Learning a Foreign Language in a Mixed-Reality Environment

This article describes a mixed-reality experience for learning Spanish as a foreign language, which takes place in a virtual world that mirrors a boulevard in Madrid. To this end, the authors have extended the capabilities of an open source multiuser 3D virtual world platform to orchestrate learning activities and use augmented reality and augmented virtuality. The results of their evaluation show positive effects on student motivation and improvement in learning outcomes.

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Three-dimensional virtual world technology's success in engaging people in video games has led researchers to study its potential for learning purposes.[1,2] Virtual worlds immerse participants in a realistic space where, by means of avatars, they can explore, interact, and modify the virtual world, which might even mimic the real one.[3] Virtual worlds provide a medium especially useful for learning foreign languages (see http://avalon-project.ning.com),[4] in which participants can strongly interact with each other free of shyness barriers. Such worlds can foster participant engagement, crucial in learning a new language, by including human presence in a mixed-reality space.[4] With this aim, we connect the physical (real) world with the virtual one through mirror worlds and mobile technologies.

Here, we present a serious application for learning Spanish as a foreign language built on a virtual world that mirrors the Gran Vía Boulevard in Madrid. Students compile information on shows available in different theaters with the goal of purchasing a ticket for the show they want to attend. A teacher in the real world helps them make their final decision. Students' learning activities include exploring the mirror world, collaborating among peers, and interacting with the teacher.

Multiuser virtual environments (MUVEs) let us deploy immersive and interactive environments as required for exploration and collaboration. Nevertheless, they lack mechanisms to guarantee the workflow of activities necessary to enact a learning application. Furthermore, to address collaboration, we must orchestrate students'

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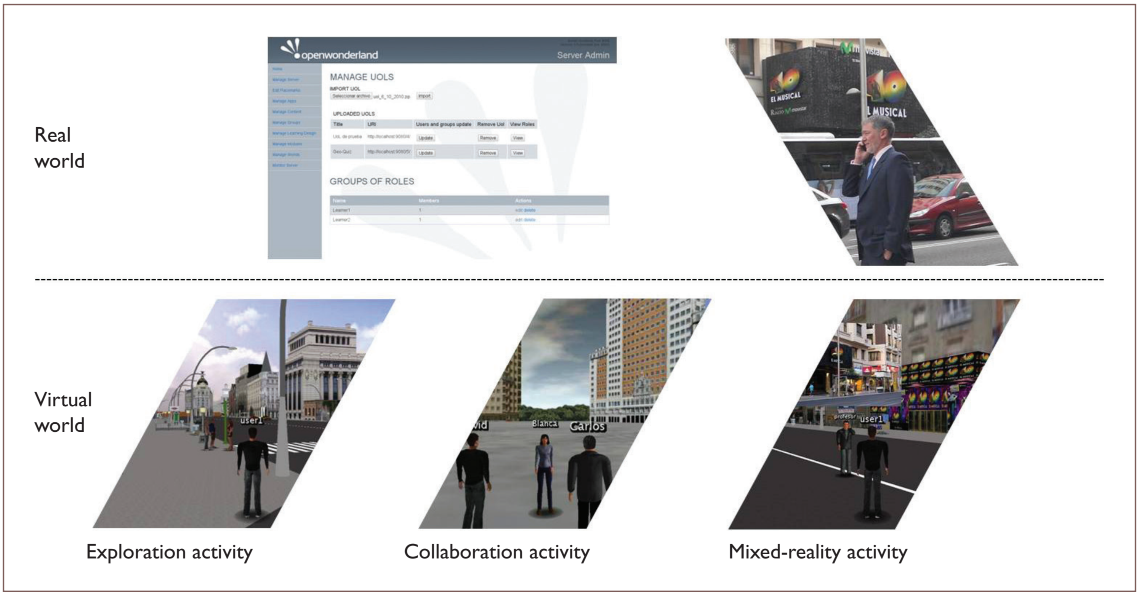

Figure 1. Learning Spanish as a second language in the Gran Vía mirror world. Students gather information about cultural events by exploring the 3D environment and exchanging information with peers. Then, they interact via phone with the teacher to enhance the virtual environment with real-time geotagged images and videos.

activities as a group. We extend the capabilities of a MUVE architecture to handle groups and include a player that organizes each student's activity sequence.

