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DentroTrento: an Example of Application of Computer Graphics to the Evolution of the Archaeological Site of Tridentum

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Abstract

This paper illustrates the DentroTrento project, commissioned by the local authority for Cultural Heritage, which has lead to the creation of an edutainment system for the visitors of an archaeological site in the town of Trento. In particular, the aim of the project was to enhance the didactic and entertaining potential of a Roman archaeological site which is located between the Theatre's foundations through the development of a computer graphics-based application capable of high visual and emotional impact. This has been made possible through the creation of an interactive system where the virtual reconstruction becomes the main means of guiding the visitor through a virtual walk across time. The relevance of the work illustrated is underlined by the profile of the project and the nature and importance of the site, which is located underground below a square. In fact this circumstance does not let the visitor perceive the urban outline of the roman town nor it lets visitors fully perceive, through the use of traditional teaching material, the way of life typical of the time. The system proposed instead engages the visitor into a more exciting experience replicating, not only the architecture, but the way of life of the Roman town. The scope of the project together with the heterogeneity of the working team has required a rigorous approach to the management of the entire project.

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

1 Introduction.

The fast-growing technological advancements in the field of Virtual Reality technology and the access to affordable high-performance Computer Graphics hardware, it has made it possible to extend the range of VR applications from the field of scientific research and medical training, to the general public and specifically to the field of edutainment.

Edutainment, as suggested by the term, it is a field combining education with entertainment issues, with the goal of rising the learning process to a more engaging and fun-filled experience. One of the main edutainment fields, which is receiving increasing attention by the research community, addresses the field of Digital Heritage. Within such setups visitors are able to virtually explore the reconstructed heritage environment and they can benefit from the additional information and learning material within the virtual environment itself offers.

The objective of the project presented in this paper was to pursue this approach to promote historical, artistic and cultural heritage in the area of Trentino through the use of Virtual Reality technologies. Through the virtual reconstruction of the Roman town of *Tridentum*, which is the Latin name of Trento, it has been possible to offer the visitors with a coherent and global view of the site, to enhance their comprehension and therefore to enrich their cultural experience. Great attention has been dedicated to the various step of development of the roman citizen of Tridentum from its foundation like military o until to *splendidum municipium* (splendid townhall). Particular attention has been paied to the area of the social theatre, which benefited from a wide spectrum of information available from the local Cultural Heritage Department.

2 Related Works

Since the first applications of computer graphics to archeology [Rei89] dating back to as early as the late 80's, several authors have tackled the use of Virtual Reality (VR) [BFS00] in the field of architecture. Three major types of applications are found in literature. A research lines sees VR used as tool supporting archeologists and specialists. The second promotes the creation of virtual reconstruction to create a scientific digital archive or to simulate scientifically the reconstruction of missing pasts of ancient structures. Finally the last line promotes VR as a powerful tool to teach and increase people's awareness towards Cultural Heritage.

With respect to the first trend Hynst et al. [HGGS01] propose a framework for the visualization of archeological reconstructions through a process that spans from the acquisition of 2D and 3D data to their organization into a scene database. Pursuing similar goals Pelfer et al. [PBMP04] propose the use of GRID technology for acquisition, storage and retrieval of worldwide archeology survey data through high end visualization tools. [BIF04] propose a VR/AR system to support archeologists.

The second research line, which aims at digital archiving of heritage, is represented by works such as [RLB*04] which presents a method for archiving and searching three-dimensional Native American ceramic vessels. Similar goal

is shared by [SCM04] who pursued extremely high rendering quality in the reconstruction of an Egyptian temple using physically based high fidelity graphics techniques. One of the key aspect of the research was to reconstruct, in a scientifically correct form, the missing parts thus being able to propose scientifically consistent forms of "virtual repairs"..

