Interconnection of Game Worlds and Physical Environments in Educational Settings

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ABSTRACT
This article describes the use of a service-oriented architecture to bridge the gap between different environments in the context of game-based learning. The basic mechanism is a unified service bus infrastructure. This is verified by a combination of face-to-face scenarios with online tools and virtual worlds. The added value of this concept is shown based on an exemplary scenario for game-based learning. Results of a prototypical evaluation are stated to verify the validity of the approach. Furthermore, the applications and possible extensions of the developed system are discussed.

Categories and Subject Descriptors
C.2.4 [Distributed Systems]: Distributed applications
K.8.0 [Personal Computing – General]: Games

General Terms
Management, Design

Keywords
eLearning, Game-based Learning, Virtual World, Service-Oriented Architecture.

1. INTRODUCTION
Game-based scenarios are an innovative approach to enhance the learning process in terms of an improved learning outcome. They can be realized in different educational settings. Currently, the most popular scenario is computer-aided face-to-face learning. This includes the extension of spoken and written content in the classroom by digital media. Usually, the lecturer is required to manually upload his material to a website or learning platform. – This marks a shift to online learning, where learners are able to individually access and work through digital content. Thus, the synchronous, lecture-based learning process is turned to an asynchronous, document-based scenario that is decoupled in time and place. – In virtual learning, this is enriched with the social appearance of teachers and other learners. 3D worlds are a popular example, but are expensive to create and to handle because of their complexity. – This drawback is compensated by digital lecture recordings (eLectures) containing the slides, annotations, audio, and video of the lecturer. Thus, they combine social presence with easy development. – All of these settings can be enriched with various communication and collaboration facilities. However, they remain decoupled from each other.

Coming from the perspective of game-based learning, the mentioned approaches allow for the realization of game-based scenarios or systems – but as described so far, they are merely innovative teaching and training scenarios. The idea to integrate aspects of games and learning is not new [1]. Nowadays, game-based learning takes place at kindergarten and at schools, being a natural part of the related pedagogies [1]. When it comes to adult education, the notion of game is not commonly used in the context of learning. Adult learning is no playing games; it has to be more serious. In contrast to that, it is highly desired to get the effects of successful games also in teaching and training (e. g. motivation, flow, and enthusiasm). However more difficult to answer (and topic of controversial discussions) is the question what exactly game-based strategies in computer teaching and training scenarios can be [2]. Classical strategies for educational settings in adult education are case-based training, narrative storylines, and role play. They are for example used in university education in medicine [3], in law, and in business sciences, to name only a few. These approaches exist for a very long time [4], they are neither related to computers nor to game-based learning. However, they can be perceived to be classical forms of realizations of computer-based teaching and training. A closer look and a comparison with basic game strategies [1] reveals that the three mentioned approaches also occur in games development: games are often based on “cases”, i.e. descriptions of a specific situation or environment (e. g. the starting situation of Settlers of Catan), game content is often provided in a narrative manner (e. g. storytelling), and quite a few games are role-playing games (e. g. World of Warcraft, Dungeons and Dragons). Thus, these approaches lend themselves for game-based learning. In a virtual world setting, participants (learners) can be given a specific training case, which can come in the shape of a game or in a playful manner. The content can be provided by the virtual teacher or tutor in a
narrative way, and moreover, the participants can take over different roles. The task of the teacher is to orchestrate and organize the didactical (instructional) structure of the training unit (e.g., the course) and to decide whether or not a game-based approach is appropriate. The most important aspect in this context is what kind of knowledge will likely be transferred from the game-based situation to the real world [16]—this is reflected in the learning goals. Usually, the resulting course will be a blend—a technical blend, but also an instructional blend between traditional and game-based education.

