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Developing a Web 3.0 E-learning Portal with X3D Technologies

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Abstract

The paper describes our experience in the development of the DIEL learning management system, and especially its 3D interface, which has been developed using X3D. DIEL allows to structure learning activities along a virtual learning path, composed by a set of virtual rooms. Each room can be represented as a 2D or 3D virtual environment. A first implementation of DIEL's 3D interface had been developed using Flash, recently such an interface was refactored using the new and innovative technologies X3D and X3DOM, with a substantial increase in terms of virtual environment personalization and in the possibility of supporting new features in the future.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual reality

1. Introduction

Web 3.0 is a new buzzword that has been emerging recently, mentioned with respect to the future of the World Wide Web, and still there is not an universally accepted definition for it. The reason is that the debate on what this future shall be is still on-going, with scientists and companies arguing on what novel features shall be part of it. For sure, the web of the future shall be supported by ultra-wide band technologies, one or more order of magnitude above today's connections, and availability of bandwidth will make it possible to distribute to every user those experiences that today are possible only inside a few research labs.

Among the various definitions of Web 3.0, the authors consider as most relevant the one given by John Smart [SCP*10]. Web 3.0 is the converge of the virtual and physical world into the first-generation Metaverse. In such a web development layer, TV-quality video, 3D simulations, augmented reality will be part of a unified environment, that will be able to enrich Web 2.0 participatory technologies into 3D space. So, availability of multimedia channels on top of 3D web technologies will be the basis on which the future of the Web shall be built upon.

In line with the above, the subject of our research has been to design and experience possible developments of web based education in the context of Web 3.0. Web based applications that shall be used for education are part of the wider world of distance learning applications (for a classification of related terminology see [Ano05]). Several recent studies have been focusing on the use of metaverses in education, see for example [MMB08, ZMH10]. Empirical studies have been undertaken, to compare virtual with real life educational experiences. Some studies like [DFPT09] have shown a favorable attitude of learners in experiencing Second Life [Lin10]. Other researchers [STFM09] have confirmed users favorable attitude, but still consider the effectiveness of metaverses in education to be quite limited, with respect to the impact achieved by suitable learning strategies.

For this reason, our system, DIEL [DFD*09], aims at assisting the tutors in the design of their learning strategy. To this purpose, it provides the tutor with a set of metaphors, for the creation of a customized metaverse, which is a virtual representation of the learning path. Earlier experiences, like [PSBwW98] have shown the benefits of modeling the learning space to ease the fruition of the contents, by providing a representational and mnemonic method of mapping semantic onto spatial relationships. In order to exploit also users familiarity with features from a well known portal, probably the most widely adopted among today's learning manage-

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ment systems, DIEL has been developed and seamlessly integrated inside Moodle [Moo10]. It does not require any additional software layer as graphical interface, and it supports different visualizations of the same metaverse structure. At the same time, we chose to use a web browser as the only required mean to access the structure, employing technologies that are not based on the use of plug-ins nor proprietary standards, and which can be supported also by mobile devices.

The key point of this paper is to illustrate how an advanced web portal with 3D functionalities has been implemented, initially based on Flash technologies, and recently refactoring it by means of open technologies, namely X3D and WebGL.

The rest of the paper is organized as follows. Section 2 briefly describes the DIEL platform and features. Then its interfaces and organization will be detailed (Section 3), focusing on the alternative representations of the metaverse. Section 4 illustrates the implementation of DIEL.

2. DIEL Framework: Objectives and Main Features

DIEL [DDS08, DFD*09] is an e-learning platform providing new ways of user interactivity and data representation in a web based real-time environment. It provides a dynamic and interaction-friendly virtual learning space for community portals in education. Its effectiveness was experienced in high schools, university courses, and in vocational training. DIEL supports educational strategies involving collaborative activities, as recommended by socio-constructivistic pedagogists, as well as individual and personalized learning strategies. It was experienced as support for traditional lecture based courses, and for blended and distance learning.

Inside DIEL, users (tutors and learners) are free to move and interact, explore the environment to find contents, and update its resources, in such a way that any action and modification to the virtual learning space could be immediately visible to other users. The organization of a learning activity inside DIEL is much like the exploration of a set of virtual rooms, each of these rooms being dedicated and supporting a specific activity. This metaphor mimics the real life, where there is a natural mapping between places and activities, like for example library, laboratory, or even cafeteria. Available resources for the given learning objective appear as objects inside the room. The tutor decides room appearance and topology, by placing inside them, among possible objects, some doors, that lead to other rooms.

