Digital Storytelling within Virtual Environments: "The Battle of Thermopylae"

Dimitrios Christopoulos, Pavlos Mavridis, Anthousis Andreadis, and John N. Karigiannis

Department of 3D Graphics and Virtual Reality
Foundation of the Hellenic World
Athens, Greece
christop@fhw.gr

Abstract. Until recently virtual environments and videogame applications rarely incorporated any deep cultural or educational principles. Current research in the area of virtual reality applications, clearly indentify that they are extremely motivating for learners and therefore can be employed as an innovative, more accessible framework to deliver education while at the same time entertain the public. On the other hand, recent advances in videogame applications and human computer interfaces, demonstrate that a combination of game applications with effective learning principles and intuitive human computer interfaces could potentially transform virtual environments to a significant educational tool that could significantly facilitate the learning process. This paper describes an interactive virtual reality application that we developed for the museum of Thermopylae located at the site of the original battle, near the city of Lamia in Greece. We utilized storytelling techniques and principles of modern videogames to disseminate historical knowledge about the battle and the associated legends. We present the hardware and software components comprising the proposed installation, while we elaborate over the educational techniques designed to reinforce the strength of virtual reality technology as a mean of designing educational experiences in the context of cultural heritage related information.

Keywords: virtual reality, interactive storytelling, educational virtual environments, video games, thermopylae battle simulation.

1 Introduction

Enabled by the advent of interactive digital media, interactive digital storytelling redefines the experience of narrative by allowing its audience to actively participate in the story. Moreover, the design of interactive storytelling scenarios in a virtual reality environment, exhibits social cognitive and technical challenges, that need to be addressed in order to educate and entertain the public. Creating VR environments for storytelling requires the development of complex software, mixing multiple disciplines: computer games, graphics and engineering, physics simulation, pedagogical approaches, and significant experience in the area of the education. The

Z. Pan et al. (Eds.): Transactions on Edutainment IX, LNCS 7544, pp. 29–48, 2013.

recent success of computer games fueled by current games technology forms new types of applications such as serious games, influencing also related application areas such as Virtual Environments (VE). VEs have been valued as being extremely motivating for learners [1] and therefore attract significant attention from institutions of informal education aiming to deliver not only knowledge in a more accessible way to the public but also entertainment [34]. Common type of information disseminated by these institutions is historical descriptions of significant battles. In most cases only textual descriptions exist for these events without any archeological findings of relics or monuments that actually could reveal what happened. In most cases, to facilitate the presentation of this information, dioramas, maps, 2D animations or movie archives are employed. Although informative, these techniques often fail to capture the interest of the visitors and often require prior knowledge.

Thermopylae unarguably one of the most famous battles in European ancient history, repeatedly referenced in ancient, recent and contemporary culture, has become a symbol of courage against overwhelming odds. The Battle of Thermopylae was fought over the course of 3 days between an alliance of Greek city-states 7000 men strong, led by king Leonidas and his 300 Spartans, and the 250.000 strong force of the Persian Empire of Xerxes I in 480 B.C. [2] [3]. Both ancient and modern writers have used the Battle of Thermopylae as an example to demonstrate exceptional military strategy, determination and courage.

The challenge of creating an educational Virtual Reality attraction for the newly created "Innovative Center of Historical Awareness of Thermopylae" consisted of finding new ways to combine the techniques used in videogames, virtual reality and the entertainment industry for telling the story of a historic event in an educational and attractive way. A holistic vision of information was needed to avoid the pitfall focusing on only one aspect such as graphics, hardware or interface. Factors such as the design of the hardware in order to support immersion, the interaction and communication with the visitors to support acclimation, the definition of clear educational goals to create an engaging storyline are all factors which contribute to the success of an educational exhibit. Taking into account the gaming culture that has been established even for older age groups through the use of portable devices like smartphones and tablets, new opportunities arise for institutions to reach users in new ways by applying elements of play to newly created educational VR attractions.

The remainder of the paper is organized as follows: Section II provides the motivation behind our work; next Section III analyzes the importance of the hardware setup utilized for creating an engaging onsite installation, Section IV analyses the software architecture of our rendering engine and all the major software components that comprise it, Section V gives the design methodologies used and describes the application. Next, Section VI highlights the importance of our decision to employ a human guide for the educational VE while the subsequent Section VII describes the engagement model that was adopted. The paper concludes by providing a visitors survey and with Section IX that summarizes the key points of our work.

2 Motivation

Those who believe in using games for education usually start from the observation that game players regularly exhibit persistence, risk taking, attention to detail and problem solving skills, all behavior that ideally would be regularly demonstrated in school. Interactive games are the medium of attention for youth who spend on average 50 minutes playing them each day [4]. Using 3D simulation technology for educational purposes is not a new concept; in the past two decades immersive VR has attracted the attention of many researchers and educators [5] [6] [7]. However recent advances in creating videogame applications imbedded with effective learning principles [8] and the study of human computer interfaces for the entertainment industry [9] [10], suggest that a combination of successful practices in these areas could provide motivating experiences and strong tools for learning in educational VE.

Recent evolution of mobile computing, connected devices like smartphones and tablets, made gaming available anywhere and at anytime, to a wider range of age groups. Moreover people claim that gaming becomes second nature to a continuously increasing percentage of the population. As a result, people expect that games will continue to move out of the traditional entertainment environment, blending seamlessly with the real world in areas such as learning and education. The stereotype of the reclusive gamer is outdated. These days, games are everywhere, and gamers are social, tech-savvy, goal-oriented people with a real drive to improve themselves and the world around them. Recent studies [35] on age groups 15-54 confirm that users view games also as a medium for self-improvement and expressed the desire to fit them into daily life activities, gamify boring and repetitive tasks and see them applied foremost for education and learning.

