Integrating 3D Virtual Reality simulations in reusable e-learning courses

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Abstract: This paper presents an example of creating and integrating Virtual Reality simulations in SCORM compliant Web-based e-learning scenarios. The simulations will be added to the e-learning content and they are composed of several passive and interactive simulations, requiring to follow a workflow in order to produce them in a reusable manner. The implemented VR simulations are shown in the results and they are related to the training of technicians in wind energy generator maintenance, which is part of the e-WindTech collaborative project. The main element of the VR simulations is the 3D wind mill model, which is used to produce different offline rendered videos and various interactive virtual worlds depending on the specific requirements of the e-learning content that will be presented to the students.

1 Introduction

The term e-learning refers to learning scenarios that are realized with the help of the computer and, in most cases also the internet, in order to enable time and location independent as well as multimedia-based learning. Today there are a lot of different e-learning scenarios possible which differ in the underlying technologies as well as in the didactical scenario, for example there are pure offline, pure online as well as mixed mode learning scenarios possible.

E-learning has the potential to improve not only the distribution and acquisition of knowledge but also to enhance the quality of learning by not only presenting static but also interactive learning materials such as interactive simulations. Especially in many technical areas, interactive simulation and Virtual Reality can provide a much more sophisticating learning experience than just using static text and images [Hu03]. For example displaying in a lively way how a machine works internally or allowing a trainee to try out a certain procedure in a simulated environment are functionalities which can boost learning and mastery [Fa08].

When realizing online learning scenarios learning management systems (LMS) are used. Nowadays, there are lots of different systems available differing in the underlying concepts as well as the functionalities available. Nevertheless most LMS allow for authoring, storage and administration of different e-learning materials and courses as well as support the organisation and moderation of online learning. Modern LMS, like *smartBLUE* which was developed at Fraunhofer IGD Rostock, strictly divide between content and presentation [Ha02].

Within this context several standards have emerged in the last decade that permit the reuse of learning materials. One of them is the Shareable Content Object Reference Model (SCORM)[1] developed by Advanced Distributed Learning (ADL) which is probably today's most popular standard in the field of e-learning [Bo02]. SCORM is a standard that allows for interchanging of e-learning objects and courses between different e-learning management systems by the use of metadata and a predefined structure of the learning material, including sequencing and tests, as well as a format for packaging courses. .But until now there is no possibility to integrate interactive simulation into SCORM compliant e-learning materials or LMS.

This article discusses one way to implement VR content in a SCORM compliant e-learning course using the LMS smartBLUE. Thereby, the main focus is on the technical obstacles and ways to overcome them.

1.1 e-WindTech collaborative project overview

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[1] Shareable Content Object Reference Model

The research and initial developments described in this paper were done in the context of the collaborative project e-WindTech funded by the European Union within the Leonardo da Vinci Program. The main goal of this project is to develop an e-learning course for wind generator maintenance technicians, enriched with Virtual Reality simulations. In order to allow the content to run on different LMS it has to be SCORM compliant.
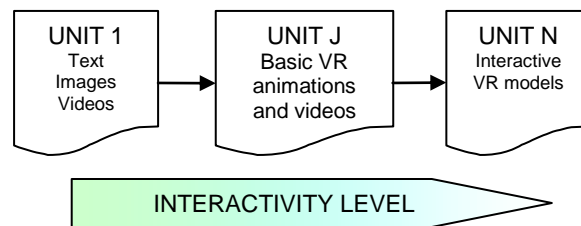
Figure 1: The interactivity degree increases as units progress

From the interaction level that is required from the student, the e-learning course units are organized in an incremental manner. In the first units, the didactical information is mainly based on texts and images.

The e-learning course units are organized in an incremental manner. In the first units, the didactical information is mainly based on texts and images. As the student is acquiring the basic concepts related to the wind mills maintenance, the units become more interactive, involving multimedia elements (such as videos) and some 3D simulations (see Figure 1). The interactivity degree of the VR elements at this stage is very limited, since the main purpose is to show the student typical examples and solutions.

The following subsection explains Virtual Reality in the context of this project, a discussion how it can be implemented in a way that can be integrated in learning objects, and a description of what has been implemented at the moment.

2 Virtual Reality in wind energy e-learning

In its strictest sense Virtual Reality refers to is a simulation of reality that includes physical simulation, real time behaviour, interactivity, and of course visual and auditive rendering. Today the term has come to describe any 3D animated representation of reality, both real-time and non real-time.

The VR elements will be visualized within an e-learning course that it is intended to be completely taken online. The use within a Web-based environment is the most restrictive requirement and reduces the number of available technologies.

The technologies available to enhance Web-based learning materials with VR elements can be categorized based on the interactivity degree from the student point of.

- No interaction: The student only watches 3D pre-rendered animations or videos with no interaction at all (apart from the typical VCR controls: start, stop and pause controls). Technically this implies embedding the videos in Web pages via *object* HTML 4 tag (relying on a player plugin) or the *video* tag in HTML 5.

