Bi-directional Distribution of eLearning Content for Cross-technology Learning Communities

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Abstract: This article describes the use of a service-oriented architecture to bridge the gap between different eLearning types and tools. The basic concept is a bi-directional distribution of web services provided by different eLearning environments. This is exemplarily verified by a combination of lectures that are held in a modern media supported lecture room with tools of the computer-aided face-to-face learning paradigm and within a virtual learning environment (Second Life). The new service-based approach allows a flexible and systematic coupling of virtual and face-to-face teaching and learning to a cross-technology learning community.

1 eLearning Scenarios and Approaches for their Integration

Today, *computer-aided face-to-face learning* is the most popular teaching and learning type. This includes the replacement as well as the extension of spoken and written content by digital media (like powerpoint slides, simulations, demonstrations, etc.). These media can than easily be made available to learners in order to support their wrap-up phase. Therefor, the lecturer is mostly required to upload his slideshow and lecture notes manually into a web-based eLearning platform in an asynchronous manner.

As another example, *online* or *virtual learning* simulates real-life educational processes and enriches them with specific communication and collaboration elements where applicable (e.g. chats, forums, or shared whiteboards). eLearning platforms are often used to implement these processes, for instance for teleacademies. In this context, 3D virtual worlds hold a significant innovation potential for eLearning as they simulate the perceived social presence of a lecturer and learners [COT07]. The commmunication mechanisms of the platform are synchronous and the individual learning processes take place at the same time. However, these environments are decoupled from real-life scenarios.

In particular in virtual 3D worlds, virtual learning is a comparative emerging paradigm. Nevertheless, the number of education activities is increasing. For instance, the virtual world Second Life [Lin09b] has around 50 registered education events per day. The reasons for the success are the advantages over other solutions like chats, instant messaging and classical learning platforms in terms of communication and felt presence. For instance, IBM's conference space [Lin09a] shows that virtual worlds really encourage people to socialize with each other. The virtual event participants truly felt as if they had attended

real-time events, interacting with others and carrying home practical information. This comes at one fifth the cost of a traditional conference and without a single case of jet lag.

Blended learning is a didactical approach to link between virtual and face-to-face learning. The learning process is pre-divided into phases, each with its own organization. Face-to-face learning phases are basically used for a guided lecture preparation and wrap-up. These phases are mixed with intensive eLearning phases for more informal scenarios. The given division into synchronous and asynchronous processes makes a compromise between technical possibilities and pedagogical needs.

However, a methodical approach for a seamless linking between tools for virtual and face-to-face learning is desirable for learners 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 the lecture (for the interaction between lecturer and learner) and asynchronous scenarios before and after (individual or collaborative preparation and wrap-up). The prerequisite is a flexible combination of used tools, platforms, and the corresponding processes. Furthermore, the approach 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.

Along with the current evolution of the Web there is another issue to concern. Learners are members of many different communities [Gru07]. This includes learning communities (built by different eLearning platforms) as well as social communities (e.g. Flickr, YouTube, and Facebook). It is to be assumed that learners prefer learning material that is provided in their familiar communities/platforms. Thus, the required familiarization effort is lower than with dedicated new systems. Hence, the content provided on the basis of a given methodical approach (e.g. recorded lectures, slideshows, and relevant literature) should be applicable for the integration in different platforms and environments.

The goal of our work was 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 systematic use of the bi-directional combination is promising a huge benefit for electronic learning and enriches the experiences of learners and probably also those of teachers.

2   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 [COT07][Gol07][RH08] 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* [JMLL00], 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* [KL06]. 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.

3 Using the Service Oriented Architecture for eLearning

In principle, different basic architectural models (e.g. Client/Server) can be used to connect different learning instances. An assessment on these architectures leds to the broker architecture (the fundamental model behind the popular Service-Oriented Architecture, SOA) 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. As figure 1 illustrates, 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 fullfil 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.