Blended learning is an approach to combine different settings in time-share mode. 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 are mixed with intensive self-learning phases in online or virtual environments. This separation into sequential processes makes a compromise between ease of implementation and pedagogical needs. However, a direct interconnection of educational settings is desirable for learners and feasible from a technical point of view. This allows for instance a seamless combination of synchronous scenarios during the lecture (with interaction between teacher and learner) and asynchronous scenarios before and after (individual or collaborative preparation and wrap-up)—regardless of the used platform. This enhances the learning comfort, increases the scope and quality of a lecture, and advances mobility and equality of opportunities for learners and lecturers. Current developments in this area can be divided into two groups:

- There exist a number of dedicated point-to-point-connections between different platforms and tools, e.g., to automatically integrate lectures into learning management systems [5][6] or to mashup virtual worlds with other platforms [7][8]. They suffer from limited extensibility and complex maintenance.
- Systematic integrations of different platforms are rare, for education [9][10] and for gaming [11][12]. Usually, they follow an approach of fundamental platform decomposition for a later flexible re-combination of modules. Here, object-, service-, or peer-to-peer-based architectures come into play. However, this is hard to realize with existing tools.

Considering state-of-the-art design principles and sustainability of developments, a systematic integration is desirable. Services have proven to be a valid mechanism for enhancement of existing platforms [13], if applied in a coarse-grained manner. Thus, we decided to develop a system for service-based interconnection of different educational settings in terms of a generalized architecture for flexible, bi-directional interchange of media between various environments.

The remainder of this article is organized in three main sections. First, the implemented game-based setting is described. Second, an overview on the infrastructure used to realize this scenario is given. Third, results of an evaluation of the system are provided. The article concludes with a summary and future research directions.

2. SETTING

After some preparation, we began introducing game worlds into regular university courses in the summer term of 2009. The idea was that computer science students might find a video game context motivational, but also that game architectures would provide us with new facilities for simulation of educational content as well as communication tools for computer-supported cooperative learning (CSCL).

For instance, we are teaching artificial intelligence (AI) theory, which can be difficult to access for the student if there is no real-world application. Autonomously moving robots are a suitable target for applying AI algorithms. If one does not have real robots or a suitable obstacle course at hand, or not enough robots, or if they are too expensive for student experiments, using a game world becomes an alternative [14]. In a 3D game, e.g., a sim game like The Sims, the player can create intelligent agents and have them act autonomously in complex, simulated and visualized environments.

In addition, we wanted to be more flexible when it comes to learning locations and learning times. During projects, students should not be required to be present on campus all of the time. There should be facilities to collaborate on a task or to have a group meeting whenever needed. In the future, we wish to share lectures with other universities, teaching to both, presence and distance learners. Players of massively multiplayer online role-playing games (MMORPG), such as World of Warcraft, are used to entering another world whenever and from wherever they like. Collaboration with other players, who might be anywhere in the world, is something they take for granted and enjoy.

To benefit from these advantages, we introduced game worlds into university education. We used the multi-user virtual environment (MUVE) Second Life. Strictly speaking, Second Life is not a game. It may look like an MMORPG, but it does not come with game rules, challenges, or game objectives. Instead, it just provides the basic physics engine and the 3D virtual world visualization, and leaves the rest to the users. Users can create games within Second Life, just as it is possible to create virtual educational settings. From a teaching point of view, we are currently making use of Second Life in three different types of learning scenarios.