In summary, the main components of the DIEL interface are:

- *rooms*, that describe the virtual learning space
- *doors*, that connect two different rooms
- *users*, which can be tutors or learners, interacting among them and with
- *resources*, that are explorable items inside rooms. Examples of resources are documents and links provided by the tutors, as support materials for the activity, and resources devoted to user interaction, like forum, wiki, chat, and assignments.

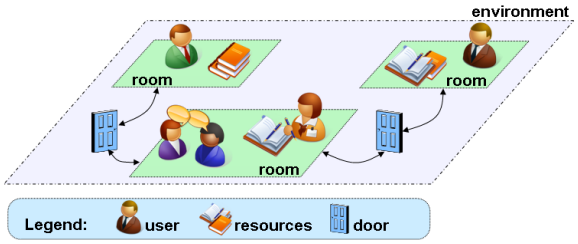

Figure 1: *Rooms, doors, users and resources inside the DIEL environment.*

Figure 1 illustrates a typical learning situation of a course inside DIEL with its rooms, doors, users, and resources.

3. DIEL Framework: Organization and Interfaces

As said before, DIEL is web-based, built upon Moodle, and by design, its user interface, functional process logic ("business rules"), computer data storage, and data access, is developed and maintained as independent modules, thus as a three-tier architecture.

The Data Layer is responsible for storing and retrieving all the information needed for the e-learning platform and processes, as for example resources (multimedia data) and pre-defined learning paths. The Business Logic controls the application functionalities by performing detailed processing. The Presentation Layer, which is the topmost level of the framework, is devoted to displaying information by outputting processing results to any HTML5 browser/client [W3C10].

In details, the DIEL Presentation Layer allows different interaction channels, namely:

- a video-chat interface by which a user can, on-the-fly, chat and talk with other users in the same learning session (described in Section 3.1);
- a 2D interface where the user can spatially interact with resources and other users (described in Section 3.2) and
- a 3D interface where the user can "live" immersed in the environment interacting and allowing a multiple layers learning procedure (in Section 3.3 the first prototype is described, while its refactoring is presented in Section 4).

A tutor selects either the 2D or the 3D interface in an interchangeable way, since they are alternative representations of the same structures and elements. In addition, including the video chat feature shall provide additional interaction capabilities to the learning community. DIEL supports both structured interactions, typical of blended or hybrid learning strategies, and unstructured interactions, taking place when

users casually meet on DIEL, and decide to cooperate, on the common ground of an activity. In either case, users decide how to interact, indirectly with their avatars or *directly* with their voice and face.

3.1. Video-chat interface

Supporting effective learning strategies, even at distance, requires human-based synchronous interaction features, like our Video-Chat facility. DIEL aim at simplicity in installation implies that its audio-video chat should be multiplatform, i.e, it uses platforms which are typically already available on most computers like Java, Adobe Shockwave, Adobe Flash. The ideal situation would be to rely on a plugin-free solution: HTML5 [W3C10] will probably natively support acquisition and reproduction of video streams (with the tags "<device>" and "<video>" respectively). But today's HTML5 is not yet universally available, and browsers supporting it do not implement its video acquisition feature yet. For this reason, DIEL video chat relies on OpenLazlo, an Open Source software that creates Adobe Flash applications [Ope10b]. Due to modularity, the video client is small, easy to maintain (an update to the chat module involves a small integration effort), and it is embedded as a Moodle block (as shown in Figure 2).

The audio-video chat is a client-server application. The client makes remote invocations to the server (for login/logout), and dynamically updates the interface (adding/deleting participants video boxes). The server layer is supported by Red5 [Red10], a Java package that manages Adobe FLV multimedia streams natively, which is once again an Open Source software.