Our architecture enables participants to be present in both the real and virtual worlds, which fosters social immersion and increases students' motivation. Because the virtual world mimics the physical world scenario, participants can geolocate any element (object, avatar, or image). Mobile technologies let participants transfer elements' representation along with their geolocated position. Thus, participants in the physical world can perceive events in the virtual world instantaneously (*augmented reality*), while at the same time, virtual world participants witness what's happening in the physical world in real time (*augmented virtuality*).

Application Scenario

The learning environment for our application includes the Gran Vía mirror world, in which students carry out activities, and the Gran Vía real-world setting, where a teacher interacts with students via a smart phone. Students interact both among themselves, via voice chat, and with virtual elements — that is, nonplayer characters (NPCs) and 3D objects — by approaching or touching them, respectively. Students visualize the learning environment through a Web browser. The system organizes them into groups and guides them to follow learning activities sequentially. Figure 1 shows the three learning activities taking place in the mixed-reality environment that we describe next.

Exploration Activity

In this first activity, students explore the mirror world to collect information about a subset of available shows. The information is provided verbally by groups of NPCs that engage in dialogues when students approach them. The system guarantees that NPCs give different (and complementary) information to each group of students. In doing so, it promotes the collaboration activity.

Collaboration Activity

In this activity, students talk with each other through their avatars to further their knowledge about the shows. The communication occurs using the system's immersive, high-fidelity stereo audio capabilities.

Mixed-Reality Activity

As a final activity, students make a phone call to a teacher located in the boulevard by touching a 3D mobile phone. While the conversation