In an educational application scenario there are some additional points that allow or even require the use of SOA. First of all, there is a number of established network addresses that are known to all clients and servers (like learning platforms); they can be used as brokers. Moreover, the content of a lecture typically is not security-relevant, which simplifies the implementation and practical use of a prototype. (Nevertheless, a cross-institutional scenario requires basic services for authentication and accounting.) Another aspect is the large number of potential users and services that demands a scalability and agility impossibly provided by conventional models (like point-to-point connection of clients and servers). Finally, a strong condition in educational scenarios is the acceptance and effective learning outcome by the users; not only those with a less technical background. This requires a transparent and easy-to-handle system architecture as well as an intuitive and satisfying client-side interface. The prototypical implementation of our system will be described in the following.
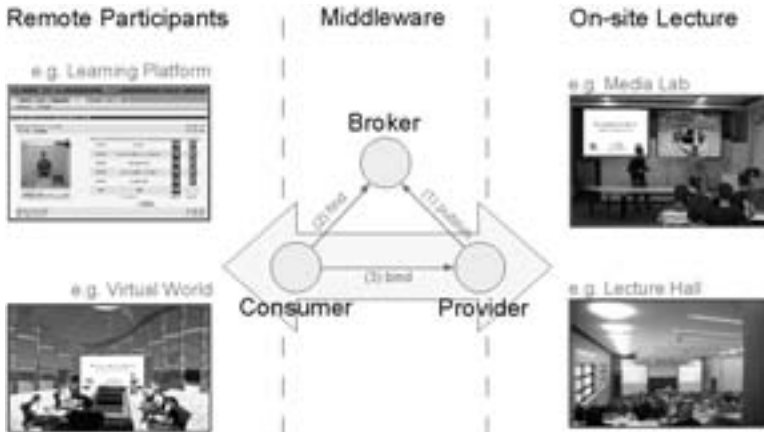
Figure 1: A service-oriented architecture can be used for the realization of a combined face-to-face and virtual lecture

4 System Architecture and Prototypical Implementation

4.1 Typical Application Scenario

Advanced eLearning settings often use dedicated environments with special equipment as for instance the media lab shown in Figure 2. These provide a lot of features besides the conventional presentation of slides. The available devices provide functions as for instance:

- Input and output of audio and video data (e.g. provided by cameras, projectors, microphones, speakers, personal computers, and laptops)

- Signal distribution control (by a crossbar switch and a wireless media control panel)

- Taping and playback of audio and video data

- Setup of a video conference session

- Access to the network of the university or the internet

The usage of such a media lab or equivalent rooms obviously leads to an enrichment of teaching and learning. Furthermore, the utilization of video streams or video conference systems gives lecturers and learners the possibility to participate remotely. However, conventional video streams normally have no real-time feedback channel. This prevents listeners of a live lecture from an active participation in terms of questions and discussions (audio and video). Video conference systems have an audio and video feedback channel but they are mostly complex and expensive systems. The integration of participants that are geographically spreaded is characteristic for virtual learning scenarios. Therefor, it is

Figure 2: Scenario and technical equipment for computer-aided face-to-face learning in a media lab

a promising approach to combine virtual environments with platforms used for face-to-face learning to achieve a flexible extension of the learning space on the one hand and to achieve close application to the real world for virtual learners on the other hand. The combined environments form a cross-technology learning community.

A prototypical system to implement a cross-technology learning community is presented below. The prototype interconnects a media lab with the virtual 3D world Second Life [?] and the eLearning platform Stud.IP [dat09]. It makes possible the synchronous participation of remote listeners in the talk (passive handling) as well as in the discussion (interactive handling). Attendees may follow the live lecture on video from different angels of view, in case multiple audio/video services exist. At runtime, the virtual audience may choose their favorite angle of view (active handling). However, recorded lectures can just be seen in a passive and asynchronous manner. Compared to a live lecture, the video and audio sources of a recorded lecture are limited to the recorded sources.

4.2 Architecture of the Prototype

The prototype consists of different components, shown in Figure 3 together with their interconnections. They can be categorized and assigned to the following three layers:

- SOA connection of the media control:
  The proprietary mechanisms of the media control component have to be extended by an interface for use within the service network.

- Service Network:
  This layer represents the core of the service-based approach. A broker as central SOA instance is made available besides the services themselves (e.g. input and output of audio and video signals, control services).

- SOA connection of virtual learning environments:
  The platforms can be directly connected to the service network (with platform internal modifications) or indirectly via a surrogate.
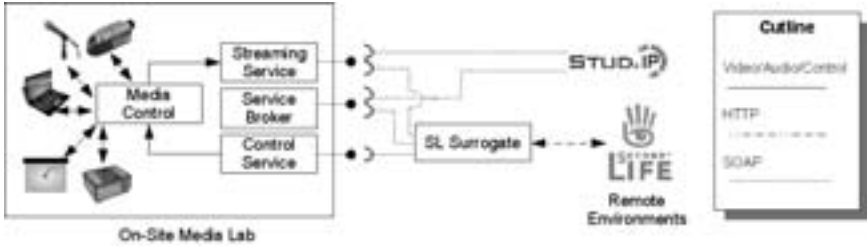
Figure 3: The basic architecture of the prototype

The architecture outline demonstrates clearly that almost any service type, provider, or consumer can be integrated into the system easily without structural system modifications, because of the abstraction in terms of the service interfaces respective the surrogate component.

The implementation of the overall system took around a half year and isn't finished as yet. The specific solutions for every layer will be explained in the following three sections.