Last but not least a further research line promotes the use of VR as a powerful edutainment tool, capable of engaging users to a greater extent. An example of this is the work carried on by Pletinckx et al. [PCKS00] who underline how VR and multimedia can play today a key role in the promotion of a city and its cultural heritage. The authors describe the experience of the town of Ename, Belgium where VR is used to guide visitors through archeological and historical findings. The authors stress the importance of this approach which permits to avoid ethical problems emerging with physical reconstructions. The project in fact has led to a number of virtual reconstructions available through VR installation throughout the city. Further within the local museum, which represent the pivotal infrastructure of the project, the visitors can interact with the reconstruction of a 3x3 km area over a 1000 year time span. Similar goal is shared by the EU project Archeoguide [Arc05] [VIK*02] which has developed personalized augmented reality tours of archaeological sites. The technological focus of the project has brought to a number of achievements such as outdoor tracking augmented reality technology to enhance the user's experience while walking within the real site onto which it is rendered the reconstruction of the ancient buildings.

3 The DentroTrento project.

The scenario of the DentroTrento project has been the archaeological site of *Tridentum* also known as "SASS" and the roman street running in its midst which represents the most relevant piece. The street connected the two distinct and most important infrastructures of this part of the ancient city: a *domus* (an ancient house) and one of the city towers.

Unfortunately the visit to the site never allows for a good comprehension of the urban outline since the experience is spoiled by the narrow space available within the premises.

Fig. 1: *S.A.S.S. area*

In fact the entire site, which was only recently discovered during renovation works, lies below one of the most important city squares sandwiched between the foundations of the theatre (see Fig. 1). The peculiarity of the site does not offer the visitor a coherent and global view of the finds.Further as illustrated in Fig. 1 the experience is repeatedly disturbed by several structural elements such as the concrete ceiling (the floor of the upper square), which occludes the vision and which does not let the visitor perceive the real height of the ancient buildings. Moreover concrete structural walls limit the overall perception of the ancient street and the theatre's foundation pillars further contribute to the spatial disorder of the place.

For this reason the project had planned the creation of a virtual reconstruction which could offer the visitor the unique chance to virtually walk past the most significant spots of this portion of the ancient city of *Tridentum*. Furthermore the final system had to let the user experience the evolution of the site from the Roman period up to today. With respect to this numerous archaeological finds have allowed to single out which architectonic elements were present in the area across the various historical ages and how the development of the city had progressed.

The final result had to lead to the installation, within the premises of the archaeological site, of an exhibit featuring a stereoscopic VR set-up. The original *leit motiv* was to let the users experience an immersive visit of the town through a virtual tour guide of the site which could provide in depth knowledge of the site before moving to the real archaeological site. Tourists and citizens willing to acquire deeper knowledge of the ancient history of *Tridentum*, as well as enthusiasts and experts interested in further investigations, were the main beneficiaries of the project.

3.1 The project's outline

During the first part of the project, different documents with a detailed description of the various activities were outlined. These included detailed plan of the project, system requirements specifications, design of technological system and of the physical VR setup. During this stage a comprehensive description of each specific activity had to be provided provided. This was done through a detailed definition of each project activity considering relevant dependencies where appropriate. This phase led to the definition of a number of development and coordination risks, mainly caused by the management of the wide and heterogeneous team working at the project which included profiles such as modellers, archaeologists and programmers. Each risk was associated to a probability factor and to the relevant countermeasure for each risk element.

Likewise during this phase all the interfaces between components, automation tools, development instruments, software and plug-ins necessary to the development of all the components were considered. The final choice was the development of a modular application controlling two different ActiveX respectively for the rendering core and the multi-track playback. An event mechanism was designed to pass data back and forth from to the computer graphics engine to the sound module.

At this stage the appropriate level of accuracy of the digital reconstruction as well as the metaphor to be adopted in

terms of human-computer interaction with the system were also defined in conjunction with the archaeologists.
Then specific system requirements were outlined defining in detail each use-case, functionality, the actors and the relevant requirements in relation to the level of importance specified by the authority commissioning the project. The "actors" (i.e. the entities beginning and ending sequences of events which describe a scene) identified at this stage were a system manager, an engineer, a guide user and the final audience.