Computer generated interactive experiences allow visitors to travel through space and time without stepping out of the museum building [11] and can therefore be used as a new way of communicating information to the public, making abstract and intangible knowledge to become concrete and manipulable, allowing visitors to immerse in historical events and explore them first hand. The majority of Virtual Heritage (VH) projects deal with reconstruction of architecture providing the experience of guided or first person world exploration in which visualization dominates [12]. Creating computer generated representation of towns and scenery is one thing, but what about less concrete things like processes, feelings or atmosphere. This is especially the case when recreating historical events like battles where the need to de-emphasize reconstruction is evident in order to place them in their historical context and make visitors understand larger connections.

Mixing 3D real-time games with documentary information has been attempted before using commercial games embedded with a cultural heritage theme that depict real historical events which the player can partake in [8] [13]. Using VR for representation of historical events was also attempted in [14] representing the siege of Syracuse by the Romans in 212 B.C. Our aim on that project was to cross-fertilize edutainment VR, core game technologies and novel techniques derived from the entertainment industry providing an educational experience that should put visitors in touch with what is fundamentally engaging about the historical battle of Thermopylae, help them build a scaffolding of the historical core concepts and motivate them to go deeper into the subject themselves. The documentation of the theories that guided our development and their implementation using techniques from a wide selection of fields should contribute to the challenging and outstanding task to study the right and applicable use of VR in education [15].

3 The Importance of Hardware

Better education media to assist teaching has constantly been sought by researchers, highlighting the importance of the technology used for visualization. This project was specifically designed with projection based VR systems in mind.

Although it can be exhibited on all displays, even monitors, we carefully designed the visitor experience for this educational, historical VR attraction on the assumption that the minimum system requirements should be a powerwall type VR system. This means high resolution images projected in stereo 3D by a powerful graphics PC on a 3D stereo capable screen and spatial surround sound. Of course systems with more degrees of immersion (more screens, tracking) can be used as well, but usually are out of reach for educational institutions for financial reasons. The main reason for usage of specialized VR equipment for cultural applications is to provide a technologically impressive setting which attract visitors, enable them to immerse easily into the attraction and also take into account the social aspect of a museum visit.

Providing a better learning experience means from a technological stand point, providing a setup that helps in creating motivation and presence. Technology by its self is a common motivator but also creates certain expectations leading to a conflict of expectation for visitors of historical VR worlds. On one hand visitors want their experience to be realistic and learn something of historical and scientific value, but at the same time they expect to have an exciting experience. With the continuous advances of game consoles, VR systems simply cannot keep up to remain fresh from a visual only standpoint. Therefore they must address more senses and provide an impressive setting using large screens, surround sound and 3D stereo that cannot be experienced easily at home.

3D glasses not only put the action right in front of the user but also make the projector screen disappear creating a convincing world. One of the main factors contributing to immersion is the Place Illusion [16] which is the illusion of the sense of "being there" in spite of the knowledge that you are not there. In the case of simple setups using desktop displays (monitors, simple projectors) this feeling is reported to come, if it comes at all, after much greater exposure to the medium and requires deliberate attention. The VR experiences that are provided in informal educational environments are relatively short in time and often come with waiting queues for visitors, thus it is essential to use the appropriate technology that helps the immersion and suspension of disbelieve.

Besides the learning experience, the social aspect of a museum visit is often underestimated. People tend to visit in groups to have shared experiences. Projection based VR can provide shared visual and audio experiences in which all hear the same and see form the same point of view facilitating social interaction and communication.

4 Software Design

Hardware alone cannot ensure the immersion of the audience. The Software Design plays an equally distinct and important role in the process. The in-house developed Enhanced Visualization System (EVS) was used to create the high-resolution stereoscopic output [14] [17] [18]. EVS was designed specifically for creating and running immersive Virtual Reality applications in a variety of hardware configurations.

EVS supports multi channel setups, allowing monoscopic, passive stereo, active stereo or left/right individual eye operation through a custom developed display library [19] that handles arbitrary display surfaces and viewing modes. In that way an application can be configured to run on a variety of Virtual Reality systems such as CAVE, Reality Center, Dome, Powerwall as well as on single screen desktop monitors and HMD. Different setups are easily configured through a simple and effective XML script allowing multiple configurations to be present in a single file and share some common features if necessary.

Handling of the various input devices is performed through a generic open source architecture network interface, the Virtual Reality Peripheral Network (VRPN) [20]. VRPN provides a device-independent and network-transparent interface to virtual reality peripherals. The library consists of a set of classes that enable interfacing between application programs and physical devices (trackers, buttons, dials, force feedback devices etc.) usually employed in virtual reality (VR) systems.

EVS supports cluster rendering through a custom protocol that was developed [19] and designed for the synchronization of multiple cluster units consisting of a central unit (master) and multiple subunits (slaves). The master unit synchronizes the slaves using special synch packets. In this way consistent representation of the virtual world from multiple viewpoints on multiple screens is achieved. The communication between the units is established through LAN network.

Our engine is script based, meaning that ASCII script files describe the virtual world and the user interactions. EVS also allows the programming of dynamic interaction and events utilizing the Lua [21] script language. The actual rendering module was developed on top of OpenSceneGraph [22] which is, an open source 3D graphics framework that offers high performance rendering along with a feature-rich scene graph implementation. It is written in C++ and uses OpenGL for cross-platform 2D and 3D graphics rendering. "Fig. 1" shows the architecture of the whole environment that was developed on a Linux operating system.