4.3 Integration of the Media Controller

Typically, the device services of the media lab are provided, used, and managed for face-to-face lectures without the use of a SOA. A central media controller allocates the specific data streams. This is the standard practice in such environments. For instance, the media control directs the video output stream from the laptop to the input of the projectors, and the audio output stream from the microphones to the input of the speakers. In our media lab a NI-3100 Integrated Controller [AMX06] is utilized as media controller. The controller routes media lab internal data transmissions (e.g. from camera to streaming server). The functions of this controller have been ported to the platform independent Java technology. The link between Java and the NI-3100 does not measurable limit the NI-3100s performance. The resulting Java interface has been used to implement one control service using the Web Service technology [WCL05].

Furthermore, the system architecture illustrated in Figure 3 includes an exemplary streaming service which preprocesses audio and video content (e.g. from camera or microphone) into streams, provided for external retrieval. In addition to live streams, the service provides access to archived lecture recordings. The technical implementation of this differentiation is transparent for service consumers.

The next section describes the SOA realization. It focuses mainly on the service provision in the media lab as well as the external consumption.

4.4 Propagation as a Network of Services

The service broker depicted above is the central component of the SOA. Even though services themseleves are also available for external use without a broker, it increases the flexbility of service discovery dramatically. The consumers do not need a priori knowledge to address each available service, they only need to know the required service type and a broker address. In educational settings there is usually a dedicated central server given and known to the clients, so it can be used as broker. Furthermore, the service description on the broker may contain additional information that helps to decide if a service is appropriate to an intended purpose or not (e.g. resolution of the video stream).

In the presented prototype the services are registered at a WS Inspection-based broker [BBM+01]. This broker is the central contact point for the external consumers that explore services in the media lab. WS-Inspect saves the services information as XML-based list that can easily be accessed via Hypertext Transfer Protocol (HTTP). Hence, an easy integration of broker requests into a wide range of consumer systems is possible.

The mechanisms used to invoke a service are specific for each service. For instance, the streaming service uses the Real-Time Streaming Protocol (RTSP), a popular protocol to control video streams. RTSP-based video streams can, for instance, be used in Second Life and many video players. The service specific invocation is an important aspect that has to be considered for the integration of consumer systems into the service network. The following section describes one consumer system, the virtual world Second Life, in detail.

4.5 Integration of a Virtual World

The 3D virtual environment Second Life is hosted by Linden Labs on a server farm named The Grid. Currently there are over 3.000 simulation servers that manage over 11.000 regions (65.535 vitual qm per region), and their database servers store approximately 50 Terabyte. The physic engine Havok Physics is applied to simulate realistic behavior for animations, object moves and other physical effects. The free client software presents the data received from simulation servers as a 3D environment to the user. Furthermore, it allows users to interact with the virtual world as well as other users (acting through their avatars). In comparison to conventional telepresence scenarios [TIM+04] Second Life affords a higher immersion and is accessible for everybody with the free client software.

The added value a virtual world provides in contrast to conventional face-to-face teaching is not only to offer a copy of a classroom or lab setting, and to broadcast a lecture in the Web. Of course, this scenario is important especially for unexperienced users – teachers as well as students – in order to orientate oneself. A big advantage is the almost unlimited changeability of the environment. From an educational point of view, this prevents the teacher from circumstantially explaining unknown situations (e.g. for learning foreign languages) or tedious theory (e.g. traffic rules for a driving license) – an appropriate scenario can be simply created for the students.

Figure 4: A virtual version of historic lighthouse and Teepott serves as virtual learning and teaching environment.

We decided in favour of two famous landmarks of Rostock Warnemuende: The historic lighthouse and the Teepott as illustrated in figure 4. As the interior of the buildings should reflect the purpose of buildings and elements, and encourage an (inter)active participation, we modelled a virtual media lab with table, several chairs, and a canvas to build an open learning and communication environment. Our virtual representation can be found in the north of the European University Island [Uni09].

The service-based communication with other environments should occur seamlessly. We use an access model based on the Second Life group concept. Registered members of our group are allowed to control the virtual and real equipment as trustable avatars. They can also authorize other avatars for specific events/lectures. Guest avatars can only consume content and communicate with each other or the lecturer by text and voice chat.

The real media lab is controlled by a so called Head Up Display (HUD) which appears when an avatar touches a dedicated 3D object as shown in figure 5. The HUD dialog shows the different sources and drains for multimedia signals and the user can assign signal routings. This allows for the selection between different video sources (e.g. camera or slideshow) for the video stream displayed on the virtual canvas. An Linden Scripting Language (LSL) script attached to the virtual 3D object sends HTTP requests to a surrogate that bridges between Second Life and the SOA. This intermediate step is required as Second Life does not support external SOAs. An adaption to a SOA is impossible, because Second Life is not open source and the server-side software is not accessible for extensions. Messages from the real media lab are also bridged by the surrogate to allow processing within Second Life. The HTTP request contains the name of the controlling avatar, the requested service, the requested service method, and optional parameters. The received response is handled by an HTTP response handler, implemented in LSL. Possible reactions on a response are a user notification via text chat or changes in object appearance or behaviour.

