Pervasive Media and Messaging Services
for Immersive Learning Experiences

Raphael Zender, Enrico Dressler, Ulrike Lucke, and Djamshid Tavangarian
University of Rostock, Department of Computer Science, Chair of Computer Architecture
18059 Rostock, Germany
firstname.lastname@uni-rostock.de

Abstract

The public availability of virtual worlds, as for instance Second Life or the OpenSimulator, has introduced a new type of online learning, called “virtual learning”. Virtual learning is used to simulate face-to-face learning, to create new and innovative learning material and to interconnect distant learners. Unfortunately, the virtual environment is mostly exclusive and connections to other learning environments are rare stand-alone solutions with a lack of universal methodologies. This paper depicts the benefit of “Immersive Learning” in the context of a systematic and flexible fusion of virtual learning and computer-aided face-to-face learning. This fusion leads to ad hoc learning scenarios, that are independent from time and location. They adapt to learners and environments with a seamless and transparent transition between both worlds. The fusion will be demonstrated and verified by an exemplary prototype implementation.

1 Introduction

Today, computer-aided face-to-face learning is the most popular research subject of teaching and learning environments. This includes the replacement as well as the extension of spoken and written content by digital media (e.g. powerpoint slides, simulations, demonstrations). Another eLearning paradigm, the online or virtual learning, simulates real-life educational processes and enriches them with specific communication and collaboration elements where applicable (e.g. chats, forums, shared whiteboards). eLearning platforms are often used to implement these processes, for instance for teleacademies. In this context, 3D virtual worlds, for instance Second Life [13], hold a significant innovation potential for eLearning as they simulate the perceived social presence of lecturers and learners [2].

A coupling between virtual learning and computer-aided presence learning offers new eLearning scenarios and enriches conventional paradigms. It can be used to systematically interconnect classroom and virtual learning in order to provide a higher level of individuality and flexibility to the user – not only in terms of a “3D remote control”, but as a generalized architecture for flexible, bi-directional interchange of media between different environments (like classroom, media lab, learning platform, virtual world). The fundament of our coupling is a service-based communication concept, exemplarily implemented for multimedia and message exchange between virtual and face-to-face environments.

The coupling enriches both environments in terms of pervasive learning. Everybody (learners and lecturers) can decide to join a lecture on-site or virtually. Particularly, the virtual lecture allows everybody to participate from all over the world. Furthermore, the used learning content can be selected dynamically and transparently, for instance depending on context information like learners native language or their level of knowledge. Thus, every learner is able to shape his individual learning process proactively by his own. Thereby, the whole learning process increases in adaptivity. Moreover, our service-based approach affords the use of appropriate learning material on different devices.

This paper depicts the basic principles and possibilities of immersive learning in an adaptive fusion of computer-aided face-to-face learning and virtual learning in section 2. This is followed by an overview of related works (section 3). Our technical requirements and an appropriate prototypical immersive learning solution will be presented in section 4, till the paper concludes with a summary and an outlook to future work.

2 What is Immersive Learning?

Our aim is the realization of an immersive learning system as a targeted, adaptive fusion of traditional ex-cathedra teaching with individual, explorative learning in a virtual...
world. The educational material can be real or virtual, and every learner can decide to consume it in a presence environment or a virtual environment. In contrast to other immersive learning approaches [7], our approach allows an immersion not only in a single (virtual) world, but through the coupling of both scenarios even in the real-life learning environment. In this way, a higher degree of immersion is achieved. This is associated with a more natural, intuitive, felt-as somatic interaction and thus with the expectation of better learning results.

One can distinguish several levels of interactivity in immersive learning scenarios, e.g. reaching from passive consumption over reactive navigation and interaction to proactive construction [14]. These levels can be mapped to different models of learning (like behaviourist, constructivist) with different learning outcome on the one hand, but also different effort in implementation on the other hand. In the following, we will give examples for some of these levels.

The basic level consumption includes the transmission of content into the virtual environment (e.g. lecture slides, multimedia recordings) as well as the display of virtual content in the face-to-face environment (e.g. virtual 3D models, online movies). This level enables, for instance, the transmission of a live or recorded lecture into a learning platform as well as into a virtual world or the display of simulated learning objects (e.g. historical buildings, virtual electric motor) in the classroom. Navigation already occurs if the video sources changes dynamically or if the avatar moves in the virtual world.