The pipeline for the creation of our virtual reality environment and assets was extended and incorporated apart from modelers and texture artists, historians and architects, as the main goal of the project was to attribute with accuracy the historical events that took place in 480 B.C. All the needed assets were initially cross-referenced with historical sources and designed in the correct proportions by architects. The prototypes produced were high-polygon models sculpted to depict accurately all the fine details. Since real-time poses limitations in terms of geometric complexity of the rendered objects, we couldn't use the actual prototypes for our VR application. From each high polygon model a simplified version was created, baking all the details of the high polygon model in normal maps and applying them to a low polygon representation. Real time material shaders use the baked normal maps to

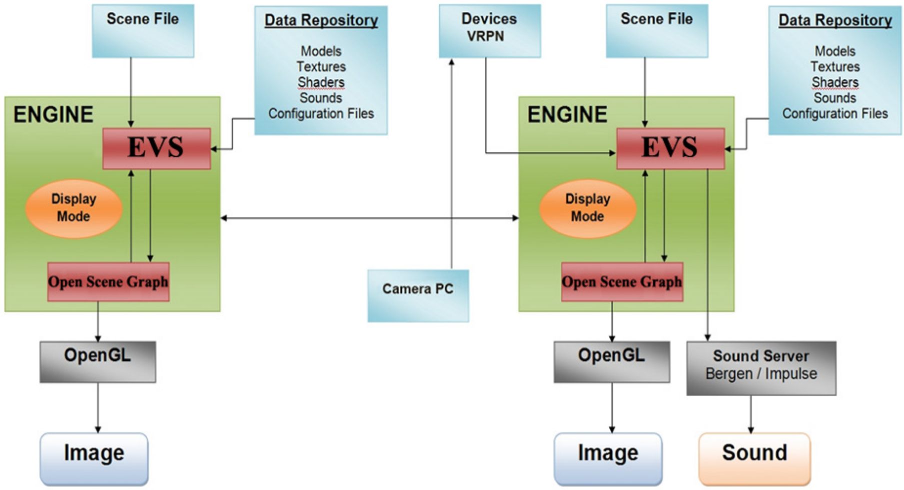

Fig. 1. The Architecture of the EVS Engine

render these low polygon models as detailed 3D surfaces during runtime, greatly enhancing their appearance.

A dedicated VR engine such as EVS gives us several advantages compared to classical Game Engines that by design addresses mainly single screen or desktop systems. The rendering demands for immersive systems that usually need stereo rendering along multiple screens become prohibitive for a single GPU/CPU computer and establishe the cluster rendering feature obligatory, favoring greatly the choice of a dedicated engine. A Cave setup for example requires five distinct projections. While in games the main purpose is to entertain, VR setups have to achieve the immersion utilizing stereo projection and advanced interaction methods using specialized input devices for tracking. On the other hand EVS had to borrow many techniques seen in modern games in terms of graphics, interaction and presentation. Young visitors are already accustomed to impressive 3D environments from playing games at home and seek this type of visual quality sometimes even more that realism.

All the shading and lighting calculations in EVS, are performed through programmable shaders. Shaders are small computer programs, written in a shading language, that are executed on individual elements (vertices or pixels) and affect the properties of this element (pixel color, vertex position). The concept of shaders was introduced with the RenderMan Shading Language (RSL)[36] and since then it is widely used in the creation of special fx for motion pictures, using offline rendering systems. The evolution of the graphics hardware in the last years permitted the introduction of shaders in real-time graphics applications, with the introduction of the OpenGL Shading Language. GLSL is a lower level language than RSL, and lighting calculations require explicit knowledge about the number of lights in the scene and their properties. EVS provides an enhanced version of the OpenGL Shading Language (GLSL) [23], called ESL (Enhanced Shading Language). ESL is a pure superset of the GLSL, meaning that any GLSL shader will work on EVS, but also exposes a set of convenience functions and uniform variables for the computation of lighting, shadowing and vertex skinning. These functions are compiled during the runtime to the equivalent GLSL code, permitting fast and easy development of shaders, and more importantly reusability of the shaders between different scenes and projects.

Several techniques have been implemented in our engine that use real-time shaders, such as Environment Mapping, Per-Pixel Lighting, Bump Mapping, and Parallax Mapping with offset limiting. Shaders are essential in our project for the realistic presentation of cloth, wood and metallic surfaces. The power of shaders was also used in rendering of the human skin. We wanted to achieve a realistic skin effect with subsurface scattering that would run in real-time. Our solution is a combination of the methods described in [37] and in [38] and achieves a realistic skin shading with subsurface reflectance and micro-surface detail.

For the critical part of shadowing in-order to achieve antialiased real-time shadows for our environments we have implemented Parallel Split Shadow Mapping (PSSMs) [39, 40]. In this technique the view frustum is split into depth layers that are parallel to the view plane. For each layer an independent shadow map is rendered. Furthermore to alleviate the shadow boundaries aliasing issues we use Percentage-closer filtering (PCF) that produces smoother results by performing multiple depth tests for each pixel.

Post-process filtering is a major part of most modern visualization engines. Real Time Ambient Occlusion, Color, Correction, Depth of Field, Motion Blur and Volumetric Light Scattering are some of the common techniques are used as post effects to increase the visual appearance of games and make them look more cinematic an immersive. For EVS we developed a parametric solution that enables us to implement all modern special effects as mentioned above. For each scene we choose the appropriate set that will enhance and dignify the feeling we want to achieve.

The gaming industry had also a strong influence in our choice of input device used for interactivity. Since visitors can actually interact with the virtual environment and participate in activities, the interaction had to be close to the one that young audience is used to with modern gaming consoles. For this reason, we used a standard gamepad with 2-analog sticks using the left one for movement and the right one for steering.

For usage in cut scenes, the engine was adapted to support high definition stereoscopic video playback by integrating the open source mplayer [24] technology. Since the target system supported stereoscopy, all produced movies consisted of two streams (one for each eye) which were converted for efficient real time playback to one side by side stereo stream using an offline procedure that utilized the open source mencoder and ImageMagick tools [24].

5 Design Goals and Description of the Project

The Battle of Thermopylae in 480 B.C. was fought between an alliance of Greek city-states led by Sparta, and the Persian Empire of Xerxes I, over the course of three days, during the second Persian invasion of Greece. This project was designed as an educational game which aims to deliver the historical context and importance of the battle, the art of warfare of the two civilizations, their cultural differences and how the Greeks were so successful defending Thermopylae for 3 days before they were betrayed leading to the heroic last stand of the Spartans.