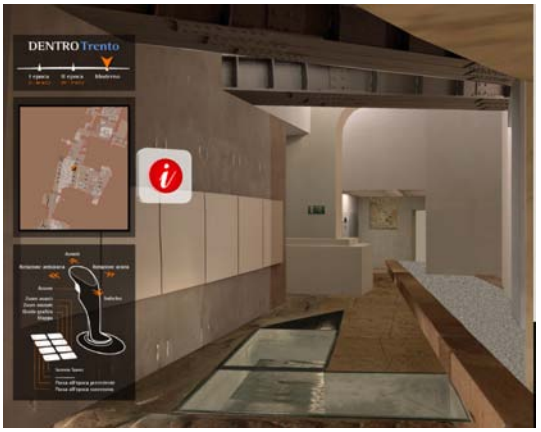

Fig. 2: *A screenshot rendering the site at the present day.*

This formal approach has allowed to set ahead rigorous quality criteria as well as technical constrains. These were defined in terms of reliability and accuracy, emergency recovery, usability and manageability requirements. Finally during this phase we have tackled the usability issue such as those implied by the definition of the navigation metaphor and the management of the multimedia content. The entire phase was grounded upon standard UML modelling language which has allowed us to outline the project's overview in a standard symbolic form. Further the use of UML diagrams has allowed easy sharing and communication of the idea from the developers team to the customer. This phase set the basis for a more detailed software architecture definition formally described through "class diagram" and "sequence diagram" in UML language.

3.2. Content creation

The development of the actual and historical reconstruction of the S.A.S.S. area was carried on by a team of specialized modellers, artists and VR experts by using commercial packages such as 3D Studio Viz and Eon Professional.

3.2.1 The creation of the virtual environment.

The construction of the 3D model saw the contemporary reconstruction of both the model of the actual site and the historical town during two different ages specifically chosen for their historical significance.
The structural complexity and the sheer size of the area to be reconstructed, together with the level of detail required and the number of people involved, have led to a careful planning of the acquisition campaign. The site was thus initially subdivided into several sections which where independently reconstructed and, given the historical and cultural importance of the reconstructed environment, carefully validated by the "Soprintendenza dei Beni Archeologici" the local Cultural Heritage department.

Fig. 3: *Two examples of the site as it is today rendered with (top) without (bottom) the presence of the modern structures.*

As far as the model of the actual site was concerned the advantage of using VR-based technology, beside providing the means for the interactive representation of the reconstruction of the site (see Fig. 2), it has brought the possibility to present the findings that, although present within the site, are normally partially or totally obstructed to the visitor. The first result therefore was to be able to show the visitors the site as it is today without those elements that limit the overall vision of the archaeological site (see Fig. 3).
As far as the reconstruction of the Roman town was concerned the construction of the 3D model has followed a much more complex process and it has been carried on starting from the acquisition of the available documentation necessary to the virtual reconstruction of the historical part. This included the collection of eventual archaeological studies and reconstructions, plans, video, photographic material and, in general, archaeological material coherent with the historical age of our interest.
Further, unlike similar projects [DVR05] [FPR*01], the lack of details such as wall colour, windows position, height of the houses within the district it has made it necessary to use documentation available for other sites of corresponding periods such as Pompei. The lack of documents providing the exact representation together with the aim of emphasizing the reconstructed part from the

present real environment, it has led to the choice of a more artistic interpretation of the site (see Fig. 4) in place of a very realistic reconstruction as described for instance in [SCM04]. For this reason the materials and the final textures used for the architectonic elements were rendered in a pictographic style inspired by the available historical documentation. This reconstruction work was repeated for two different models of the town, representing two distinct yet representative developments of the roman city at two different ages.

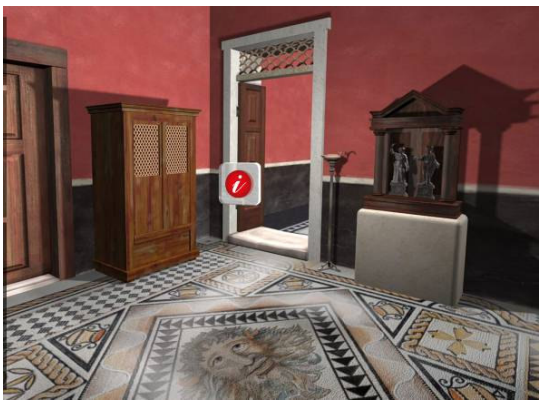

Fig. 4: *Two screenshots of the system showing the quality of the reconstruction and one of the "hotspots".*

