Some Real Experiences in Developing Virtual Environments

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Abstract – *The paper presents some experiences in developing a virtual environment using a videogame engine. It provides the details and the caveats met during development, with particular attentions to the architectural reconstruction problem, the textures resolution and the programmability. Some considerations are also reported from an historical point of view, emphasizing the importance of virtual reconstructions, and from a psychological point of view stressing how a narrative context enhances the learning process.*

1 Introduction

Only until few years ago, using 3D videogame engines to create immersive environments was a sparely used technique in spite of the commercial success and the high level of photorealism that is achieved by current software/hardware technology. More recently, interest has grown on the efficiency and photorealism that can be provided on inexpensive hardware by using engines. Several (so called) "Serious Games" have been studied, and the interest is witnessed by the crowded tracks in the Computer Games Conferences (in the last few years) and by the growing number of non-ludic applications that are based on 3D videogame engines (see, e.g., [1, 5, 8]).

In [3] it was investigated how using videogames technology was particularly suitable for the development of interactive 3D environments. There are various arguments supporting this decision: *(a)* the presence of development tools (e.g. map modeler, exporter from/to modeling software); *(b)* support for modern graphics hardware; *(c)* scripting language providing great expansibility. These arguments were helpful in suggesting that the research direction was worth exploring and that more experiences had to be collected on using a videogame engine for developing a complete virtual environment.

This paper follows the path indicated by [3], by presenting our real experience in developing an educational virtual environment[1] based on a reconstruction of the Poseidonia-Paestum archaeological site. The experience was particularly significant, since the consistent amount of modeling, "visit" design (rather than game design) and user interaction that were employed. Moreover, the heterogeneity of our team (composed by computer scientists, artists, psychologists and historians) underlined the value of our experience, by showing the importance and the effectiveness of a well assorted and strongly motivated team.

2 PaestumGate project

The goal we had to pursue was to build an Educational Virtual Environment that would allow to provide a different experience to the young tourist who approaches the Poseidonia-Paestum site. The intended experience for users is different from the passive one provided by traditional DVD/VHS media, more immersive, cooperative and able to convey the "appeal" of a videogame. On the other hand we did not want to oversimplify the value of the architectural monuments yet visible in the site, in particular an important issue was to emphasize how different civilizations occupied the site through the centuries.

PaestumGate [2] represents a virtual environment that presents the reconstruction of the town of Poseidonia-Paestum with the following characteristics:

• *fidelity of reconstruction*: we paid attention in recovering architectural details that cannot be found in the Poseidonia-Paestum archaeological site. For instance we have compared the rests from Poseidonia-Paestum with coeval rests that can be found in other sites, this enabled us to reconstruct edifices, streets, houses and crockery

[1]We call "virtual environment" a 3D world rendered through a computer which provides highly interactive experience to users who navigate it and prefer it to the often abused "virtual world" or "virtual reality".

[2]For further information see `http://isis.dia.unisa.it/projects/paestumgate`.

with a reasonable precision;
• *cooperation*: the virtual environment can be visited by several users simultaneously: each user is aware of the position of other users and can "see" the actions the other users are performing;
• *scalability*: by leveraging on the development framework, we paid attention in assembling a virtual environment that is able to run on high end workstations with a full fledged set of visual effects, but it can smoothly run on low end PC with an appreciable frame rate and good visual results.
• *engaging for the learner*. Narrative methods are used by presenting the learner with challenges whose goal is to stimulate the exploration of the town and foster comprehension of a complex setting like Poseidonia-Paestum. As an example, the first challenge is to help the citizens to celebrate the Emperor's visit to the town, by bringing perfumed essences to a temple. The subtasks of locating the perfumer store and the temple bring the learner to cope both with the commercial and the monumental nature of the town.

In a preliminary phase we assorted a team that would be able to address the development of the product on three levels, the technological one, the psychological one and the historical one.

2.1 The technological level

The videogame engine we have chosen to use for the development is UnrealEngine 2 (*UE2*) Runtime from Epic Games [10]. The first version of UnrealEngine has been made available in 1998, since more than 2000 releases have succeeded divided in two main versions. UnrealEngine is currently under development toward version 3. UE2 is the current one and provide a lot of interesting features we shortly describe here:

Graphics. UE2 manages various typology of geometries static meshes, CSG and Heightmaps. The rationale in choosing one of the methods is: CSG is useful for interiors like rooms, while static meshes are topically used for high polygon-count objects built and textured in an external modeling program such as 3D Studio while heightmaps are useful to describe the terrain. In Figure 1 we provide examples of the results that can be obtained with the different techniques. An interesting feature provided by UE2 is the capability of exploiting current graphics hardware, commonly dubbed with DirectX8, but in the same time, also able to provide a fallback rendering support for previous generation graphics card, also known as DirectX6; this wide range compatibility ensures a great scalability.