On the next level, an interaction takes place. A good example is the starting of a virtual electric motor to illustrate its functionality to a face-to-face audience. On the other side, a virtual audience could control a movable camera in the classroom to choose the best perspective on the lecturer, the audience, or real objects.

At the level of construction learners or lecturers create virtual or real objects. This is one of the most interesting features of virtual worlds. Things can be created without real costs and by everybody (e.g. sketch on a virtual blackboard, create new 3D virtual objects, add dynamic behaviour to objects). Additionally, this offers several possibilities for collaboration between learners, both in the virtual world and on-site.

The following exemplary scenario shows the potential of pervasive immersive learning: A lecturer enters a lecture room to give a lecture about nuclear power plants and the room adapts automatically to an individual room configuration like immersive lecture. It configures a virtual room, to integrate remote learners and provides remote access to audio (voice of the lecturer) and video (slides) content in the virtual room. A learner sitting in the local lecture room is able to listen the lecture and to exchange text messages about the topic with other local and virtual learners. A diseased learner is also able to listen the lecture through the virtual room and to communicate with all (virtual and real) learners, because of a virtual messaging interface. He arranges with some fellows for a learning session on the weekend. Furthermore, the lecture room provides access to virtual content during the lecture. Thus, the lecturer can visit and demonstrate a simulated nuclear power plant, by moving his avatar. Remote learners can directly follow the avatar and local learners see the simulation on a canvas in the local room.

3 Related Work

Computer-aided face-to-face learning as well as virtual learning have already been performed by many educational institutions. In particular from virtual worlds a wide spectrum of innovative learning scenarios [2][6][17] recently emerged. However, there’s just few work on the systematic, seamless fusion of face-to-face and virtual learning.

Some approaches, for instance the QuickWorlds Project [8], deal with virtual learning material (e.g. virtual 3D models), that have been integrated into face-to-face lectures through special equipment. Unfortunately, all these approaches are unidirectional, because the material comes always from the virtual world while learners interact from real classrooms. An input of face-to-face learning material to enrich virtual lectures has not been taken into account.

Another interesting project is Sloodle [9]. Sloodle integrates multi-user virtual environments such as Second Life with eLearning platforms such as Moodle. However, this project provides just an interface for one virtual environment to control another virtual environment. Sloodle does not consider face-to-face lectures, but these are essential components in our understanding of immersive learning. The required integration of face-to-face lectures goes beyond the simple use of an interface like the Second Life client. Virtual participants should be able to consume more face-to-face content than just the voice of the lecturer. Therefore, immersive learning requires a systematic architecture that integrates additional media sources as the live lecture slides and a video stream of the lecturer (for instance to watch live experiments). In particular this direction (face-to-face to virtuality) is where related works lack.

One of the greatest challenges of an integration between face-to-face lectures and virtual environments is communication. Integration of face-to-face lectures also means the integration of questions, discussions, and learning material interchange. Therefore, the integration of messaging is the first step towards a seamless general communication between both worlds. The technical possibilities to realize this are numerous. Previous work has clearly brought out the demand of a concept, that integrates existing messaging technologies (e.g. eMail, instant messaging) in terms
of pervasive messaging [18]. This can be interpreted as a variation of timing, direction, audience, and addressing in a multidimensional message space. Nevertheless, the presented solution lacks of generality. For immersive learning, a messaging architecture is required that transparently and seamlessly fits into existing learning environments, online as well as on-site.

4 Network Architecture for Immersive Learning

Immersive learning scenarios require a systematic fusion concept to handle the diversity of available tools, platforms, corresponding processes, and content. This is desirable for learners and teachers and feasible from a technical point of view. The users in this approach (lecturer and learner) can decide on specific modalities in an ad hoc manner. This allows for instance a seamless combination of synchronous scenarios during a lecture (for the interaction between lecturer and learner) and asynchronous scenarios before and afterwards (individual or collaborative preparation and wrap-up). The prerequisite is a flexible network architecture to combine all the tools, platforms, and the corresponding processes (eLearning instances). Furthermore, the network architecture should be applicable for scenarios involving different educational providers. This enhances the learning comfort, increases the scope and quality of a lecture, and advances mobility and equality of opportunities for learners and lecturers.

