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Tools for Populating Cultural Heritage Environments with Interactive Virtual Humans

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Abstract

Modern 3D VR systems rely heavily on the interplay of heterogeneous technologies. Because of this inherently interdisciplinary character, VR domain can be viewed as a melting pot of various technologies which although complementary are non-trivial to put together. Frameworks can be used to address this challenge as they offer advantages such as reusability of components, as well as easiness of replacements, extensions, and adaptations. Hence, this paper presents developments within the EPOCH project, in particular the Characterize NEWTON, to improve and release frameworks that support the incorporation of avatars in interactive real-time 3D VR systems. The purpose is to enable avatars to be interactive and to react to model metadata; thus adding realism and engaging the user's interest. This vertical middleware offers the advantage to be based on open source generic frameworks, such as OpenScenegraph and OpenSG as well as offering complementary functionalities.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Three-Dimensional Graphics and Realism]: Virtual reality I.3.4 [Graphics Utilities]: Graphics packages

1. Introduction

Once Cultural Heritage (CH) data has been captured, stored, and interpreted; CH professionals usually turn their attention to the display of their findings in interactive 3D Virtual environments. For this, it is not only necessary to create a 3D scene but also to add realism to it by including virtual humans, often referred to as avatars.

Modern 3D VR systems rely heavily on the interplay of heterogeneous technologies. Because of that inherently interdisciplinary character, VR domain can be viewed as a melting pot of various technologies which although complementary are non-trivial to put together. Many of those technologies gain a lot of individual R&D interest but still it is not generally understood and there are barely any accepted guidelines and approaches in the matter of integration of those functional artifacts under the roof of one consistent framework. In other words, there are many masterpieces of atomic technologies but still there is a lack of a well understood and generally accepted strategy for putting them up so they would constitute the whole bigger than the simple sum of its parts. The missing element is an open source framework which would curb the complexity and make the resulting system machinery a consistent and seamless unity, leaving at the same time open handles and hooks for replacements and extensions.

It becomes visible that the complexity of such systems reaches the levels that cannot be handled anymore efficiently by methodologies and technologies of today. Object oriented toolkits, knowledge of well established architectural and development patters plus human skills and experience still help and do the job but in order to stay on the cutting edge of tomorrow development speed, massive reusability of components, easiness of replacements, extensions, adaptations, reconfigurations and maintenance must be addressed. These are exactly the features offered by the frameworks.

Within the context of the EPOCH project, in particular the Characterize NEWTON, we aimed *to improve and release frameworks that support the development of interactive audio-visual real-time 3D VR systems*. In particular, environments which feature real-time virtual character simulation with state-of-the-art clothing. For this, the main challenges undertaken by this research were: elaboration of methodology, guidelines, architectural, design and behavioral patterns leading to the construction of vertical middleware frameworks. This resulted in the release of an easy to use set of tools to incorporate avatars that react to model metadata adding realism and interest for users. This vertical middleware offers the advantage to be based on open source generic 3D graphic frameworks, such as OpenScenegraph [Ope08a] and OpenSG [Ope08b] as well as offering complementary functionalities.

The following sections will describe the frameworks resulting from this work: a) the release as open source of the VHD++ kernel and plug-in and b) the improvement of the UEA Scene Assembly

Toolkit. The latter supports the use of natural language interaction. Furthermore, two applications will be presented illustrating the environments and efficient virtual human simulation which could be created by using these tools. A brief overview on the usability and acceptability for the type of application produced by this framework is also described.

2. VHDPlus

UNIGE and EPFL have been actively involved in the EPOCH project contributing with virtual human simulation technologies as part of the EPOCH Common Infrastructure in both showcases as well as the Characterize NEWTON projects by adapting and releasing their core platform vhdPLUS as open-source tool for the cultural heritage community. The vhdPLUS Development Framework is a modern, fully component oriented simulation engine and software middleware solution created by and reflecting many years of the R&D experience of both the MIRALab, University of Geneva and VRlab, EPFL labs in the domain of VR/AR and virtual character simulation [PPM*03].

vhdPLUS is a highly flexible and extensible real-time framework supporting component based development of interactive audio-visual simulation applications in the domain of VR/AR with particular focus on virtual character simulation technologies (see figure 1). It relies heavily on multiple, well established Object Oriented design patterns, uses C++ as the implementation language and Python as a scripting language.