Due to the flexibility they provide, virtual environments can compensate for the shortcomings of traditional instructional strategies, satisfying the needs of different cognitive styles and contribute to the understanding of abstract ideas making them visually concrete [25]. Games promote understanding, motivation, enjoyment and are terrific at immersing players in complex, feedback rich problem spaces. And while they are most often not sufficient in and of themselves for a course study they can help many students advance beyond the memorization of facts and procedures, attainments that are usually lost when classes stop [26]. Thus our goal besides investigating the educational potential was to be accessible, letting the visitor experience the story in an extraordinary new way, from unique points of view and motivate them to go deeper.

The project combines 3D computer generated imagery (CGI) and interactive games by dividing the experience in two parts. The first part consists of a short (10 min.) high resolution, stereoscopic, CGI movie which employs a documentary style approach. It introduces the historical context of the battle, how the Greek and Persian troops assembled, and the route they took and why they met at Thermopylae. Zooming into a map of the ancient world and onto the coast of Euboea we witness the naval battle of Artemisium which took place simultaneously with the famous land battle of Thermopylae and was vital for its success. 270 Greek battleships had to hold off at the straits of Artemisium the entire Persian fleet of 800 ships to avoid the overrunning of the land troops, stressing the importance of the naval fleet for the outcome of the invasion.

The depiction of the land battle was divided into 3 parts, one for each day, showing all the important facts. The picture alternates between action packed close ups and documentary style explanations of the terrain topology, the advances of troops and battle tactics “Fig. 2”. Cinematic bullet time visual effects stop the action to explain topics and points of interest such as the fighting style of the famous Greek hoplite phalanx, the armor of a hoplite, the battle style of the Persians and their weapons. Special attention had to be given to the correct depiction of the terrain using topographical surveys and geographical data and to the representation of weaponry by consulting historians, archeologists and experts in ancient warfare. We refrained from the Hollywood approach of using exaggerations, gore violence and bloody scenes. Although casualties are depicted after the battle there is no scene where someone is actually killed. Instead we decided to use other cinematic techniques like visual effects, fast camera movements, depictions of the battlefield after the end of each day to infer the drama and tension. After the movie the storyline transfers the action to the interactive game. It was of primary importance that the movie and game aesthetics were matched to produce a visual unified experience. Both productions featured the

Fig. 2. Stills form the CGI Movie. Top left, the battle of Artemisium. Top right, the battle of the first day starts. Bottom left, combat inside the phalanx. Bottom right, the battlefield after the first day.

same render quality, the movie was rendered using game like shading and polygon techniques, and the interactive game raised the average graphics quality using expensive high detail material shaders and animations.

The interactive game which follows the movie travels the visitors back in time to the dawn of the first day of the battle, where both the Greek and Persian camps have to be visited in order to help prepare the two main protagonists, the Greek Dienekis and Persian Aribazo for battle. These names were not selected randomly, according to historical sources high ranking officers of those names actually existed and participated at the battle. The visitors are called to traverse the camp, find the corresponding equipment and weapons and apply them one by one on the main characters. During this quest they learn about the culture, battle preparations, tactics and weapons of these ancient warriors. The tasks of finding and applying weapons or equipment are laid out in such a way that essentially all the camp has to be visited in order to complete the final goal. Every time a task is completed the user is rewarded with narration about its usage and other relevant historical information. During the search in the camp a variety of interest spots are met like places for rest, food preparation, conversation, armor repairs, and camp fires which are populated with virtual characters and objects relevant to the battle “Fig. 3”. Some of these spots transmit historical information automatically when visited but their primary usage is to provoke the interest of the visitor to inspect them nearer, guiding him essentially through the story and giving the opportunity to a human guide for personalization of the experience according to the target group. We decided to have a basic level of

Fig. 3. Screenshots from the interactive game. Top left, the Spartan camp. Top right, Spartan interactivity hot-spot for the chest armor. Bottom left, Persian interactivity hot-spot for hand arms. Bottom right the Persian camp.

information transmitted automatically by the story in the game and let a museum educator decide whether more information is required. The museum educator is a human guide who operates a game pad controller, controls the pace of the storyline, gives commentary in accordance with the story written, helps during the interactive parts and adapts the experience according to the visitor level. After the completion of all the tasks in both camps, the interactive game zooms out and focuses the camera onto the rendering of an old book with which the battle outcome is narrated. As the narration progresses, the book's pages are browsed showing hand drawn pictures of what is just narrated. This technique refers to the way fairy tales are told and is used to soften the impact of an otherwise brutal ending.

Besides providing entertainment the experience supports several learning methodologies as proposed by [26]. It can be used as a content system to deliver understanding about the subject or content area, as a trigger system to create an experiential context for understanding around this topic, as a point of view system allowing visitors to take on certain identities and associated points of view by visiting both the Greeks and Persian camps comparing differences in strategy, choice and values held by the two main characters of the story and as an assessment system for visitors who have already been taught that subject to asses and consolidate their understanding. Furthermore through the usage of a museum educator which we will cover in the next section, opportunities for reflection and discussion are provided to let the visitor see the experience as part of a larger body of knowledge on that subject.

6 The Human Guide

Despite the fact that the community has used for year's museum educators as mediators for VR tours, we deliberately choose to design the experience with the participation of a museum educator as a prerequisite, since it proves to be very beneficial for the educational context. Recent studies [27] [28] [29] [30] highlight that one of the most crucial factors in terms of educational benefit, entertainment and construction of meaning for visitors remains the human factor of the guide as presenter and mediator. The studies conclude that the majority of visitors prefer to explore the application with a human guide, because it allows direct interpersonal interaction with which the museum educator can immediately adapt to the audience and solve doubts or provide more information. The experience is regarded to be more alive, spontaneous and not standardized comparatively to passive mediums like movies or planetariums.