This mechanisms allow remote listeners, for instance, to select between different video sources of the media lab to be shown on the virtual canvas (e.g. video stream of the lecturer, the audience, or archived recordings). In the other direction, the Second Life client software shows the virtual content (e.g. audience or virtual 3D objects) to on-site
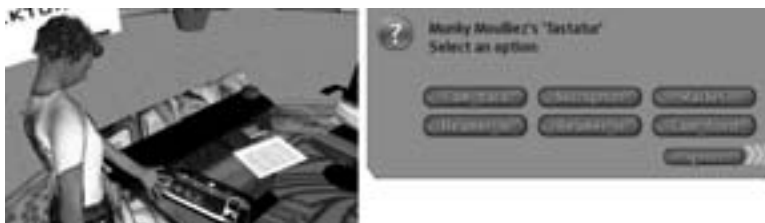
Figure 5: A HUD dialog appears when an avatar touches a dedicated 3D object (keyboard)

listeners and the lecturer. More details of the Second Life Integration can be found in [LRZ^{+}08].

The prototypical integration of Second Life closely interweaves the tangibility of real-life objects with elements in a virtual 3D world. Such an intuitive interaction with the learning environment exhausts the cognitive capabilities of students to a much larger extent than in traditional classroom settings, where learners are typically acting in a much more passive and less individual way.

Several other platforms for virtual worlds exist beside Second Life. Some of them are even open source as for instance the OpenSimulator [Ope09] and Project Wonderland [Sun09]. Therefor, a mediative surrogate would not be necessary. Unfortunately, these solutions are in their infancy and not as popular as Second Life. Therefor, Second Life is promising to be the best accepted platform for now.

Besides the virtual world, we integrated two other platforms into our cross-technology learning community to proof our concept: The classic eLearning platform Stud.IP as another (HTTP-based) virtual environment [GZLT08] and individual on-site cellphone clients for individual cross-environment messaging [ZDLT09].

5 Summary and Further Developments

The service-based linking of face-to-face learning scenarios and different virtual learning environments described in this article goes far beyond previous approaches that address the combination of devices and interfaces for learning. Connections between Second Life and traditional eLearning platforms already exist [KL06], but they are restricted to static hypertext references or a common database. There are no systematic approaches or standards to combine synchronous and asynchronous learning paradigms for a variety of targeted platforms. A systematic combination of real-life and virtual interaction is promising a huge benefit for electronic learning, in terms of (not only virtually) tangible E-Learning interfaces that enrich the experiences of learners – and probably also those of teachers.

The presented system achieves a flexible and systematic coupling of platforms and tools for face-to-face and virtual teaching and learning. Consequently, it makes use of a service-oriented architecture (SOA). Therefor, the prototype is easy extendable concerning other platforms and tools. 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 predefined phases (Blended Learning) or environments (decoupled face-to-face and virtual learning). This can be modified during the lecture, dynamically. In addition, the emerging independency allows a unification of synchronous and asynchronous learning and teaching scenarios. This can be realized across different educational providers. An interference of administrative areas of responsibility is not longer required thanks to the transparent encapsulation of a SOA.

Nevertheless, the prototype can and will be extended at several points. First of all, a more natural interaction patterns is desirable, e.g. touching media devices (screen, speaker) instead of keyboard and dialogue. Moreover, a service-based feedback channel from the virtual learning environment into the face-to-face learning environment does not yet exist. Although currently not required (clients and browser satisfactorily perform this task) it is desirable with regards to higher flexibility. 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).

There are additional problems with SOAs. The SOA hype produced a large amount of different and incompatible technologies. The Web Service technology is used in our prototype. Thus, alternative but also widely distributed technologies are ignored (e.g. Jini and Bonjour). A mechanism that bridges between separated SOA islands can significantly increase the spectrum of available teaching and learning services [ZDLT08].

Furthermore, one could think of automated avatar movement and gestures in the the virtual world, generated from capturing the on-site speaker. Finally, interaction between teachers and learners can be designed more intuitionally. This is feasible by a fusion of the presented approach with principles and technologies of self organization and pervasive computing [LT08].

From the non-technical view, didactical aspects need further research. The system has been tested on dedicated events. Until now, an evaluation in regular lectures is pending. 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 require novel approaches? How do learners and lecturers experience the linking? This question will be answered by comprehensive practical tests with intensive pedagogical supervision in the upcoming term.

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