Figure 1: *Screenshots from the final 3D interactive real time virtual heritage simulations based on vhdPLUS*

vhdPLUS has been released as open source as part of the EPOCH-NEWTON Characterize activities. In support of this release, and as per the Common Infrastructure activities, we have created several resources that should lead to a more effective use of vhdPLUS for users in general, but especially for those involved in the Characterize activities. Some of the components in the vhdPLUS version include:

- OpenSceneGraph rendering.
- OpenSG based rendering for static objects.
- VRML97/HANIM1.1 low level parser library.
- Helper library for Virtual Human control: libvhdOSGExt
- Configuration of vhdPLUS through XML files

To allow the interaction between vhdPLUS and OpenSG a new Service (a vhdPLUS plug-in) has been written that allows for the rendering and placement of geometry through OpenSG. Furthermore a library has been provided for the loading and animation of HANIM1.1 virtual humans and we included a service template with basic code to demonstrate the inclusion of new services into vhdPLUS.

A further explanation of the use of XML in combination with vhdPLUS has been given on the website: [vhd08b]. We have also included basic doxygen generated documentation showing the structure of the various components that make up vhdPLUS as well as a paper demonstrating the use of VHD++ (and therefore vhdPLUS) in cultural heritage contexts [NMTCY07] and [MTP06]. Based on various user inputs, UNIGE has updated the basic building environment and scripting tools for easier adoption of the framework. EPFL has proceeded with the addition of specialised to virtual human simulation math library.

Finally, following a recommendation from the last EPOCH review, clear references and acknowledgments to EPOCH have been added on the dedicated web-site. Since 2007, more than 200 downloads have illustrated the interest of the open source community on the above framework.

2.1. Availability

vhdPLUS has been made available through Sourceforge [vhd08a], and has been released under the LGPL2 license. It is accompanied by a website [vhd08b] in which we have made available a number of documents [PPM*03] and [MTP06] detailing the full structure of vhdPLUS as well as its capabilities and uses. Especially [Pon04] gives a full description of VHD++ (vhdPLUS's parent framework) including information plug-in structure (called Services in vhdPLUS) as well as XML initialisation.

3. UEA Scene Assembly Toolkit

The University of East Anglia (UEA) has been, as part of the Characterize NEWTON, involved in improving a toolkit for 3D scene creation. This toolkit supports the user through an assembly pipeline by offering the following components:

1. Terrain Converter (see figure 2): converts terrain data from a regular grid to a ground model.
2. Avatar Research Platform (ARP) toolkit: supports the design and animation of Virtual Humans capable of speech and sign language.
3. Scene Assembler: used to combine objects in the scene using scriptable operations and manual tweaking. For this, every command is stored in an XML script format for rapid semiautomatic assembly of scenes.

The Avatar Research Platform (ARP) toolkit includes tools for conventional mesh attachment and design. Some of its features include:

- Advanced tools for facial morph creation (as shown in figure 3).
- Bespoke avatar creation for procedural animation (UEA Animgen).
- Imports industry standard Maya and FBX.
- Exports to Maya and FBX.

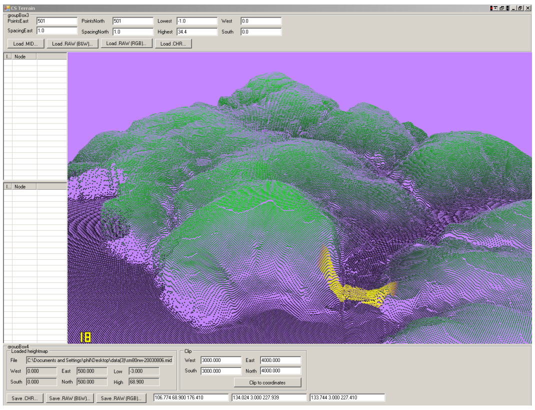

Figure 2: *Scene Assembly Toolkit: Terrain Converter component*

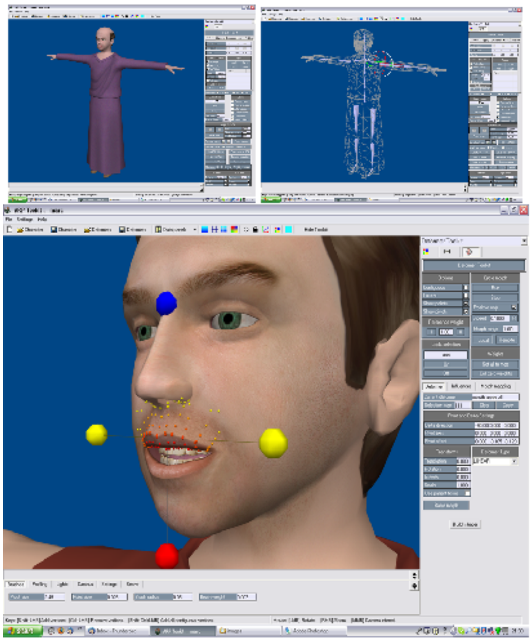

Figure 3: *Screenshots of UEA Avatar Research Platform (ARP)*

- ARP format used by EPOCH Scene Renderer.