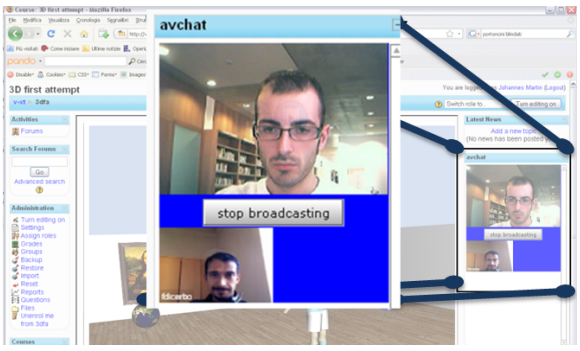

Figure 2: *the Video-Chat client embedded in a Moodle block, fully integrated with DIEL in the centre of the web page.*

3.2. 2D Interface

The simplest possible interface for DIEL is a 2D map of a room. Users are represented by avatars, which can move in the virtual environment by point-and-click of their mouse; by clicking on Doors, they reach another room. Users can interact with each other, activating a 1-to-1 text chat; tutors can create a room-specific text chat, which is available to all users in the room. The interaction with resources is very intuitive: for accessing one resource a user simply clicks on the corresponding icon. Generally, this originates a pop-up window, presenting the requested resource or service. When an avatar moves, all other avatars in a room can see it, thus the status of the room is updated in real time, just a few seconds after each modification.

Objects and graphic widgets have been implemented in HTML and Javascript. The Dojo toolkit [Doj10], an Open Source DHTML toolkit written in JavaScript, makes our software browser-independent, and is used for supporting asynchronous calls (AJAX interactions).

Figure 3 shows an example of the 2D interface in DIEL. Different doors, resources, avatars are shown.

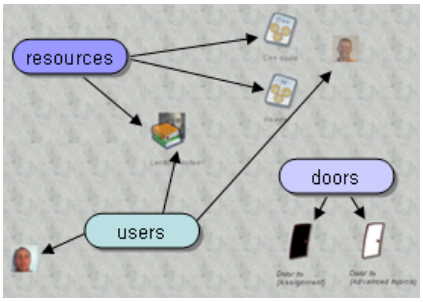

Figure 3: *DIEL 2D graphical interface, in a setting where 2D avatars and resources are displayed.*

3.3. 3D Interface: First prototype in Flash

An experimental extension of DIEL towards 3D interfacing was developed around one year ago using FFilmation [Min10], a 3D isometric graphics programming engine, focused mainly on games, and based on the Adobe Flash technology [Ado10]. This implementation allowed us to use very quickly a number of basic scenes, where characters could move and interact (very simply) with the environment. The framework demonstrated to be able to fulfill our expectations for quick prototyping. However, we had to get acquainted with ActionScript (AS), a scripting language similar to Javascript, and to the specific API exposed by Flash player, and to follow its version changes.

Figure 4 shows our 3D interface developed in Flash. Users move their avatars using the keyboard arrows, or click on a target (resource, door) to reach it. As for the 2D interface, in the latter case a pop-up window is created, presenting the requested resource or service. The client-server communication protocol is the same for 3D and 2D interfaces: the server keeps track of all the user's avatars and resources, letting the 3D clients download them when necessary.

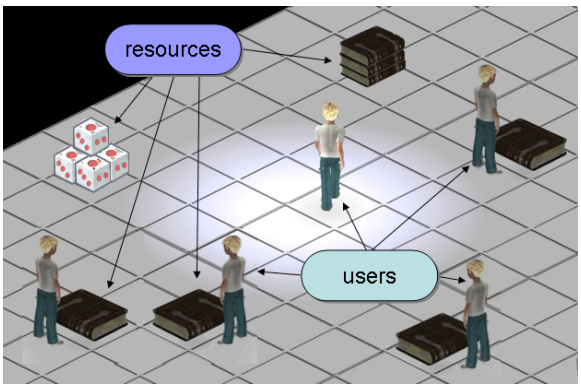

Figure 4: *DIEL early 3D graphical representation, in a setting where avatars and resources are displayed.*

This 3D prototype was initially developed in order to compare the adequateness for educational purposes of 2D and 3D representations of the same applications and services. It was tested with 30 high school students, to verify usability and user satisfaction of 2D and 3D DIEL interfaces in e-learning. Test results show that, when substituting standard classroom activities with others based on the 2D/3D version of DIEL, the same learning objective may be achieved with more personal satisfaction.

Thus, the implementation of this prototype met the user expectations: we were able to create a simple 3D virtual environment. However, FFilmation presented also some drawbacks for the sake of the project.