In principle, different basic architectural models (e.g. Client/Server) can be used to connect different learning instances. An assessment on these architectures leads to the broker architecture as best suitable for the proposed fusion. It has the best scalability, fault tolerance, and performance, as few bottle necks as possible, and avoids a priori knowledge on any eLearning instance. The broker architecture separates between instances by introduction of a broker, which dynamically determines the service of a respective provider (e.g. a lecture hall) that is best suited to fulfill the request of a consumer (e.g. a virtual world) on the basis of service descriptions (e.g. video streaming of a given lecture) registered by the provider.

This concept (as fundamental model behind the popular service-oriented architecture, SOA) currently gains importance not only for selected eLearning systems [1][10] and eScience platforms [11] but also in general for university [20] or corporate infrastructures [16]. Technically, the broker model requires a service-based approach in contrast to procedural or object-oriented models in other architectures. Thus, the user dynamically decides what, when, and where to do, and the technical infrastructure supports his activities in an absolutely transparent manner. Therefore, it selects and combines most suitable services available (loose coupling) in a heterogenous network. Furthermore, the service-based infrastructure or the user can dynamically react to changes, extensions or faults at runtime.

The following prototypical implementation shows how immersive learning can be realized with SOA.

5 Immersive Learning Prototype

The immersive learning prototype interconnects a face-to-face lecture room with the virtual 3D world Second Life [13] and the eLearning platform Stud.IP [3]. Figure 1 shows the basic prototype architecture. This prototype uses Web Services, as specific SOA technology. Even so, the prototype is interoperable to other SOA solutions (e.g. Jini, Bonjour, UPnP). Therefore, we use the Service Technology-independent Language (STiL) [20], an abstract service format that can be used to generate services of different SOA technologies, through associated plugins. Thus, the prototype is adaptive to multiple SOA technologies and a broad spectrum of devices, as the vision of pervasive computing promises [19].

In this article, we focus on two specific services: An individualized lecture streaming and a pervasive instant messaging system. These applications will be presented in the following. They are our first steps towards a seamless integration of both worlds.

5.1 Individualized Lecture Streaming

The prototype integrates lectures and talks, given in a computer-aided classroom, into Stud.IP and Second Life [5][12] as representative tools for computer-aided face-to-face learning and virtual learning. It uses different video and audio sources to combine them as audio/video content. Available audio/video elements are for instance:

- Video and voice of the lecturer
- Video of the lecturer’s slides (often combined with the lecturer’s voice)
Video of the audience (often combined with a mobile microphone to get the audience’s voices)

- Recorded video and audio material (e.g. past lectures)

A streaming server is used to transmit the combined content to external consumers. Furthermore, every content item gets registered as Web Service in a service broker. The virtual learners or lecturers select from available streams of a course, and these are automatically integrated into the virtual environment, for instance Second Life. Because Second Life is not natively able to consume Web Services, we developed the so called **SL Surrogate**. The surrogate can be used by Second Life through HTTP and accepts commands as for instance the registration of virtual objects or inputs for external services. Therefore, the surrogate is able to provide Web Services for all registered virtual objects and to proxy their use. Furthermore virtual participants can use services that are provided outside of Second Life just by sending requests and receiving responses through the surrogate that again acts as proxy. Thus, the SL surrogate enables the virtual world to use Web Services indirectly. Figure 2 demonstrates the integration of streaming content either live or from archive into Second Life.

This scenario uses the video stream of the lecturer’s slides to display them on the virtual canvas. The voice of the lecturer is mapped to a virtual representative (avatar). Furthermore, the face-to-face audience is able to see and hear the virtual audience through the Second Life client software running in the lecture room. Thus, this scenario is actually interactive. This enables all participants to listen, discuss and cooperate. The lecturer just publishes his lecture at the broker (assisted by a graphical web interface) and all learners get instantly access. Additional provider or consumer can be integrated without any problems, because of the loose coupling of SOA. Furthermore, the SOA concept allows the integration of external educational providers.

### 5.2 Pervasive Instant Messaging System

Because of the single feedback channel (the Second Life client software), the lecturer or someone else in the lecture room has to coordinate the discussion between real and virtual participants. But, this feedback channel can not directly be integrated in the prototype, because it is not SOA-based. Therefore, the prototype uses a new cross-technology communication concept [20]. The concept is based on several chat services that enable individual pervasive communication between users in different environments. Figure 3 illustrates a setting with a number of real and virtual environments. Our messaging solution can, for instance, be used for collaborated learning scenarios. Furthermore it can be enhanced for an one-to-many communication like in traditional discussions. Therefore, the lecture is not needed to technically coordinate the discussion any longer.