A museum educator affects the type of experience visitors will have allowing them to focus more easily not only on the technology but also on the content. Even a simple, human guided tour of the VR world creates a space of kinesthetic illusion which is both visual spatial (3D reconstruction) and textual spatial (guided tour) [27]. Nevertheless the traditional use of a human guide seemed unidirectional, letting information and action flow only one way, from the guide to the visitor. This is not the way games work, which have to provide feedback and information to the user, inducing him to act. Slater [16] argues that a major component for the suspension of disbelieve is the Plausability illusion which is the illusion that what is apparently happening in the VE is really happening and defines that the key component for its realization is the existence of events in the virtual world over which the user has no direct control and which refer directly to her. Based on this we introduced a bidirectional flow of information and action, by handing at certain moments control over to the application, so that not all information and actions would come from the museum educator. Through the usage of in-game characters at the various interest points in the VE and mainly during the assignment or completion of a task, historical information is provided and events initiated which advance the storyline. After the playback of the initial movie both the museum educator and visitor are forced to cooperate with the interactive application in order to advance the story, providing a game like experience. The reception of information and tasks both from the museum educator and the application allows not only the direct participation in an interactive experience but also the passive observation placing the visitor in the middle of the action.

Using this combination of constructivist and guided exploration techniques as a recipe for an effective virtual experience we aimed to trigger the Kolbs experiential learning cycle which in effect is triggered when learners have also to observe rather than only directly participate in an interactive experience [7].

7 Creating Engagement

Research suggests that most VH projects should strive to have a successful blend of three components. Representation to accurately visualize or reconstruct data, experience to present the virtual environment with motivating elements that incorporate knowledge and interaction to provide the ability to gain insight by actively engaging and even modify the experience [31]. Based on these 3 components we tried to incorporate the principles of current VR, entertainment and game industry practices to support the educational and motivational aspect of the project.

7.1 Representation

The first priority of any educational institution is to maintain its scientific and educational character. Not only has the rendered environment, the characters and the weapons of the Thermopylae project to be appealing as in modern games but also historically correct. A variety of disciplines ranging from designers, artists, architects, archeologists and historians worked together to produce all our 3D assets, historical information and storyline. As described in the software section we made elaborate use of game technology and next generation graphics for rendering, trying to keep a unified appearance across the movie and interactive game. Younger visitors and children are already accustomed to the look and feel of these high detail 3D representations through the usage of computer games minimizing the time of acclimation.

Believability is not necessarily linked with perfect realism; on the contrary maximal realism can be counterproductive for students with little knowledge. Despite the use of high profile rendering, we don't pursue perfect realism but preferred to create emotional response providing personalization in character, environment, animation and sound design. Using personalization to provide a specific mood and aesthetic to the application and create something memorable that stands out, is a common practice in games design [32]. Especially during the interactive game the sound, the color ramp, shading and lighting was chosen to transfer the tension of a camp before the battle. The environment needs to be impressive but also has to make the unimportant details natural so that the visitor focuses on the important parts [33]. In general the quality of the representation influences the overall experience since as we will explain later on, it is one of the three major factors that control interest. The more beautiful the art, the more interesting and compelling the visitors will find the experience.

7.2 Experience

A successful entertainment experience should use the right combination of interest to focus attention, empathy to make us feel we are part of the story world and imagination to let the visitor fantasize alternative realities [10] [9]. Storytelling proves to be the best vehicle for that. The more compelling the story the more focused the listener will be and the more likely that true understanding will take place.

Fig. 4. A graph showing the designed visitor interest curve during the experience, as the storyline progresses. The initial spikes both in the CGI Movie and Interactive game are the "hooks" which grab the attention of the visitor, followed by smaller interest spikes used to unravel the story and keep the interest.

The story for this project was designed in such a way as to provide the desired amount of historical information and foremost maintain a good interest curve "Fig. 4". Usually the visitor enters the experience with high interest and expectation fueled by the hardware 3D capabilities of the system and the shared group experience which is about to start. The high action stereoscopic CGI movie shown at the start acts as a "hook" that grabs the attention and provides an interest spike that helps stay focused and show what is to come. Although the 10 minute duration of this movie might be considered too long it was necessary in order to be able to narrate the whole story. Through a rich arsenal of cinematic and stereoscopy techniques the tension and interest is attenuated throughout the movie playback so as to keep the interest. The switch to the interactive game fuels again the interest curve motivating the visitors to pay attention to the historical facts narrated and complete the tasks assigned to unravel the story leading to the climax and final resolution. Although the definition of interest during an experience might seem at first a little abstract, research [10] has determined that it is composed of inherent interest, representation and psychological proximity.

Inherent interest defines the motivation and interest in the actual historical event. Since the project is about one of the most famous battle in history and presented in high tech 3D it provides an incredibly rich back story that everyone can relate to. The attraction and place immediately gets everyone in the correct mind set.

Representation defines the aesthetics of the entertainment experience which, as explained earlier, were carefully designed using next generation graphics with strong personalization of the environment to serve the purpose of the story line.

Psychological proximity is what compels visitors to use the powers of empathy and imagination to put themselves into the experience. Although traditional passive media like the introductory movie shown lag in this respect, the following interactive game was planned to create an environment with events that visitors can emphasize with.

Fig. 5. The two main protagonists who during the story seek assistance from the visitors. On the left the Spartan Dienekis and on the right the Persian Aribazo. According to historical sources high ranking officers of those names actually existed and participated at the battle.

The game assigns a specific role to the visitors which are asked by the main virtual character in the story to complete specific tasks in order to help him "Fig. 5". The storyline and the additional explanations of the museum educator help bring the places and characters visited in the camp into a human and cultural context. Initially visitors are strangers to the environment and its characters, but as the events progress through the interactive tasks completed by the visitors, the interest and understanding about the culture, customs and way of living of these warriors' increases, allowing them to mentally enter the world and place themselves into the experience. To support these goal virtual characters were placed into the environment for interaction, performing actions of social and cultural importance. As an example for the Spartan camp, the warrior helmet that has to be found in one of the tasks is given by a Spartan who prepares himself for battle combing his hair and anointing his body with olive oil. This action refers to the physical and mental preparations of the ancient Spartans before battle. Besides the automatic narration explaining this, the museum educator can then enrich this information with relevant myths and stories.