First of all, human characters (with their animation sprites), textures and resources need to be encoded in specific Flash files (and in order to be used they have to be embedded into the 3D client). This requires nontrivial graphical skills in designing anthropomorphic avatars. Second, avatar interaction is limited, i.e., any new feature or action in the virtual environment has to be developed from scratch, without any support from the engine. Third, the need of purchasing an Adobe Flash developer suite to work with the system represents a minor but significant discontinuity with the choice of Open Source technologies. Especially the first aspect is a huge limitation for a highly interactive web portal. Nowadays, as it happens in Second Life and in other social networking sites, users expect to be able to customize not only contents, but also any other personal aspects, like avatars. This possibility reinforces the identification of users in the virtual environment, having positive implications with respect to her involvement and participation. To allow the same inside our Flash 3D visualization would require users to have skills in Flash technologies, which is clearly unsustainable.

These considerations, together with the good results from the evaluation and usability test, led us to consider our 2D visualization as a reference model for a new 3D visualization development. We found in X3D [Web10], WebGL [Kro10] and X3DOM [X3D10] the technologies able to sustain our new initiative. These technologies, and the new 3D interface, shall be described in the next section.

4. An innovative X3D/X3DOM Interface for DIEL

Today several technologies exist to create 3D content for the web. Most of them are plug-in based systems, which means they depend on an additional piece of software running inside a web browser. This adds more complexity for the end user to use such 3D content. The user has not only to deal with plug-in installation but also with potential security issues and incompatibility.

The following subsection is devoted to a brief presentation of the chosen technologies, and the next one shall detail the 3D interface implemented.

4.1. Authoring 3D content on the Web: X3D, WebGL and X3DOM

X3D [Web10] is an open ISO standard developed by the Web3D Consortium for creating the next-generation of specifications for representing three-dimensional graphics. X3D is XML based, and its benefits are: readability for both humans and computer systems, multi-vendor support and freedom from licenses, and availability of well structured, web compatible data. XML also allows a direct extension of the X3D language, providing in this way a mechanism for extensibility. Applications that can parse and render X3D scenes are called X3D browsers, and are often implemented as a plug-in into web browsers. These X3D browsers expose a so called Scene Access Interface (SAI) for manipulating the content of a scene. X3D also provides bindings for programming languages like ECMAScript. Internally X3D uses a *scene graph* to model objects in a three dimensional space. This is why it can model basic 3D objects, or very complex real-time 3D scenes with user interaction, dynamic scene graph manipulations, animations and event based programming.

WebGL [Kro10] is a cross-platform, royalty-free web standard for a low-level 3D graphics API. It is developed by the Khronos Group, a consortium founded by industry leading companies, and it aims at bringing plug-in free 3D graphics into modern web browsers. Major browser manufactures like Apple (Safari), Opera (Opera), Google (Chrome) and Mozilla (Firefox) already implemented the first draft of WebGL into the development version of their browsers. Technically, WebGL is a DOM API, exposed through the HTML5 canvas element. It is fully integrated with the web page DOM interface and can be used by DOM compatible languages, like JavaScript. It is based on the OpenGL ES 2.0 specification [Ope10a], uses the OpenGL shading language and, for our purposes, it is similar to the OpenGL API.

Recently, the Virtual and Augmented Reality Department of the Fraunhofer Institute proposed X3DOM [BEJZ09], an open-source framework developed with the aim to bring the X3D standard to HTML5 on top of WebGL. X3DOM is a framework for integrating and manipulating (X3D) scenes as HTML5-DOM elements, which are rendered via WebGL: consequently, X3D content is displayed without plug-ins nor additional software. The system supports a declarative definition of 3D-scene description, and its runtime behavior. The first stable version of the framework has been released on March 2010. Examples and API can be found in [X3D10].

4.2. The new 3D Interface

We developed our new 3D client based on a new set of technologies:

- **X3D**, to model avatars and resources, as well as any other aspect of the virtual environment;
- **X3DOM**, to manage any X3D directive, and the integration with the HTML page;
- **Web3D**, to actually render the X3D directives directly on the web page canvas.

The introduction of X3D altered slightly the graphical resource management, and therefore the client-server interaction. Graphical elements are stored in specific files and reside on the server; each 3D client requests them when the server points to them.

The 3D client is implemented as an agent: it is responsible to manage server communication and download of X3D files, pointed by the server to render the needed scene. It also manages user interactions, by listening to HTML and Javascript events, and by sending the appropriate messages and notifications to the server. Scene template definition is stored on the server, and it is generated according to resources and users' positions in real time. An asynchronous shared communication channel allows each client to communicate with the server, enabling quick and live updates to the 3D scene.