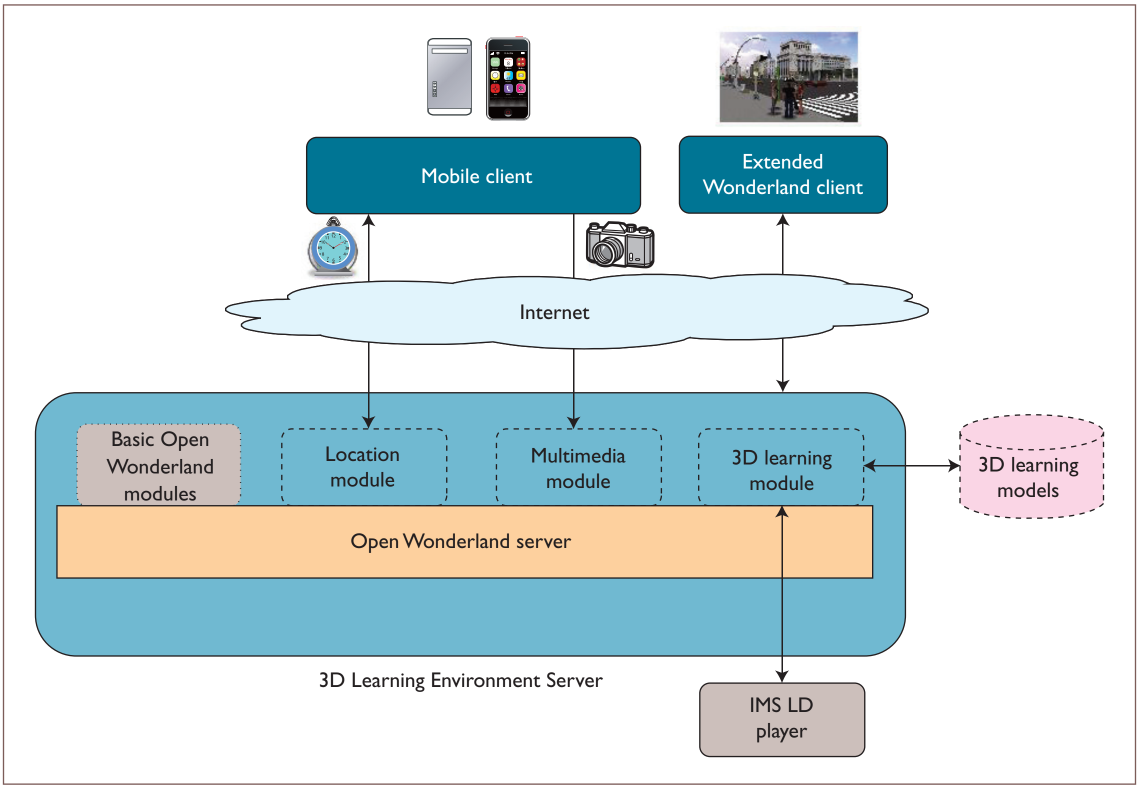

Figure 2. 3D learning engine architecture. The engine extends a multiuser game architecture to handle workflow learning activities in a mixed-reality environment.

takes place, the teacher sends students geotagged information (video and pictures), located in its equivalent latitudinal and longitudinal position in the mirror world (augmented virtuality). Furthermore, superposing images of students' avatars onto the mobile screen helps the teacher plan the route to follow (augmented reality).

System Architecture

Our proposed architecture, shown in Figure 2, is based on Open Wonderland (http://openwonderland.org), a Java open source MUVE toolkit with functionality that we can extend by adding or modifying *modules* (Open Wonderland's version of plug-ins). Our architecture extends the Open Wonderland server into the 3D Learning Environment Server (3D-LEnS), with capabilities for establishing correspondence between physical and virtual objects, exchanging multimedia information between the physical and virtual world, and orchestrating learning activities. We also extend the Open Wonderland client to visualize information from the real world.

We must create the 3D learning models that populate the virtual world using authoring tools that follow the Collada (*Colla*borative *D*esign *A*ctivity; www.khronos.org/collada) specification, the format used in Open Wonderland. Although Open Wonderland lets users include 3D models dynamically, we didn't use this capability.

Mirror worlds, understood as digital representations of the physical world, are based on positional correspondence of objects from real and virtual worlds. On both sides of the mirror, elements (people, avatars, and objects) can dynamically change their positions, and users can perceive these changes in both worlds. To capitalize on these features, we extended Open Wonderland with the *location* and *multimedia* modules, which communicate with a mobile client in the smart phone. The location and multimedia modules store geolocated information received from the mobile client in 3D-LEnS. The mobile client reconstructs avatar 3D models and superposes them on the mobile screen (augmented reality).

The location module creates a teacher-avatar and keeps track of it in the mirror world. The multimedia module is in charge of associating geolocated information to images and video received from the real world. The extended Wonderland client includes extended video-player and image-viewer Open Wonderland modules to display images and videos geolocated by the multimedia module (augmented virtuality).

At regular intervals, the mobile client initiates communication with 3D-LEnS to exchange information with the location and multimedia modules. Once communication is established, the location module receives the teacher's GPS coordinates so that his or her avatar can be relocated in the mirror world. Conversely, the location module sends student-avatars' positions to the mobile client. Sometimes, the user in the real world must send a picture or a video, in which case, the multimedia module receives its geolocated coordinates and includes it as part of the mirror world's 3D objects.

Finally, the 3D learning module has the ability to enact *units of learning* (UoLs) — that is, the sequence of activities and resources (3D objects and NPCs) that each group of students requires for the course. These UoLs are specified using a well-known educational modeling language (IMS-LD[5]). The 3D learning module informs the IMS-LD player (CopperCore[6]) about the actions detected in the 3D learning environment and receives the next set of activities that each student should do according to the workflow.

Students who participated in a preliminary evaluation reported that it was useful to have a mirror world where they could observe the city's cultural activity. We noticed that students were quite engaged in the mobile conversation with the teacher located on the boulevard in Madrid.

Open source MUVE platforms (such as Open Wonderland) improved with extension capabilities enable new opportunities for learning and teaching. Such platforms can support learning with activities in controlled environments that can pique students' curiosity and hold their interest by including real events in activity deployment. In our case, the controlled events were carried out in the mirror world, while activities were enriched with information from the real world.

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