7.3 Interactivity

Interactivity is considered a cornerstone in creating engagement building an overlap between perception and imagination allowing the directly manipulation of the story world. This is why games can take events of low inherent interest or representation and still be compelling, because they make up for in psychological proximity. Even though the interactive world gives the freedom to go anywhere, a well designed environment will lead the visitor through the highlights letting her think she found them herself. By allowing interactivity the creator loses control over the sequence of events and exerts only indirect control. Perception studies [33] show that we usually turn towards movement and strong colors or other markers. The camp environment of the interactive game was designed to draw the attention of the visitor guiding him to interesting places. Animated virtual characters, objects with shiny colors, camp fires, trees, smoke and rocks were strategically placed in the environment to define spots for exploration. The use of in-game characters asking for help and the use of storytelling provided clear goals and reason for participation. Being focused on a particular task not only helped to achieve high motivation but was also the primary method for influencing the visitor who by completing a series of goals essentially creates a linear storyline.

8 Visitor Survey

In order to evaluate the effectiveness of our story telling techniques at disseminating historical knowledge, in the context of our virtual reality exhibit, we gathered data through in situ observations and face-to-face questionnaires with visitors. Since the experience of the visitors contains a lot of interaction with the museum educators, especially in the interactive part, we believe that the observation of the visitor reactions during the showcase, through the questions they pose to the human guides, is essential to have a complete picture. Along with the results of the user survey, we present a qualitative analysis of the gathered data.

The survey was conducted to a group of twelve visitors, of age’s nine to twelve. Data where gathered by observations during their visit and with semi-guided interviews, taken when the visit was over. We concentrated on children of that age group because the historical information presented in our work is also covered as core material in their educational school cycle. During the interviews, we verified that the subject of our exhibition was interesting to this age group. As we said earlier, the main goal of our survey was to investigate the value of the exhibit as a means to pass historical information, but also questions were posed to evaluate the amount of immersion achieved and the usability of the exhibit. Finally the visitors were asked to state if they would like the traditional means of education in schools to be augmented with the story telling methods presented in this paper. Fig. 6 presents an overview of the survey results. In the following paragraphs we will further analyze the answers to the survey questions, in order to better evaluate the results.

The first series of questions were related to the historical details presented during the CGI film and the interactive game, such as the place and the exact date of the historical event, the outcome of the battle and some questions about the combat outfit of the Greek and the Persian army. These questions were used to evaluate the amount of historical knowledge acquired by the visitors. All the children answered correctly in these series of questions, and with the exception of one child, they even remembered the exact date when the battle took place. It is noteworthy that all the children could correctly name at least three items from the combat outfit of both the

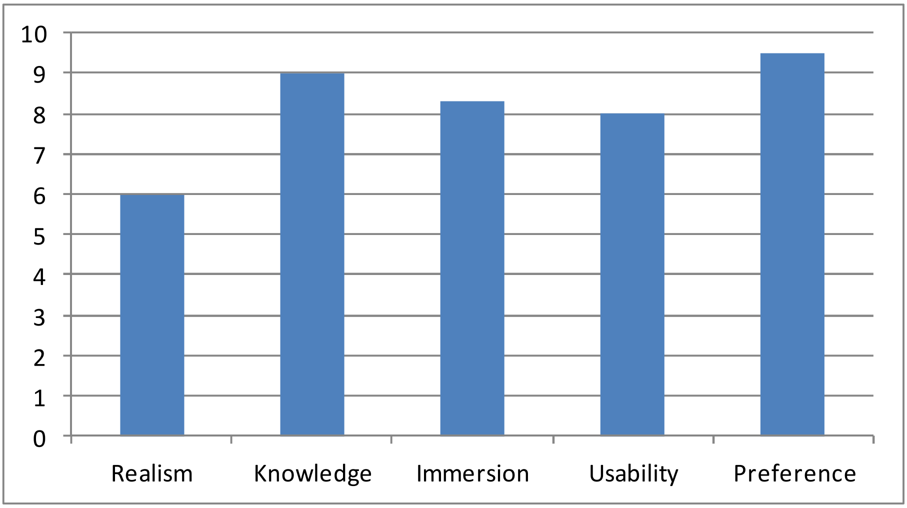

Fig. 6. An overview of the visitor survey results. The rates were deduced from the visitor answers to questions related to the realism of the graphical representation, the historical knowledge they acquired from the production, the amount of immersion, the usability of the real-time game, and finally if they prefer the story telling methods presented in this paper to be used in traditional education. We observe that while the graphical presentation was not rated as photorealistic, the amount of historical knowledge acquired by the production is impressive.

Spartan and the Persian army. Those results give us confidence that this exhibition kept the attention of the children focused during the whole period of their visit, something that we believe an educator with traditional teaching practices will have difficulty to achieve, for children of such ages. Recent surveys [29] [30] compared VR exhibits and traditional museum exhibitions dealing with the same historical topic and reported that the visitors from the guided VR tours (probably consumed by the audio and video) could not remember a single concrete historical fact from the show. It therefore seems that our approach to include linked elements of text, interactivity, 3D graphics and verbal explanations in an engaging storytelling experience overcomes this problem. Surprisingly in many cases even detailed historical facts which were explained by the museum educator were remembered. Finally, when asked, all the children stated that they would prefer some history classes in the school to be taught this way, further reinforcing the educational value of storytelling techniques in the context of education.

With a second series of questions we tried to evaluate the amount of immersion achieved during the film and the interactive game. When asked, the children stated that the virtual world was not photo-realistic, but the majority of them liked the aesthetic result as it reminded them of the video games they play at home. The most frequent answer, when asked about the role they believe they had during the game, was that of a Helot (servant), who has to help the soldiers prepare for battle. The second most frequent answer was that they were spectators. All of them stated that they wanted to help the heroes when they asked for help and although the story urges you the help both the Greek and Persian hero, some stated that as being Greeks they preferred to help the Greek hero, confirming the creation of empathy and psychological proximity during the story. Most children stated that their favorite moment was the battle as depicted in the film, and the second most frequent answer was the search for the weapons in the interactive game. Based on these answers we believe that immersion and engagement was achieved in a great extend in this production, initially by using the CGI movie as a “hook” to build interest and then keeping it by introducing interactive story driven events.