- Low interactivity: Some simple user interfaces are shown to the users, where the interaction is reduced to a set of predefined actions such as staring animations or moving the point of view. For example: a 2D diagram where the user can click on an "active" part and view an animation explaining the purpose and functioning of the selected part. The integration of this kind of interactive elements is done via installed plugins in Web browsers, such as Adobe's Flash or a VRML viewer for 3D.

- Fully interactive simulations: A 3D world where the user can move freely in a realistic way (physics mode) [Al04]. The user could be able to interact with the world elements via direct manipulation and experience the reaction of the model [Fa08]. Driving simulators belong to this category.

2.1 Available technologies for 3D Content on the Web

Due to the Web browser context of e-learning courses the VR simulations included in such a course must be embeddable in Web pages, which restricts the available technologies.

The same is due to integrated video files which will be rendered by the Web browser using the installed video and audio codecs [Hm07]. Although HTML 5 eases through its *video* tag most sites today rely on commercial systems such as Adobe's Flash.

2.2 Standards and browser extensions for 3D

A review was made of the existing standards for interactive 3D content suitable for embedding virtual models in Web page. These include VRML, X3D, U3D and COLLADA. We studied their features and suitability for our application (see Table 1).

We also performed a survey of existing software extensions for Web browsers for displaying real time 3D content. We reviewed a few VRML/X3D viewers such as Cortona, BS Contact and Flux, and other systems such as Anfy, Blaze3D, Kaon and Papervision.

Table 1: Different Web browser plugins and their supported 3D formats. For each plugin, Web platform and scripting capabilities are provided.

Viewer	Format	Platform	Scripting (internal)	Scripting (external)
Cortona3D	VRML +extensions	Firefox, IE	yes	yes
Flux/Vivaty	VRML, X3D	Firefox, IE	yes	IE only
BS Contact	VRML, X3D	Firefox, IE	yes	?
Blaze3D	Flash3D	Java	ActionScript	-
Kaon	Proprietary	Java	?	-
Anfy3D	none	Java	Java API	Possible
Adobe Reader	U3D in PDF	Firefox, IE	Javascript	-
Papervision3D	COLLADA	Flash	ActionScript	-

Some of them enable more sophisticated integration via mechanisms for scripts in the Web page to access the 3D model and viceversa. That is what the external scripting column refers to in the above table.

3 Methodology

Although the final e-learning course for wind mill maintenance is not finished yet, the steps necessary to provide the VR simulations are already defined. This section explains the methodology used, including a VR simulation test to be extended for the final version: the offline rendered videos and the interactive virtual worlds.

3.1 Windmill 3D design and workflow

In order to produce VR simulations, we need a 3D model of the wind mill which will be the base material for all simulations and animations to be added to the e-learning course.

First, a 3D wind mill is built using a 3D modelling application such as Autodesk's 3DS Max, Blender or equivalent. If a realistic model is needed, it would be better to get the necessary information directly from the manufacturer, otherwise, the results may not be as realistic as needed.
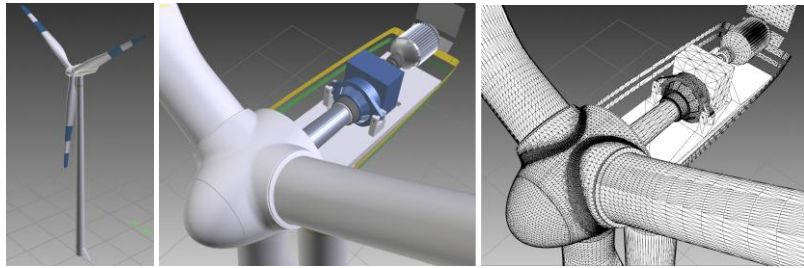

Figure 2: Some screenshots of the 3D model of the windmill. Left: complete view of the windmill. Centre: A view of the internals of the windmill, in solid colour. Right: The same view, but visualised in wireframe.

A generic model representative of most wind mills was then created (actually two models will be designed, one gearbox-based like the one pictured in Figure 1 and a multipole one).
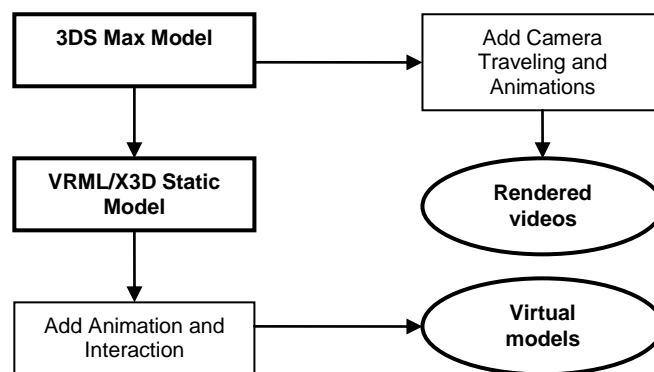

Figure 3: Process to create the videos and Virtual Models

With the 3D model of the wind mill, VR simulations can be created. In Figure 3, the workflow and the steps we followed to create the VR videos and the interactive virtual worlds are sketched and they will be explained in the next subsections.

3.2 Offline rendered videos

As shown before, using the 3D model of the windmill as the main element, some high quality videos highlighting different parts and from different perspectives of the windmill were rendered.