Lighting. UE2 supports dynamic lighting on all geometry types. The light within the scene can be provided as directional lights, point lights and spot lights. More complex lighting effects can be obtained using projected textures (e.g. the shadow produced by a tree foliage).

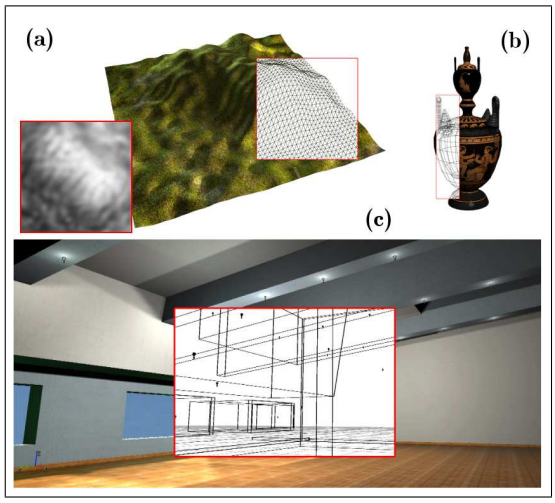

Figure 1: A comparison among the three kinds of geometry managed by UnrealEngine2 (a) Heightmaps for terrains (b) Static mesh used for high polygon-count meshes (c) A room modeled using Constructive Solid Geometry

Effects. Various "special effects" are available to increase the visual appeal of a the final results, in particular, is possible to use particle system to simulate things like flames, fluid surfaces dynamically deformed can reproduce the water surface of a lake or a pool.

Terrain. The Height Map terrain system allows complex terrain rendering described trough an gray scale image. In Figure 1.(a) is shown a textured terrain, the wire frame geometry and the gray scale image used to generate it inside the UE2 editor.

Textures. In a virtual reconstruction, further than the details provided by the geometry, also the texturing has a great importance. In particular experimented how the texture details, whose UE2 was capable of, was suitable to represent particular artifacts like crockery and vases. The maximum resolution for textures in UE2 is 1024x1024 pixels.

Networking. A fundamental gain in using a UE2 as a framework to develop virtual environments is the support for network gaming. The low-level game networking transport is UDP-based and combines reliable and unreliable transmission schemes. The servers supports upto 64 players.

Versions. The version 2 of UnrealEngine has been made public with an appeal licensing policy: there were two licenses, a free one, dubbed "Demo Version" targeting a student audience, particularly suitable for universities' game design courses and a "Registered Version", which costs 7999$. The Registered Version allows to distribute an unlimited number of clients as long as the product is

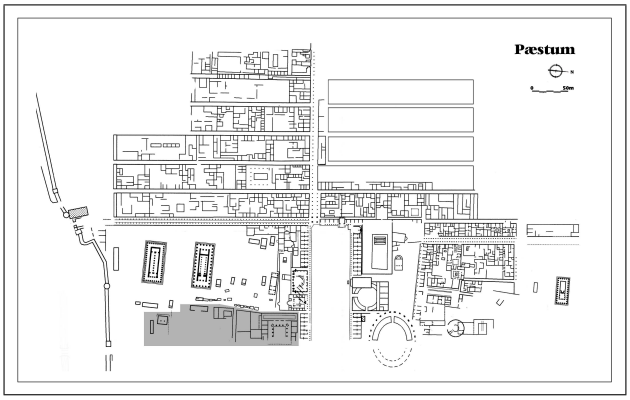

Figure 2: A Poseidonia-Paestum map. In gray the surface area that has not (yet) been reconstructed.

not a videogame (in the stricter sense).

2.2 The psychological level

PaestumGate, as an immersive virtual environment, provides an excellent bridge between knowledge contents (historical and archaeological) and several essential psychological features of a successful learning process. The following points resume the main psychological characteristics of the PaestumGate virtual environment:

• PaestumGate is a gratifying background for educational activities. The quality of virtual reconstruction allows the learners to have an impressive sensation of "real participation". As contemporary educational psychology extensively highlights, the importance of the participation (physical or virtual) is one of the necessary conditions of learning. Situated Cognition and Activity Theory represent two of the significant paradigms that suggest an idea of learning as "apprenticeship". Apprenticeship is to consider a process that may reflect the "participation" to the more efficient modes of learning involved in everyday situations [4, 6].

