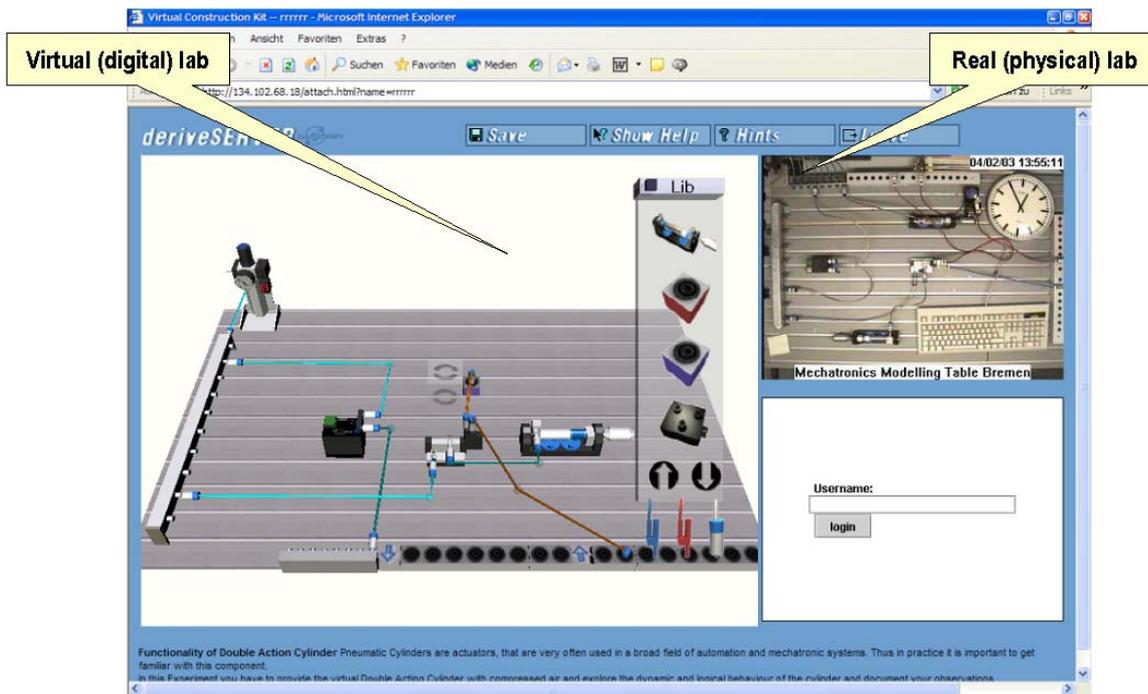
Figure 2: Real and virtual environment for training in electro-pneumatics (deriveServer)

An important aspect within MARVEL is that concepts and examples for real working and learning are developed and accessed virtually through remote processes. These concepts support the social aspects of learning, as learning is necessarily integrated in communication processes, among different learning groups while working at the same machine. Because learning by experience in a real and social context is more and more restricted in pure virtual environments, our taxonomy of a Mixed Reality Learning Space might help to make the appropriate didactical decisions.

4. Conclusion

This paper outlines some key ideas of the MARVEL project. The approach, which is presented in this paper, describes an *organisational* concept, in terms of learning scenarios and their implementation into learning and/or working processes. It is based on the idea of a mixed reality learning space that spans the reality-virtual continuum and integrates the local and remote and different learning modes. This can be achieved by learning arrangements where E-learning with simulations and remote laboratories is combined ('mixed') with experiential learning in real laboratories and at the workplace. Our approach is seen as a step for realizing the concept of "Virtual-reality e-learning" within a particular subject field of mechatronics. E-learning or even Blended Learning – in the classical sense characterized as web-based training – is limited in scope because learning experiences are restricted to working within virtual situations. That is why a learning concept following the idea of mixed reality could promise new learning perspectives and could go further than Blended Learning.

5. Acknowledgements

6. References

Benford, S, , Greenhalgh, C., Gail R., Brown, C. Koleva. B. (1998): Understanding and constructing shared spaces with mixed-reality boundaries. ACM Transactions on Computer-Human Interaction (TOCHI). Volume 5 , Issue 3 (September 1998).

Bruns, F.W. (2001): Hyperbonds - Enabling Mixed Reality. artec paper 82, Bremen 2001.

Bruns, F. W., Erbe, H.-H. (2004): Mixed Reality with Hyper-Bonds - A Means for Remote Labs. IFAC INCOM Symp. Inform. Control Problems in Manufact., Salvador, Brazil.

Faust, M., Bruns (2003): Mixed Reality Web Service ”Air through the Internet”. Proceedings of the Technology Enhanced Learning International Conference, (TEL'03), Milan, Italy, November 2003.

Hammond, N. (1993). Learning with Hypertext: Problems, Principles and Prospects. In C. McKnight, A. Dillon, J. Richardson: Hypertext - A Psychological Perspective (pp. 51-70). New York, London, Toronto, Sydney, Tokyo, Singapore 1993.

Kolb, D.A. (1984): Experiential Learning. Englewood Cliffs, NJ: Prentice-Hall, 1984.

Milgram, P., Colquhoun, H. (1999): A Taxonomy of Real and Virtual World Display Integration. Mixed Reality - Merging Real and Virtual Worlds. Yuichi Ohta and Hideyuki Tamura, editors, Ohmsha (Tokyo) & Springer Verlag (Berlin), pp. 1-16.

Milgram, P., Kishino, F. (1994): A Taxonomy of Mixed Reality Visual Displays. IEICE Trans, on Information and Systems, E77-D(12), pp.1321-1329.

Müller, D. (2001): Entwicklung rechnergestützter Simulatoren aus der Perspektive eines erfahrungsbezogenen Lernkonzepts. In: Petersen, W. et. el. (editors.) (2001): IT-gestützte Facharbeit - Gestaltungsorientierte Berufsbildung. Ergebnisse der 12. HGTB-Konferenz, Baden-Baden, pp. 255-266.

Müller, D., Ferreira, J. M. (2003): MARVEL: A mixed-reality learning environment for vocational training in mechatronics. Proceedings of the Technology Enhanced Learning International Conference (TEL'03), Milan, Italy, November 2003.

Pimentel, J. R. (1999): Design of Net-Learning Systems based on Experiential Learning. In: Journal of Asynchronous Learning Networks (JALN), Vol. 3, Issue 2. Nov. 1999. [On-line]: http://www.aln.org/publications/jaln/v3n2/v3n2_pimentel.asp. Accessed: 29 May 2004.

Wolf, Ch. (2002): iWeaver: Towards an Interactive Web-Based Adaptive Learning Environment to Address Individual Learning Styles. EURODL 2002. [On-line]: http://www.adaptive-learning.net/media/html/iWeaver.htm. Accessed: 29 May 2004.

Author:

Dieter Müller, Dr.
Universität Bremen
Research Centre artecLab, Laboratory for Art-Work-Technology
Enrique-Schmidt-Straße 7 (SFG)
D-28334 Bremen
Germany
mueller@artec.uni-bremen.de