The first use is that of a virtual laboratory [15]. We built an AI lab in Second Life—a virtual building in which students could place objects: virtual characters like robots, laboratory mice, monsters, or their own avatars, but also furniture and equipment, e.g., a maze. In the actual programming tasks tied to learning objectives in our AI course, the students outfit their characters with intelligent, autonomous behavior by first conceiving cognitive models, and then implementing these using the Linden Scripting Language. They can then execute the code, and watch a simulation of their models over space (the three dimensions of the virtual world) and time. To make the series of intended experiments more motivating, we enriched it with a background story involving escaped laboratory mice chased by a genetically engineered monster. A lab exercise was therefore also a game-like experience in which students programmed the behavior of the mice or that of the hunter. Next time we give this course, we intend to extend the game part. Notice that this scenario can be computer-aided face-to-face learning—a teacher in class states a modeling task, and the students access the virtual lab via their laptops—or online learning, when a student is doing homework in the virtual lab, accessed from anywhere—or even virtual learning, when two students in different places are working together.
The second use is a virtual-learning scenario: a virtual meeting room. When the instructional part of the AI course was finished, students were given a project. They had to design and implement a game using Second Life. Each team was to create a level of the game in one of the five floors of the AI lab building. It had to feature at least one intelligent agent as an adversary of the player, as well as some decoration. To arrive at a consistent game, our ten students had two meetings, moderated by a teacher, in which they presented their concepts to the others, agreed on a storyline as well as on interfaces between the levels. For this, we used the ground floor of the lab building, and equipped it with seats for the avatars of the students, as well as virtual whiteboards, poster walls, and the like to act as cognitive tools [16] to make orientation and interaction in the multi-user game world more intuitive. Still, it was not the same as a face-to-face meeting. For instance, predefined avatar gestures are limited, and the group had to improvise ways of determining whose turn it was to speak. As it turned out, strong involvement was required on the part of the teacher to keep discussions focused and goal-directed. Technically, we mostly used text chat for communication. Speech fit smaller groups better.

In three courses altogether, the AI course, one course on eLearning and one on Service-Oriented Architectures (SOA), we used the game world to a third end: as a virtual lecture hall. A face-to-face lecture is a social situation in which students and the teacher communicate and experience a shared involvement in a subject matter. This is difficult to recreate in basic online learning, where students just download lecture notes from the Web. We recorded and made available live videos of our lectures, but this was still a restricted experience. Game worlds can provide a more social and intuitive setting. From the outside, our lecture room in Second Life is a replica of Rostock’s major landmark, the ‘teapot’, an oddly formed building at the beach, the centre of touristic activity. Inside, our virtual teapot looks like a conference hall, with a table, chairs, and a large canvas for multimedia presentations. Outside, a number of features, like a mysterious teleporting device, a movable boat, or a flying seagull increase the feeling of being in a game. Inside, a student will meet avatars of fellow students as well as the teacher’s avatar. During its owner’s lecture, it would stand in front of the canvas, where students can watch the slide presentation and listen to the talk, as the teacher’s voice is mapped onto the avatar. The teacher operates the presentation from the real-world lecture hall – a multimedia lab equipped with recording and communication technology –, which is also filled with real students. The main challenges in this scenario are how to best deliver the face-to-face lecture to the distance learners, and how to establish communication between real-world and game-world locations. Notice the multimodal and cross-media aspects of this scenario. The present teacher can reach the distance learners, for instance, by talking or making gestures. This is realized as text, speech, avatar animation, displayed video, etc. The teacher might point out something on the slides using a virtual laser pointer or text marker within the video stream. Or, which is more complicated to realize, he or she might direct the avatar to point a finger to a certain spot on the canvas.

All in all, the requirements collected in our three pilot courses point to the question: In a blended, virtual learning scenario using game worlds, how do we best connect a present teacher and teaching material situated in a physical environment to a game ‘played’ by distance learners?

3. INFRASTRUCTURE
This section is focused on the technical infrastructure for realization of the game-based scenario. It consists of three parts: a general overview on the interconnection architecture, and a more detailed look on the integration of on-site as well as virtual environments.