A third series of questions tried to evaluate some usability aspects of our interactive production. The children properly identified that the goal of the simulation was to find the military equipment of the two soldiers and return it to them. When asked about how easy was to identify the missing objects through the environment, they stated that although they had some difficulty to identify them, due to the low luminance of the projection screen, the fact that they were shining helped them a lot. Many remembered with enthusiasm a piece or problem that they found or solved first, stating that it was much better that they had to actually do something themselves instead of just watching a guide to do it for them. As detailed in a previous section, we designed the important objects to stand out of the environment, to draw the attention of the user and to circumvent the low contrast and low brightness of some VR projections environments and the results of this survey support our design decision. It is important to take into consideration the limitations of the underlying hardware when designing content for virtual reality exhibitions. Some also requested more interaction and be able to fight in the battle themselves, indicating that interactivity is something visitors seek in such experiences.

During the interactive game, the importance of the presence of the museum educator was apparent. The main problem in many interactive virtual reality exhibitions is that the visitor can be confused about the rules and the purpose of the simulation or get too fascinated by the experience focusing more on the technology then the content. The presence of the human guide prevented this from happening, by explaining the purpose of this exhibit, answering any questions of the visitors, and by guiding them through the virtual environment. After our observations, we believe that the presence of a museum educator is essential for the success of such exhibits.

The questions posed to the museum educator by the visitors also revealed some aspects of the story were not clearly communicated by the story, and needed further clarification. One such case, asked by the children, was about the chronological order of the events in the film and the interactive game. It was not apparent to all the visitors that we were witnessing the preparation of the two armies for the battle we saw at the film. The social interaction between the peer group and its guide also helped to satisfy the curiosity characterizing those ages by answering simple questions regarding the content, like why Spartans had red coats or why all Persians had mustaches. Those types of questions, which arise perhaps from some omissions of the digital content, are easy to answer with the presence of the museum educator.

All the information and the user feedback we gathered proved valuable in order to improve both the educational and the entertainment value our future productions.

9 Conclusion

Virtual heritage applications should start to have a holistic vision of information and not focus on only one aspect such as graphics, hardware or interface. The design of an educational experience must take into account factors such as the design of the hardware in order to support the immersion, the interaction and communication with the visitors using a museum educator or any other method to help visitor acclimation, define clear educational goals and create an engaging storyline which fosters the learning of these.

The Thermopylae project investigated on the fusion of techniques used in videogames, virtual reality and the entertainment industry for telling the story of a historic event in an educational and attractive way. Current research in the field of immersive VR, videogames, human computer interaction and educational studies were used to drive the design of the whole experience. The evaluation results appear to be quite promising, indicating that new practices in the area of games could significantly facilitate learning and overall produce more effective learning environments.

Tomorrow's gamers are interested in applying elements of play to the world around them. This creates opportunities for educational institutes to reach users in new ways. It is at the intersection of videogames and entertainment industry where virtual environments should find new ideas and opportunities for creating innovative educational experiences.

The presented work has been developed within the project "Innovative Center of Historical Awareness of Thermopiles, of Municipality of Lamia", for the creation of a virtual museum in the area of Thermopylae. It is one of the exhibits of the new museum. The project has been co-funded by European Commission and National Funds within the 3rd framework of Support.

References

1. Bricken, M.: Virtual Reality Learning Environments: Potentials and Challenges. Computer Graphics 25, 178–184 (1991)
2. History of the Greek nation volume B', Ekdotike Athenon, Athens (1971)
3. Herodotus, Rawlinson, G. (Trns): The History of Herodotus: Polymnia (2005)
4. Roberts, D.F., Foehr, U.G., Rideout, V.J., Generation, M.: Media in the Lives of 8-18 year-olds. Kaiser Family Foundation, Menlo Park (2005)
5. Lee, E.A.-L., Wong, K.W.: A Review of Using Virtual Reality for Learning. In: Pan, Z., Cheok, D.A.D., Müller, W., El Rhalibi, A. (eds.) Transactions on Edutainment I. LNCS, vol. 5080, pp. 231–241. Springer, Heidelberg (2008)
6. Gaitatzes, A.G., Christopoulos, D., Roussou, M.: Virtual Reality Interfaces for the Broad Public. In: The Proceedings of Human Computer Interaction 2001, Panhellenic Conference with International Participation, December 7-9. Patras, Greece (2001)
7. Roussou, M., Slater, M.: A Virtual Playground for the Study of the Role of Interactivity in Virtual Learning Environments. In: Proc. of PRESENCE 2005: The 8th Annual International Workshop on Presence, London, UK, September 21-23. International Society for Presence Research, pp. 245–253 (2005)