A propietrary extension for COLLADA [Col08] standard is used as the format for exporting from the ARP toolkit. The Scene Assembler can import virtual humans in this format into scenes. To work smoothly, it has been required to resolve some issues in OpenSG with the dynamic nature of virtual humans, such as memory overheads, rendering speeds, synchronization of audio and visual components important for speech. This was done by utilising "deprecated" interfaces that allow low-level use of OpenGL. Furthermore, interfaces have been provided for attaching hyperlinks to objects so that users can access related resources, for example websites.

As illustrated in figure 4, the Scene Assembler tool creates a final scene by adding simple static geometry objects from popular modelling software (3DSMax, Maya, etc.). In addition, billboard objects defined by text are used to represent trees, lamp posts, and other street furniture. Objects from a group can be "planted" with a single click, especially useful for rapidly adding vegetation. Then, individual virtual humans are placed in the scene with animations as shown in figure 5. The Scene Assembler tool can export scenes in .OBJ format (static objects only) or COLLADA with extensions. Rendering of the final scene is based on the open source OpenSG rendering framework and utilizes occluder culling techniques for rapid animation.

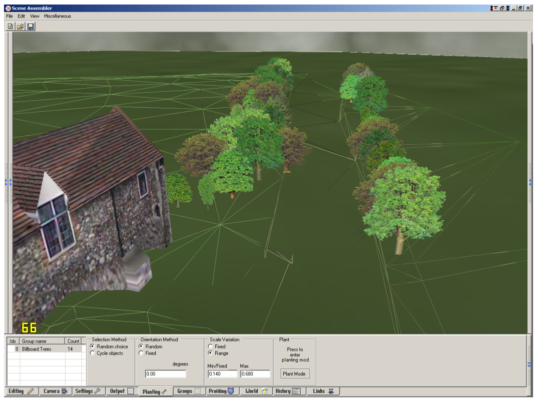

Figure 4: *Scene Assembly Toolkit: Scene Assembler component*

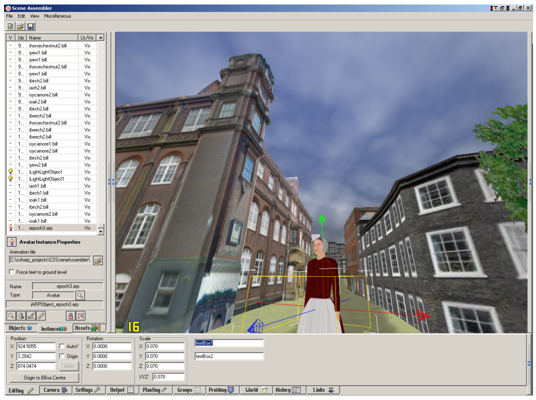

Figure 5: *Inclusion of virtual avatars in a 3D scene*

Within this framework, the Natural Language Processing and Generation module developed by the University of Brighton provides natural language interactivity within the environment. This functions as a question/answer system using predominantly natural language. For this, language technology automates the structuring and querying of heterogeneous and semi-structured information in databases which are structured within the CIDOC-CRM ontology [CID08]. The CIDOC Conceptual Reference Model (CRM) provides definitions and a formal structure for describing the implicit and explicit concepts and relationships used in cultural heritage documentation.

In addition, the system uses semantic similarity for producing appropriate answers to user's queries. This similarity is computed using dynamic programming where deletion, insertion and substitution are given a cost. WordNet provides a measure of the cost for substituting one word for another. As a result, the user query Q is compared with a set of n predefined queries. If the most semantically related Q-Qi pair is above a given threshold of confidence, the corresponding answer Ai is selected. Otherwise an Eliza-type of interaction is adopted.

Finally, the potential for integration of the resources and 3D environments produced by both of these frameworks is achieved by using the common open source generic frameworks OpenSG. For this, vhdPLUS includes an OpenSG rendering plug-in and UEA framework is based on the OpenSG rendering framework.

4. Interactive 3D Virtual Environments

In order to illustrate the environments and efficient virtual human simulation produced by both frameworks, two different real-time interactive 3D VR systems environments will be presented in the following sections. Both of these applications recreate a city or town populated by virtual humans for visitors to explore and gain information on the history of the place in an engaging and entertaining way.

4.1. Reviving the ancient city of Pompeii

Its main goal is to simulate in real time a crowd of virtual Romans exhibiting realistic behaviors in a reconstructed district of ancient Pompeii as illustrated in figure 6.

In an offline process, the city is first automatically reconstructed and exported into two different representations: a high-resolution model for rendering purpose, and a low-resolution model labeled with semantic data. Second, the city is populated with crowds of convincing virtual Romans presenting several different behaviors, and thus offering a realistic and varied simulation.