3.1 General Architecture
The basic paradigm implemented by our infrastructure is the Service-Oriented Architecture (SOA), which offers valuable potential not only for traditional software design but also in pervasive or immersive scenarios [17]. Relevant functionality of a system is identified on the basis of a comprehensive process model and provided as a service. Figure 1 provides an overview on the proposed architecture. A SOA infrastructure is the core

![Figure 1: Service-based interconnection architecture with adapters to various platforms and with exemplary services](image-url)
component of the system, represented by the University Service Bus. Here, various services can be deployed [18]. In our game-based scenario, services for the dissemination of learning content (uni-directional) as well as communication services (bi-directional) gain the most importance. Several target platforms can be integrated. Up to now, we developed connectors to on-site facilities for face-to-face teaching/learning, to traditional eLearning platforms, and to virtual worlds. Other types of environments are possible, too. The focus of this article is on face-to-face and virtual environments, as depicted in the left-hand side of the figure.

While the integration of additional platforms is comparatively easy, the implementation of the University Service Bus requires some efforts. It is responsible for:

- delivery of messages between service providers and consumers, including dynamic routing based on given requirements and conditions
- transformation of messages between different formats, protocols, and technologies
- monitoring features for surveillance of service usage and proper system functionality
- orchestration of available services, based on a given process model, in order to fulfill higher-level tasks (optional)
- security, i.e. encryption of messages, authentication of service providers and consumers, authorization of consumers, accounting of invoked functionality (optional)

In the given prototype, we included fundamental delivery and transformation mechanisms. A monitoring component is still missing. Optional components for orchestration and security are considered for later extensions, since they are not essential in our current scenarios of use.

A special challenge was to bridge the gap between existing technologies combined in today’s heterogeneous infrastructures. We developed and implemented a mechanism for multi-level interoperability on network and service layer, realized in a so called General Purpose Access Point [19]. On network layer, communication functions are mediated between different technologies by plug-ins for Ethernet, WLAN, Bluetooth, and so on. On service layer, an abstraction language unifies the capabilities of different technologies like Web Services, Jini, and so on. The University Service Bus manages the resulting unified services. As an example, this allows us to transparently exchange messages between avatars in the virtual world Second Life (based on Ethernet and Web Services) and on-site users with mobile phones (based on Bluetooth SDP), as shown in Figure 2.

### 3.2 Physical Environment

Typically, the on-site media equipment (notebooks/PCs, cameras, beamers, canvasses, speakers, microphones, DVD players, and many more) is directly managed by the lecturer or administrator. A central media controller associates the available data/control interfaces of devices. Exemplary commands for a lecture might be “connect output of rack PC with input of right canvas”, “connect output of front camera with input of left canvas”, “connect output of headset with input of speakers”, and “set volume of speakers to 60%”. These proprietary mechanisms of the controller had to be extended by a SOA interface for use within the service network. Therefor, a Java-based wrapper was developed that on the one hand sends commands to the media controller and on the other hand deploys this functions as a Web Service.

Additionally, multimedia services for recording, streaming, and archiving of lectures have been developed. As an example, different audio and video sources can be compiled and provided as a stream for external retrieval. It is possible to simultaneously record and stream a lecture. The physical environment acts as a provider of these services. For the user, it is fully transparent if a stream is live or from archive.

Moreover, messaging services as shown in Figure 2 can be applied to live scenarios. Every device in the physical environment that is capable of receiving text messages provides this information, which is gathered by our infrastructure and provided as a service. The individual communication enables a wide range of collaboration scenarios, e. g. learning groups.

Numerous other services (like entertainment or context) were developed, but are outside the focus of this article.

### 3.3 Virtual Environment

Most platforms provide an API to extend their functionality. Depending on the nature of the software, internal code modifications can be possible, too. This applies to several educational systems, but not to the virtual world Second Life used in our scenario. That’s why we had to develop a so called surrogate that extends Second Life using its API and acts as a consumer/provider of services on its behalf.

Objects in the virtual world (like the canvas in our virtual meeting/lecture room, the headsets of our avatars) are enhanced with specific functionality regarding our media and messaging services by use of the Linden Scripting Language. Via the

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**Figure 2:** Seamless exchange of messages between Second Life and mobile phones across different network and service technologies.
surrogate, HTTP requests from virtual objects are translated to service messages for our SOA infrastructure, and vice versa. The HTTP request contains the name of the acting avatar, the requested service and its method, and optional parameters. Possible reactions on a response are a textual notification (e.g. for system acknowledgements or user messages) or changes in object appearance or behavior (e.g. for lecture streaming).