A script or story board made by wind mill experts served as a basis for designing camera paths and animating moving parts for each video clip. Once all the video parameters are detailed and designed, the video rendered with high quality shading algorithms. Since it will be watched offline, rendering time is not relevant and may take several hours.

Videos are then postprocessed to add effects such as highlighting specific parts. Different versions the master video are finally created in several video formats and resolutions for the target platform.
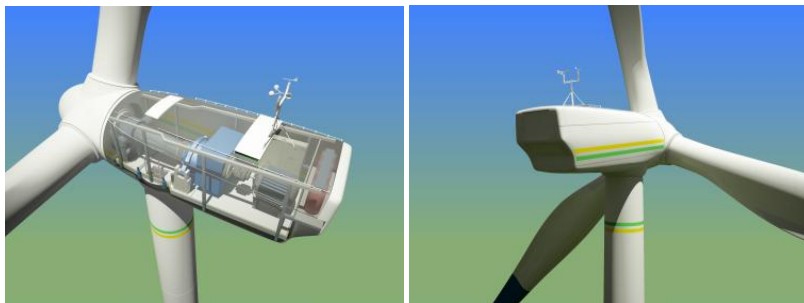

Figure 4: Two frames of an educational video (rendered offline).

3.3 3D interactive animations embedded in a Web browser

As discussed previously, we are using VRML/X3D standards to create the interactive virtual models. The first step is to export the 3D wind mill model to a VRML file, making sure its hierarchical structure is preserved, because it is necessary to add animations that the student will control via the provided interface.

As the 3D model will be rendered in real-time, its complexity (number of polygons, textures, etc.) should be reduced for a smooth rendering in lower end computers. Even if interactivity is guarantied, the screen size of the virtual world should be taken into account to optimize the user experience.

Once the 3D model is exported, it is convenient to add additional elements to the virtual world. In the test cases, adding a simple terrain, a background image and some trees gives the student a spatial reference. It is up to the designer to offer the students the most suitable environment to the topic they are learning, which may even be an empty environment.
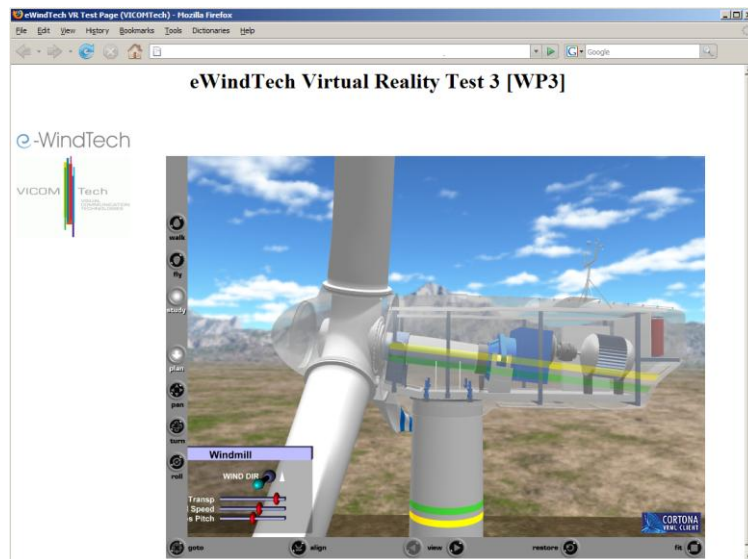

Figure 5: A screenshot of an interactive virtual world (VRML) visualised in a simple Web page (Browser: Firefox 2, VRML Plugin: Cortona 3D).

Animation and interactivity are then added exploiting the functionality of VRML/X3D. Adding rotations and translations to some nodes is straightforward using the *ROUTE* constructs and some *Interpolator* elements to the appropriate transform nodes.

In this work, the animation of the rotor and connected parts inside the nacelle simulate the behaviour of the wind mill in different wind conditions that the user can control. We wrote Javascript scripts for this purpose.

In Figure 5, a test virtual world is shown in a Web browser, using *Cortona 3D* to display the VRML model. The test scene contains a highly detailed exterior of a windmill with the main elements of the nacelle. A GUI embedded in the 3D scene provides user interaction. The user can: change the opacity of the nacelle to see the elements inside, change wind speed and direction, and see how the generator reacts, and control blade pitch.

4 Conclusions and Future Work

This work describes a methodology for integrating two kinds of 3D Virtual Reality simulations in an e-learning course to teach wind mill maintenance, both interactive and non interactive. Interaction is intended to increase as learning units advance presenting the student with practical tests in the latter ones. In order to ease the creation process of all the Virtual Reality simulations, a workflow has been designed, allowing a fast modification of the existing VR elements and the reutilisation of the existing ones.

As future work, the content of the e-learning course will be finished and integrated in a SCORM module compatible with any SCORM compliant LMS. There are still some challenges in the packaging of all this content in reusable modules.

The communication between the Web browser, the e-learning platform and the Virtual Reality simulations will be standardised following the SCORM protocols, in order to allow data persistence of evaluations.

Acknowledgements

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