• The activities in the PaestumGate environment are thought as "narrative" steps. In a large number of current contributions educational psychologists emphasize the importance of a "narrative construction of knowledge". Especially in a cultural perspective [7] educational narrative methods are widely considered successful modalities of teaching/learning.

As a result, PaestumGate is proposed to the user as a sequence of steps, historically motivated and situated, whose goal is to engage and stimulate the learner to explore the town and participate to its daily life.

• PaestumGate is an environment that easily allows collaborative practices. As developmental psychologists perfectly know children (adult) usually play (work) in groups sharing their experiences socially [2]. The consistent tradition of researches on "social interaction" considers the collaborative practices a powerful feature of cognitive development and learning. [9] explicitly writes "psychological functioning is intimately intertwined with social interaction".

By leveraging on the embedded capabilities (in UE2) of building cooperative virtual works, PaestumGate offers small groups, either locally or remotely, the opportunity to visit the town cooperatively, seeing each other avatar and collaborating into the tasks that have to be taken. As an example of such experience see Figure 5.

2.3 The historical level

Historical setting. The town of Poseidonia, established by Greek settlers around the end of the seventh century B.C. on the left side of the river Sele in the Salerno gulf, flourished in the successive centuries because to its wide territory and to its agriculture and was embellished with magnificent temples. In the fourth century B.C. it was occupied by an italic people, the Lucanians and, successively, since 273 B.C., it became a Roman town and its name was changed in Pæstum. The Romans changed the aspect of the city and removed some monuments that were a symbol of the Greek autonomy, they also built some new buildings like the *Forum*, the *Comitium*, some *Templa*, the *Curia*, the *Amphitheatrum* and the *Thermæ*. The maximum prosperity was reached in the last century of the Roman Republic until the firsts two centuries of the Empire (100 B.C. - 200 A.D.).

The importance of a reconstruction. The virtual reconstruction of Poseidonia-Paestum has to face an important historical problem: the structures, whose rests are present in the archaeological site, belong to different epochs of the history of the town. In the Poseidonia-Paestum site have been found at least three different levels of exploration: the Greek-Lucanian, the Republican Roman and the Imperial Roman. This is a problem quite common among archaeological sites that had different dominations along centuries, and the casual tourist rarely is aware of this phenomenon. To tackle this problem we have fixed some didactic goals: the ability of orientate oneself in the ancient town and in its history, the ability of identify the urban environment through the various epochs, the ability of identify the most important monuments and archaeological find. In our opinion meeting these goals in a reconstructed town would enable the tourist to visit the archaeological site with an increased awareness.

3 The real experience

3.1 Design and modeling details

The final version of PaestumGate provides a reconstruction of 0.2 square kilometers, using more than $600,000$ polygons. In Figure 2 we show a map of the archaeological site and, in gray, the surface currently under de-

velopment. The map contains about 25 completely reconstructed "important" edifices, like the Amphitheatrum (7439 polygons) and the so-called Temple of Neptune (18582 polygons); more than 300 houses, part of them are low polygon count (98 polygons) and some of them have a more complex structure with a pool and gardens (6368 polygons); more than $1/2$ of the total polygons budget has been expended for the modeling the vegetation, streets and the squares.

The textures are about 160Mbytes heavy. The typical dimension of textures we used is 1024x1024, this because the intentions were not only to create a interesting product for the tourist, but also to provide a reconstruction that can be appreciated by the archaeologist. High resolution textures allowed to bring right inside the reconstructions details like the illustrations of a vase or the details of a particular pavement. Choosing the resolution for textures is a critical decision because it is bound to the size of the memory available on board on the graphics card and this is something that cannot be easily expanded.

Filling the entire memory of the graphics board with textures will request a swap of information to/from the central memory and this usually means that the FPS (Frame Per Second), that is the measure of the quality of the game experience, will decrease dramatically.

As an example of the decreasing of performances, we have experimented how in certain points of the town (for instance from the roof of the Temple of Neptune) the FPS goes down on certain low level systems. The reason of this is that from such point is possible to see the entire town that is the complete set of textures and the complete set of geometry. A solution for this performances degradation is to use *compressed textures* that is textures with a lower memory occupation, whose details are slightly decreased, and whose rendering will need an additional computation effort (the decompression is performed directly in hardware during the rendering phase). We had experimented good results in using texture compression.

A substantial benefit in using a videogame engine is the availability of a full fledged programming language useful to develop in-game logic. In UE2 this programming language is dubbed UnrealScript and provides a complete set of commands to modify and expand not only the behavior of the objects presents but also to increase the visual appeal characteristics.

In PaestumGate we used UnrealScript to create an object that once taken would activate some other object in other places of the map. We used these kind of objects to create a chain of events that will push the player to visit the entire map pursuing the next object that must be found. This kind of programmability actually is the backbone of the narration that will involve the player visiting the virtual environment.