The city reconstruction is based on a CGA Shape grammar with nine different facade designs derived from archaeological drawings. It contains 4 levels-of-detail, 16 different wall types and three roof styles. Of this grammar 16 variations were automatically generated by combining the facades and roofs with specifically designed color palettes. This number could be arbitrarily increased, but practical aspects of the rendering limited the usable number of materials. The CGA Shape grammar has proven its great flexibility, for instance during the optimization of the levels-of-detail for the rendering process.

There are several buildings in the city model where virtual Romans can enter freely. Some of them are labeled as shops and bakeries, and the characters entering them acquire related accessories, e.g., oil amphoras or bread. These accessories are directly attached to a joint of the virtual character's skeleton, and follow its movements when deformed. We can attach accessories to various joints, depending on their nature. In Pompeii, this variety is illustrated with the amphoras: rich people leave shops with an amphora in their hand, while slaves leave shops carrying them on their heads.

The idea of rich and poor districts is based on age maps that were provided by archaeologists taking part in the EPOCH project. These maps show the age of buildings in the city. Although we do not yet have the building textures to visually express this kind of differences, we have decided to install the rich Roman templates in the most recent districts, while poor people have been established in old buildings. From this, virtual characters know where they belong and while most parts of the city are accessible for everybody, some districts are restricted to a certain class of people: rich Romans in young areas and slaves in poor zones.

As for the crowd, seven human templates have been exploited: a couple of nobles (one male and one female), a couple of plebeians, another couple of patricians and finally, a legionary. These seven templates are instantiated several hundred times to generate large crowds. To ensure a varied and appealing result, per body part color variety techniques are exploited. The resulting application is presented in [MHY*07].

Figure 6: *Crowds of virtual Romans in a street of Ancient Pompeii*

4.2. Touring the town of Wolfenbuttel

This application uses the UEA Scene Assembly Toolkit. It recreates Wolfenbüttel as it once stood during the seventeen century. This town sits on the Oker river in Lower Saxony-Germany, just a few kilometres south of Braunschweig. Within the 3D interactive application, the user navigates the scene accessing information about important buildings. For this, important landscapes in the scene are annotated with meta data so that visitors can explore related websites or other resources during a virtual tour.

To build the application, 3D modelling packages were used to model the most important buildings of the town. These models and other generic models of houses were imported to the Scene Assembler and the final scene was exported in the COLLADA [Col08] format. The showcase demonstrator was used for real time rendering of the imported COLLADA file using OpenSG [Ope08b], and provides user interfaces for navigation through the scene.

An interactive female virtual avatar was created using the ARP toolkit in order to have a highly interactive application and to create a more engaging presentation of the history of the town. Thus, the avatar was design to act as a virtual guide which responds to user's questions related to the building and events in the town. This is achieved by modeling appropiate gestures animations and adding natural language understanding to the application.

A "virtual tour" was created by generating interesting route paths in the environment. Six locations have been selected for the user to visit in the virtual reconstruction. The user navigates from one to another by clicking on labels "floating" in the sky. Once at a location, the user can look around, rotating the view or move freely with the use of keys. The user can request more information about any of the six locations in town using the following approaches: i) typing a question or ii) "pointing&clicking" on one of the predefined questions. The user also has access to a webpage when arriving at certain locations.

In this environment seen in figure 7, priority was given to building a mock-up that will allow users with different backgrounds to be part of the full interactive loop (navigation-request-processing-response-navigation) of interaction with a virtual guide. Taking into account contextual (location on the site) information about the user during the interaction provides a first impression of what natural interactive systems can achieve for navigation through Cultural Heritage sites.

Figure 7: *Avatar guide interacting with users of the virtual city of Wolfenbüttel*

The usability and acceptability of the Wolfenbuttel 3D Interactive application was investigated in order to identify the effectiveness and satisfaction of users when interacting with this type of 3D environment. In general testers found the application a good and entertaining representation of a historical place. Avatars were regarded as useful to add life to the environment, and users suggested that the levels of interactivity of the application should be higher. In addition, once testers understood the navigation and interaction mechanisms, they find the system easy to use.

Users had a more divided opinion on the best way to use these systems for presenting heritage and how they can replace current presentation systems. Testers tend to perceive them more as entertainment. This highlighted the need to make a real connection between the heritage/artefacts in display and the virtual environment. They should enhance the museum/site experience rather than try to be the experience themselves. The results of the testing are presented in [REMM*07].

5. Conclusions

The paper has presented results on the Characterize NEWTON within the EPOCH project. Both frameworks presented, vhdPLUS and UEA Scene assembly framework make use of open source generic frameworks to provide vertical middleware for constructing interactive 3D Virtual Environments. Furthermore, the paper has presented example of applications which can be built with this frameworks as a demonstrator of their potential for the Cultural Heritage sector.

The software is available from: [vhd08a] in the case of vhdPLUS and contacting the developers for the Scene Assembly Toolkit.

6. Acknowledgements

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