The used messaging tools depend on the specific environment. In the real environment (e.g. a classroom) users communicate via Bluetooth-enabled cellphones or laptops. A messaging client on these devices enables every user to find other users through Bluetooth service discovery. On the other side, most virtual environments (e.g. Second Life) provide chat interfaces to their users. We developed a Second Life messaging object (virtual cellphone) which is able to find other messaging objects. If an avatar is “wearing” this object, it connects to the SL surrogate through HTTP and requests for the list of available messaging services. Furthermore, it registers itself as messenger and the surrogate provides a corresponding Web Service. In Second Life the list of available chat partners is displayed as textual list and the avatar is able to send messages to each chat partner through the virtual cellphone. Figure 4 shows the
interfaces of cellphones in the face-to-face and the virtual environment.

To bring together the two environments we make use of a service bus that contains abstract STiL services. As every real messaging client provides its messaging ability as a service as well as the surrogate does for every virtual messenger. These services can be transformed into STiL services. This transformation is performed by the General Purpose Access Point (GPAP) [4] in the real environment and the above mentioned SL Surrogate for the virtual environment. Furthermore, these devices continuously search for new messaging services on the service bus and provide them in their environment of responsibility. Thus, virtual messaging services appear as Bluetooth messaging services in the real environment and Bluetooth services as virtual messaging services in the virtual world. This transformation remains transparent to the users and allows everybody, whether in the real or the virtual environment, to send messages to everybody else.

Regarding the classification of electronic messaging services proposed in [18] our system has the following characteristics:

- **Time**: Immediate (all messages are short lived)
- **Direction**: Technically simplex (different services for every direction), but the system appears as duplex to the user.
- **Audience**: World (because of worldwide accessible virtual environments) but perceived as group because of presented list of nearby buddies based on automated service discovery.
- **Address**: Single (one receiver per message) but extendable to list.

Unfortunately, the classification does not respect flexibility as dimension. This are the major advantages of the Walkie Talkie and causes its pervasiveness. New devices can be integrated easily by using their own SOA and network technology as well as their own user interface. Therefore, it makes sense to extend the classification by the dimension flexibility with respect to devices, operating systems, network technologies, and users.

### 6 Summary and future work

This article introduced the concept and a system for immersive learning as an adaptive fusion of computer-aided face-to-face learning and virtual learning. The educational material as well as the learners and lectures can be either on-site or in a virtual environment and users or an automated system dynamically select appropriate learning contents, as the vision of pervasive computing promises.

The presented prototype achieves a flexible and systematic coupling of platforms and tools for different learning paradigms. Consequently, it makes use of a service-oriented architecture (SOA), which is a powerful and well-promising architectural model for pervasive computing applications [15]. An intermediate service layer between the different environments contains all services that are provided by the specific platforms. Thus, any environment is able to consume services available in this layer. For the first time, learner and lecturer can shape the specific learning and teaching processes in an ad hoc manner beyond pre-defined phases (Blended Learning) or environments (conventional face-to-face or virtual learning). The learning and teaching processes can dynamically be modified during the lecture because the SOAs loose coupling. In addition, the emerging independency allows a unification of learning and teaching scenarios across different educational providers. An interference of administrative areas of responsibility is not longer required thanks to the transparent encapsulation of an SOA.

Nevertheless, the prototype can be extended at several points. First of all, more natural interaction patterns are desirable, e.g. touching media devices (screen, speaker) instead of keyboard and dialogue. Moreover, the inter-environment text messaging solution will be extended to transfer voice, video or advanced learning material (e.g. PDF files) in order to enhance the collaboration possibilities. Furthermore, a direct integration of SOA mechanisms into virtual worlds like Second Life would also increase the flexibility of the developed system just like an extension of
virtual environments to further data formats (e.g. HTML and PDF).

From the non-technical view, didactical aspects need further research. It has to be clarified if such a close contact between face-to-face and virtual learning requires own didactical strategies for the involved types of teaching and learning. Can the traditional didactics of face-to-face learning be used or do we need novel approaches? This question will be answered by comprehensive practical tests with intensive pedagogical supervision.

Acknowledgement

This research is partly supported by the German National Science Foundation (DFG, GRK1424).

References