8. Anderson, E.F., McLoughlin, L., Liarokapis, F., Peters, C., Petridis, P., de Freitas, S.: Serious Games in Cultural Heritage. In: 10th VAST International Symposium on Virtual Reality, Archaeology and Cultural Heritage (VAST 2009), VAST-STAR, Short and Project Proceedings, Eurographics, Malta, pp. 22–25, 29-48 (2009) ISBN: 978-99957-807-0-8
9. Jesse, S., Shochet, J.: Designing Interactive Theme Park Rides. IEEE Computer Graphics and Applications, 11–13 (July-August 2001)
10. Shell, J.: Understanding entertainment: story and gameplay are one. In: Jacko, J.A., Sears, A. (eds.) The Human-Computer Interaction Handbook, ch. 43. Lawrence Erlbaum (2003)
11. Roussou, M.: Incorporating Immersive Projection-based Virtual Reality in Public Spaces. In: Proceedings of 3rd International Immerse Projection Technology Workshop, Stuttgart, Germany, pp. 33–39 (May 1999)
12. Paul, H.: VR as Performance for an Audience. Leonarda Electronic Almanac 13(11) (2005)
13. Waring P.: Representation of Ancient Warfare in Modern Video Games. Master's thesis, School of Arts, Histories and Cultures, University of Manchester (2007)
14. Christopoulos, D., Gaitatzes, A.: Multimodal Interfaces for Educational Virtual Environments. In: IEEE Proceedings of the 13th Panhellenic Conference on Informatics (PCI 2009), Corfu, Greece, September 10-12, pp. 197–201 (2009)
15. Sanchez, A., Barreiro, J.M., Maojo, V.: Design of virtual reality systems for education: a cognitive approach. Education and Information Technologies 5, 345–362 (2000)
16. Slater, M.: Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments. Philos. Trans. R. Soc. Lond. B. Biol. Sci. 364(1535), 3549–3557 (2006)
17. Christopoulos, D., Gaitatzes, A., Papaioannou, G., Zyba, G.: Designing a Real-time Playback System for a Dome Theater. In: Proc. Eurographics 7th International Symposium on Virtual Reality, Archaeology and Intelligent Cultural Heritage VAST, Cyprus (2006)
18. Gaitatzes, A., Christopoulos, D., Papaioannou, G.: Virtual Reality Systems and Applications: The Ancient Olympic Games. In: Bozanis, P., Houstis, E.N. (eds.) PCI 2005. LNCS, vol. 3746, pp. 155–165. Springer, Heidelberg (2005)
19. Gaitatzes, A., Papaioannou, G., Christopoulos, D., Zyba, G.: Media Productions for a Dome Display System. In: Proc. ACM Symposium on Virtual Reality Software and Technology (VRST 2006), pp. 261–264 (2006)
20. Taylor II, R.M., Hudson, T.C., Seeger, A., Weber, H., Juliano, J., Helser, A.T.: VRPN: A Device-Independent, Network-Transparent VR Peripheral System. In: Proceedings of the ACM Symposium on Virtual Reality Software & Technology 2001, VRST 2001, Banff Centre, Canada, November 15-17 (2001)
21. `http://www.lua.org` (last visited September 17, 2010)
22. `http://www.openscenegraph.org` (last visited September 17, 2010)
23. Rost, R.J.: OpenGL(R) Shading Language. Addison Wesley Longman Publishing Co., Inc., Redwood City (2004)
24. `http://www.mplayerhq.hu` (last visited September 17, 2010)
25. Scanlon, E., Tosunoglu, C., Jones, A., Butcher, P., Ross, S., Greenberg, J., Taylor, J., Murphy, P.: Learning with computers: experiences of evaluation. Computers & Education 30(1/2), 9–14 (1998)
26. Klopfer, E., Osterweil, S., Salen, K.: Moving learning games forward, obstacles opportunities & openness. An Education Arcade paper (2009)
27. Tzortzaki, D.: Museums and virtual reality: using the CAVE to simulate the past. Digital Creaticity 12(4), 247–251 (2001)

28. Alexaki, M.: The Role of the Mediator in Virtual Archeaology Experiences. Master of Arts thesis, University of Athens Department of Museum Studies, Athens
29. Pujol, T., Economou, M.: Worth a Thousand Words? The Usefulness of Immersive Virtual Reality for Learning in Cultural Heritage Settings. Journal of Architectural Computing 7(1), 157–176 (2009)
30. Economou, M., Pujol, T.: Educational tool or expensive toy? Evaluating VR evaluation and its relevance for virtual heritage. In: Kalay, Y., Kvan, T., Affleck, J. (eds.) New Heritage: New Media and Cultural Heritage, London, Routledge, pp. 242–260 (2008)
31. Roussou, M.: The Components of Engagement in Virtual Heritage Environments. In: Proceedings of New Heritage: Beyond Verisimilitude - Conference on Cultural Heritage and New Media, Hong Kong, pp. 265–283 (2006)
32. Bear, J.: Finding Personality in Games. Why Mega man's jumping facial expression is More important than normal mapping. Game Developer Magazine 17(8), 13–18 (2010)
33. Fencott, C.: Content and creativity in virtual environment design. In: Proceedings of VSMM 1999, Dundee, pp. 308–317 (1999)
34. Andreadis, A., Hemery, A., Antonakakis, A., Gourdoglou, G., Mauridis, P., Christopoulos, D., Karigiannis, J.N.: Real-Time Motion Capture Technology on a Live Theatrical Performance with Computer Generated Scenery. In: 14th Panhellenic Conference on Informatics (PCI 2010), Tripoli, Greece, September 10-12, pp. 148–152 (2010)
35. Gosseling, K.: The future of gaming. A Portrait of the New Gamers. Latitide Research, `http://www.latd.com/2011/08/23/the-future-of-gaming-a-portrait-of-the-new-gamers/` (last visited September 2, 2011)
36. Hanrahan, P., Lawson, J.: A language for shading and lighting calculations. ACM SIGGRAPH Computer Graphics 24(4), 289–298 (1990)
37. Beeson, C., Bjorke, K.: Skin in the 'Dawn' demo. ACM SIGGRAPH Computer Graphics 38(2), 14–19 (2004)
38. d'Eon, E., Luebke, D., Enderton, E.: Efficient Rendering of Human Skin. Eurographics Symposium on Rendering 2007 (2007)
39. Zhang, F., Sun, H., Xu, L., Lee, K.-L.: Parallel-Split Shadow Maps for Large-Scale Virtual Environments. In: Proceedings of ACM International Conference on Virtual Reality Continuum and Its Applications 2006, pp. 311–318 (2006)
40. Zhang, F., Sun, H., Xu, L., Lee, K.-L.: Hardware-Accelerated Parallel-Split Shadow Maps. In: International Journal of Image and Graphics (2007) (in press)