The current implementation presents many advantages with respect to the previous one: first of all, users shall be able to upload their own 3D avatars to DIEL. A growing number of games already allow to create and export avatars and resources in X3D format, and users need no specific drawing skills for doing that. The 3D client is fully implemented in Javascript, so it is straightforward to modify and extend its set of features, without the need to rebuild the client, as it happened with the previous implementation. In fact, specific interaction rules can be attached to resources, embedding them into specific ECMAScript nodes in X3D files.

5. Concluding Remarks

The paper has presented a Web 3.0 portal, DIEL, which aims at creating educational metaverses. The organization

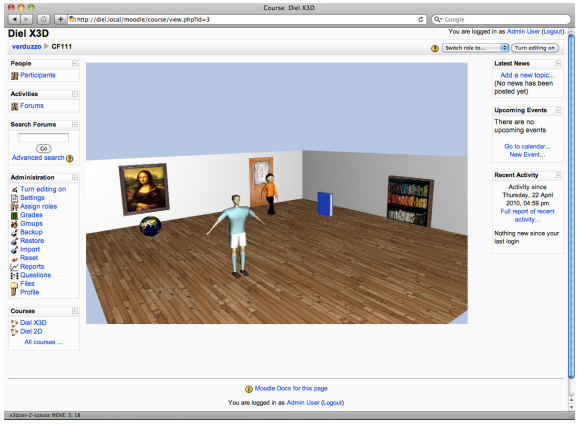

Figure 5: *The 3D interface integrated in Moodle, showing a learning room. Two avatars (students) interact with the environment. On the walls and on the floor different resources are located.*

of DIEL, its interfaces, and their implementation has been described, from the 3D initial implementation (based on Flash) to its recent refactoring with open source technologies, namely X3D, WebGL, X3DOM and HTML5.

The lessons learned in our experience apply both to the educational and to the 3D graphics research and development environments.

The use of 3D metaverses in education has raised very positive user reactions, while its educational added value is still to be demonstrated. The contribution of DIEL to this respect is to provide, with respect to other implementations ([DFPT09, STFM09]) an easier system, more flexible to tutor's requirements, where no software nor plugins need to be installed at client side, and, more importantly, all user data can be stored on just one non-cloud (and not shared) server. This has already made it possible, for example, to use DIEL in schools where limited technical staff is available, without security concerns.

From the point of view of 3D implementation, refactoring from the existing Flash implementation to the X3D compliant interface has been achieved with a limited effort. This activity has provided some improvements with respect to the previous implementation: improvements in terms of customization of avatars and resources, satisfying a very important users' need; easier extensibility, as the different 3D visualization allows to introduce new 3D resources as they are needed, even modifying the interaction schema currently in place; stability of the interfaces (it is not necessary to migrate periodically to new APIs, as it was for the Flash-based system); opening up a new set of possible future developments and enhancements to DIEL.

Relying on an open standard like X3D will make it pos-

sible, in the future, to seamlessly extend DIEL resources to comprise whatever resource can be X3D-compliant. Any 3D model can be included in learning paths as a resource, for example a terrain model for exploring a landscape, or a CAD/CAM model representing an engine, for studying its components. Thanks to the use of X3D, these models could have semantic annotations attached, thus providing multi-level representations and semantic-enriched content, possibly guided by ontology-driven metadata. 3D simulators can be provided as additional locations in the learning path, opening up the virtual learning environment and integrating it with other valuable educational resources. When audio-video bidirectional streams will be fully supported by X3D tools, the video chat could become a regular resource, and be inserted in specific rooms. Young users will be happy to upload their own customized avatar, which they created in their favorite videogame and then exported in X3D compliant format.

Finally, the availability of true 3D potential in visualization of the learning path is now stimulating educators to extend the concept of learning path to a 3D model as well. In one such extension, the vertical dimension can be considered the place to store the "traces" that over time each learner keeps for himself, a sort of individual portfolio or backpack where artifacts can be kept for future use, across courses and for a longer time. The debate on such issue is just starting among researchers ([SG10]) and tools like DIEL shall play an important role in experimenting and validating research issues.

6. Acknowledgments

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