The 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 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.

4. EVALUATION
During summer term 2009 we evaluated the developed infrastructure for distribution of eLectures in three courses with all together 25 students. Half of them were involved in the development of a virtual game as described in section 2, the other students only used the eLecture services.

In a first inquiry we asked the students for initial attitudes regarding innovative eLearning materials and settings. The answers ranged from open-minded (15%), to deliberate (35%), to sceptical (50%) – in contrast to conventional slides and scripts which were generally rated as important. The final attitude after finishing our tests changed, where eLectures gained the same relevance as slides and scripts (almost 100%), and also live transmissions and virtual lectures were rated as mostly important (75%). This demonstrates that the results of our evaluation are not biased by a general affinity of the students towards eLearning mechanisms or material.

During the course we asked the students for their opinion on the virtual gaming scenario. The game itself was considered as “a welcome breaking-up” and “motivational”. One student wrote that the game story, at first, seemed to be unnecessary to him, but demonstrated that teachers were highly motivated. Another student confirmed that applying the AI theory to practical problems – and thus, the directly perceived experience – was strongly positive. Nevertheless, several negative comments were given on the features of Second Life, for instance: “It’s annoying to spend my time with the originalities of the Second Life engine and the Linden Scripting Language, rather than focussing on AI algorithms. But, as a computer scientist, we should get along with this. So, it’s interesting to try this out.”

The frequency of using the service-based dissemination of eLectures did continuously rise during the tests (compared to traditional linking of material in an eLearning platform), though students initially signaled no willingness to make use of these mechanisms. Comparing different transmission techniques, streaming was recognized as appropriate especially for participating and frequent re-working of a lecture, while download was considered as helpful mostly for targeted revision of lectures prior to exams.

As Figure 3 shows, the technical solution was rated mostly average to good. In general, the eLecture integration into Second Life polls worse than the compared version for the learning platform Stud.IP. As weak points mainly the image and sound quality as well as the interaction facilities were mentioned. This helped us to fine-tune the resolution and sampling rate in the streaming server, and to define some guidelines for a lecturer how to deal with annotation features of the recording software and with interactive elements in the setting. Moreover, the students provided a number of suggestions for improvement especially of the Second Life solution and the overall organization of the lecture.

We’re going to repeat and intensify the test in a broader scenario throughout the upcoming terms.

5. CONCLUSION AND FURTHER WORK
The article described our development of a service-based infrastructure for educational scenarios. After successful tests of the prototype in a number of singular events we evaluated the system in two regular lectures as well as in a game-based setting in summer semester 2009. We obtained positive results regarding the acceptance by the students and the benefits associated with the services.

Current work covers the completion of the University Service Bus with monitoring and security mechanisms as well as the extension of available services. Moreover, we put in a variety of efforts to integrate context information into the services for an

![Figure 3: Student ratings for the quality of integration between eLectures and online/virtual platforms for the gaming scenario](image-url)
adaptive system behavior. Our final goal is the realization of a pervasive university [20].

Future directions of our work include: gesture recognition of the lecturer and mapping to the avatar in the virtual world; integration with technologies for ambient assisted environments (e.g. for physically exhausting games); evaluation in broader scenarios including users from outside university (school, industry, interested public); and integration of open-source 3D virtual worlds like Open-Sim or Project Wonderland.

Moreover, we intend to transfer our application scenario from intra-institutional to cross-institutional cooperation. Facing the spatial distance, we expect a higher motivation of the participants because of missing physical meeting facilities and thus the need to interact virtually. Especially, the game-based strategy seems to be well-promising to bridge the gap between different learning styles, educational standards, or cultures.

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7. REFERENCES