3.2 Performances

As suggested in [3], the choice of a 3D videogame engine can show interesting side-effects. In fact, besides, the quality and the photorealism, the support for high interaction and the amount of support for developers (SDK), a videogame engine represents a carefully tailored software framework to get the maximum mileage out of any reasonably configured PC. In several contexts, like the educational setting we are developing PaestumGate for, it is crucial make the best use of the (somewhat dated) terminals you are to deploy the product onto, since the schools rarely have the opportunity to invest regularly money in computer labs and very often educational software products have to be designed keeping as requirement to be run on 2-4 years old software/hardware platforms.

Part of our experience was valuable because we were able to measure up how much a virtual environment, based on 3D videogame engines, can be effective and efficient both on high-end graphic workstations equipped with state-of-the-art graphic cards, but also on low-end, 3 years old computers.

In figure 3, we report the benchmarking of an extensive walk into PaestumGate, of approximately 3 minutes, visiting almost all the most important (and computational heavy load) landmarks. The efficiency was measured in average frame per seconds and, for each hardware platform, we included the value for 800x600, 1024x768 and 1280x1024 screen resolutions. It must be noticed that the smoothness in the rendering is obtained around 20 frame per seconds and that almost all the configurations are way above this threshold. The configurations of the platform tested are reported in terms of the most important component, i.e., the graphic card. The first two columns of the chart report the result on a high-end graphic workstation, equipped with two *n*VIDIA Quadro 4500 graphic cards with a SLI configuration whose cost is around 6,000-7,000$. SLI stands for Scalable Graphics Interface and is a high-performance technology that combines multiple *n*VIDIA GPUs in a single system in order to scale graphics performance. This workstation provides excellent features as for instances high resolutions, large amount of memory for textures and full scene anti aliasing useful for entertainment systems with large groups of people like virtual theaters.

The first column indicates the results with 4x antialias activated. The remaining configurations all pertain to ordinary PCs, equipped with the graphic cards indicated. It should be noticed that the 7800 is the most recent graphic card from *n*VIDIA, the *n*VIDIA 6800 is one year old and the ATI 7500 is 2-3 years old. Finally, the last column indicates that, anyway, by lowering the detail (in the Unreal2 configuration panel) it is possible to achieve smooth and enjoyable visit with close to 20 fps, even on the lowest

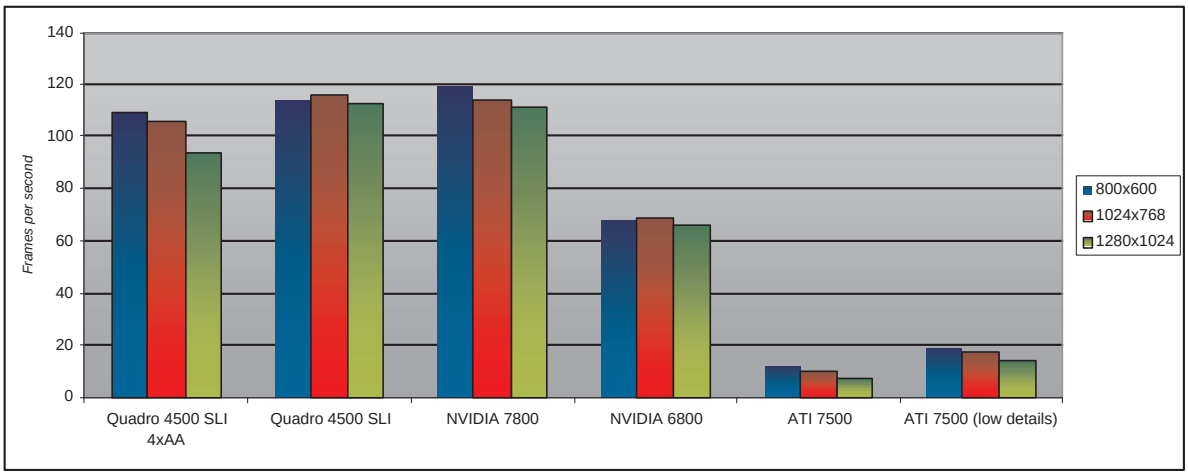

Figure 3: The comparison of the performances obtained by PaestumGate on different graphic cards.

end machine that we tested.

3.3 Caveats

Developing a videogame is an activity which has to take into account two categories of requests the aesthetic ones and the technological ones: an example of technological request is to have a detailed reconstruction of an architectural details like a column or a statue, but on the technological details cost in terms of CPU and GPU speed and memory occupation for both geometry and textures.