The final model was finally optimized to guarantee the necessary level of interactivity. To do so the 3D models of the town (one for each different age) have been subject to various processes of optimization to guarantee both excellent visual effects and good performance in terms of rendering speed. To allow a fluent real time navigation and to avoid the calculation of the lighting system on the entire site at runtime we have run a pre-processing step during which lights, shadows and the materials reflection have been pre-calculated on the final textures. In this way the final textures used in the geometry take into account the correct lighting conditions and they guarantee at the same time the best possible representation without performance trade-offs.
A custom tailored level of detail was implemented through hard-code programming with the aim of further improving the performances, by manually programming the system to hide those sections of scenegraph representing portions of the town not visible to the observer.

3.2.3 The content of the Audioguide.

The project also required the development of a streaming system which could provide visitors with audio comments in synch with the navigation of the environment. Further the content, which had to be provided through the use of personal headsets borrowed at the museum hall, had to be concurrently streamed in several languages. Therefore in order to create such multi-language audio streaming of guiding information to the public the team started the acquisition of the documental material such as didactic material, texts, videos etc in order to define the content of the audio guide. The content have been selected through opportune comparisons and discussions with the didactic staff of the SASS and in conjunction with the department Cultural Heritage.
The communication style has been adapted to the targeted audience (child or adult) and as consequence of this process the final contents has been developed. Subsequently professional speakers performed a studio recording of the content. Particular attention was paid to the synchronisation of the duration of the content between the different languages.

3.3 The development of the application.

After the creation of the models the team of VR specialists proceeded with the creation of the interaction metaphor through the software EON Professional. We have chonsen EON because it is a complete GUI based authoring tool for developing real-time 3D multimedia applications with high quality of visualization. Once the model is imported in EON, behaviours can be easily associated to the models though scripting, compiled C++ code or through an intuitive graphical programming interface. The latter provides for the creation of the event mechanisms by arranging and connecting basic components called nodes. These represent the various features that may be included in a simulation.
An EON application was then constructed in a three steps process. The first step was to add and enhance the 3D graphic objects. In a second step the behavioural properties of these objects were defined and it was defined the way user should interact with them during the simulation. To further enhance the emotional level of the scene, sounds and other special effects, e.g. fading between different scenes, were added. Most of this features were implemented either through standard nodes or through VBScripts contained within the scenegraph.
Finally the third and last step was the creation of a fully-featured ActiveX control from the EON scene. Specifically we have decided to display and control the ActiveX component from an external programming layer created ad hoc for the project.
The final application in fact needed to allow the playback of the multiple-track audio files used by the audio guide in synch with the interaction of a number of "hotspots" (see Fig. 4) placed in the virtual world. The application plays the multiple tracks to a transmitter with in turn sends the content through an RF emitter to the wireless headphones worn by the visitors .
The synchronisation of the application with the ActiveX component is achieved through a method (SendEvent) within the application which is used to communicate with the ActiveX component itself. To do so a number of special fields within the simulation, so-called external in-event fields, must be created within the scene using the appropriate authoring tool. The SendEvent method triggers specific events within the running scene by sending values to these external in-event fields. The audio content related to each specific hotspot has been thus controlled by changing these fields.

4 Conclusions.

The project described throughout the paper has met the objective of delivering a media-rich edutainment tool where it is possible enjoy and learn the history of our cultural patrimony by exploring the archaeological site across space and time. The entire process of data collection, reconstruction and delivery of the final system, as described throughout the paper, has been carried on with the constant validation of the domain experts. The final result has been the integrated application shown in this papers which combines the high quality visualisation of an environment which is, from the archaeological point of view philologically consistent, with synchronised sounds and commenting audio.
This delivers high emotional impact which transforms the learning process of a visit of an archaeological site into a new more engaging experience. This way computer graphics becomes a powerful tool supporting the learning process through the coupling between the virtual and the real visit to the site.

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