We report here some decisions we took and we try to show how we managed them.

The shadows An important element in a virtual environment is the use of shadow. Shadows add a touch of realism to how the virtual reconstruction is perceived, particularly in a large external environments. The accuracy of shadows is a direct effect of the type of geometry used to build up the architecture. UE2 supports two different type of geometry: static meshes and BSP (Binary Space Partitioning). A static mesh is a set of polygons that never change its shape, that is the reason for the emphasis on static. It is drawn in a very efficient way by graphics card and can be cached in its memory. Static meshes are used to model objects that must be placed several times into the environment (e.g. houses, columns, tabernæ, trees).

The BSP Geometry is the geometry used to model the basic “shell” for the entire environment and the larger structures (e.g. the temples). Lights affect the two types of geometry in a different ways. On BSP surfaces, the editor creates lightmaps during an preprocessing phase of lighting rebuild. During this phase very realistic projective shadows are created on surfaces considering that they can receive shadows from other BSP surfaces and from static meshes. The main drawbacks of the use of BSP are that these surfaces use a lot of memory, can not be cached and are difficult to model.

Also for static meshes lighting is calculated for every surfaces but only surfaces that are facing the light get lit and no lightmaps is calculated nor applied.

During the modeling phase it must takes into account these considerations because one has to choose what to model as static meshes, having less accurate shadows, and what to model using BSP having accurate shadows at the cost of a more difficult modeling and some performances issues.

The problem of dimension A problem we had to face off is choosing the scale of the reconstruction. To take a good decision we adopted an empirical approach, that is we took a series of photos comparing an average tall man to some columns and walls yet available on the site. These photos gave us a proportion between the in-game avatar height and the dimension of the 3D models. This decision enhanced the experience because allowing the tourist to being able to appreciate the sense of distances and the dimensions was a goal.

4 Conclusions and Future Works

The use of UE2 allowed use to realize a virtual reconstruction of an entire town, this is an appreciable result, but the PaestumGate project is far more than a traditional “virtual reconstruction” of an archaeological site: it is an ideal background to create stories to let the player/tourist to visit the reconstructed town with increased awareness, and this is one of the goal we are aiming to. Another value added for free by using a suitable technology is the support for a cooperative visit, and this is a result that has been greatly appreciated by the users during some early tests. Another approach that worths noting is how easily we have been able to connect how the town varies

Figure 4: A landscape view of the reconstructed Poseidonia-Paestum. The user is nearby the Temple of Neptune and is looking southward.

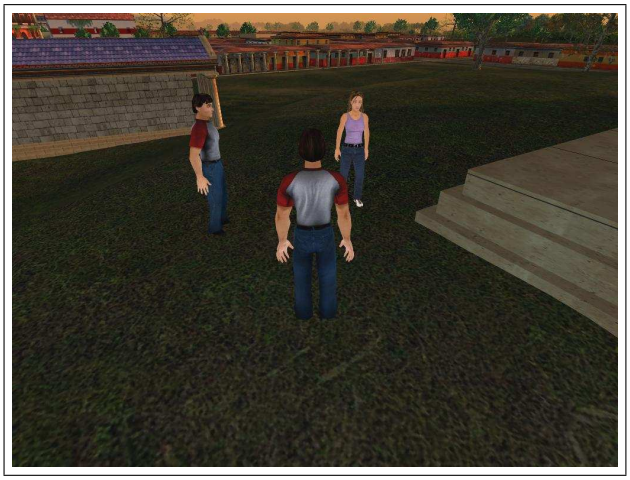

Figure 5: The cooperative visit of the reconstructed site.

through the centuries: starting from the town at the moment of maximum prosperity, under the Roman domination, just substituting a selected number of edifices we obtained the same town under the Lucanian domination, the Greek domination. This different "version" of the same town will be easily visitable by tourists across a sort of "time travel machinery", once again a narrative tool to use an history as a support to the visit.

On the strict technological side we are investigating how to make the visit *location based*, that is using the virtual reconstruction not just on a traditional PC at home or at school but right inside the archaeological site through a tablet PC that can be tracked with an high resolution, in order to allow that the visit on the virtual reconstruction to be synchronized with the the visit in the real archaeological site. This kind of service would allow to the the tourist to visit not only the actual rests inside the archaeological site, but also be able to use the tablet PC as a "window on the past" to look how the place he/she is walking through appeared through centuries.

On the performances side as along as the virtual reconstruction become more and more complete and complex the decrease of FPS performance is an issue. A techniques we are investigating is to use some clipping planes in order to partition the landscape and let the engine to handle a smaller part of the polygons.

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