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Virtual Visit at Palacio de Bellas Artes of Mexico for Engineering Education*

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Virtual environments are head-referenced computer displays that give users the illusion of displacement to another location. They have potential uses in applications ranging from education and training to design and prototyping. In this paper a virtual visit at Palacio de Bellas Artes in Mexico is described. The Palacio de Bellas Artes is the biggest and the most important cultural center in Mexico City which has halls for exposing pictorial and sculptural works and it shelters the National Theater and the National Museum of Architecture. The interior of the building is decorated with murals painted by the most prominent Mexican artists. The whole place is a place of culture. The application is educational software developed by computer engineers that allows users to visit this cultural place from any part of the world. The modeling of the building is accomplished by the use of three-dimensional techniques and online services. The virtual visit is not panoramic and the user can get around the scenarios that have a texture that allows the virtual world to be more real, therefore, the view is more attractive to the visitors. The software is an important contribution for education because it allows the knowledge of one of the most important cultural contents in the world via Internet.

Keywords: Virtual environments; Education; Three-dimensional techniques; Blender; Fine Arts Palace; 3D

1. Introduction

The idea of a Virtual Reality [1] was first conceived in 1956, when Morton Heilig designed the Sensorama, the first device to provide the user with a fully immersive interactive experience. The Sensorama was mechanical but it had the ability to replicate sight, sound, touch, and even smell. Present technologies surfaced in 1968 when Ivan Sutherland created "The Sword of Damocles" (SOD), the first fully-integrated head display. The system used two separate monitors for each eye to provide stereoscopic viewing, and motion tracking equipment to monitor the user's head movements. The result was the first fully virtual environment. The first haptic interface was developed in 1977, and was known as the Sayere Glove. It used light tubes and photonic sensors to detect hand movement. Though the Sayere Glove was primitive, it led to the creation of the VPL Dataglove in 1987, the first commercial glove, and variations on the design of the Dataglove are used in most VR interface systems today.

Scott Fisher was the pioneer developing a NASA project in1985: the Virtual Environment Display System, a multisensory interactive display environment in which a user can virtually explore a 360 degree world [2]. At the same time, the US Army Air Force was developing a computer flight simulator for training airplane pilots. The virtual reality had evolved through the time and has different interest areas and applications. There are Virtual Reality Systems for training like the flight simulators, car drivers, operators for hazardous environments like mines and seabed. Other systems are oriented to health like simulate surgeries or make displacements inside the human body using a computer [3].

A 3D virtual cranial [4] was designed to improve surgeons skillful and different cranial can be recreated in a faster and cheaper way.

Sørensen et al. [5] built a training tool for complex heart surgery. It can illustrate various elements of difficult surgical procedures, and it allows surgeons to rehearse these elements virtually. For the first time, surgeons can rehearse open-heart surgery interactively in a virtual environment. As a consequence, an entire new field of surgical education is emerging to help young surgeons accelerate their learning curve for the safety of patients.

Computers games are also using VR, many games allows the use of devices like gloves and helmets to manipulate the environment.

The VR is used to preserve and allow access to human cultural heritage. In the world, the museums are the authority to preserve culture and rebuilt the past of the nations. They can use VR to this task. The Foundation for Hellenic World has developed cultural center's two immersive VR exhibits/theaters: the *Magic Screen* (an ImmersaDesk™) and the *Kivotos* (a CAVE-like cubic immersive display for up to 10 people). The VR exhibition have been open

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to the public since 1999, and is the most popular attraction at the museum, with over 200,000 visitors, most of whom are students visiting the Center with their schools [6].

Some countries, as Spain, have projects to preserve cultural heritage in many ways, specially museums and buildings. Tuy cathedral, Museo del aceite de Puente Obispo, Jaen and Lavaix Monastery are examples of Spanish cultural projects [7].

At Mexico are many virtual reality projects of museums which are in development. The Instituto Nacional de Antropología e Historia has developed a virtual tour of Templo Mayor, ancient Aztec ruins in the heart of Mexico City [8]. In the same place the Museo Nacional de Antropologia e Historia and the Museo de la Tolerancia have similar projects [9, 10].

In this paper a virtual visit at Palacio de Bellas Artes in Mexico is presented. This building is one of the most visited touristic centers in Mexico City and it is a space for art and it shelters painting and sculpturing exhibitions, besides, the Palacio de Bellas Artes is the main site for cultural shows. The interior of the building is decorated with architectonic motifs representing the Mexican fauna and flora, and masks with pre-Columbian motifs of Art Decó style, and with murals painted by the most prominent Mexican artists: Diego Rivera, José Clemente Orozco, David Alfaro Siqueiros and Roberto Montenegro. The Palacio de Bellas Artes has halls for exposing pictorial and sculptural works and it shelters the National Theater and the National Museum of Architecture. Therefore, it is important to have software that allows the user to access to this cultural building and to learn about Mexican culture, from any part of the world.

The view is not panoramic, i.e., the user does not have a view from a static point; instead the user can get around the scenarios which have a texture that allows the virtual world to be more real.

The modeling of the objects was accomplished by the use of three-dimensional techniques embedded in Open Source Software.

2. Basic concepts

There are two types of virtual reality which are complementary [11]. Both types vary in the sense of immersion. First type is called augmentative reality or non-immersive and it pretends the user can interact with the virtual world without losing the contact with the real world. The augmentative reality uses basic resources of a PC with the pre-installed Internet tools; this technology implies low costs, facility of using and more acceptance of the users to the software. The way of displacement in environments non-immersive is through the keyboard and de mouse.

The second type of virtual reality is called immersive, and it describes the interaction of the user with a three-dimensional environment by the means of adapted devices to create real sensations and situations of the immersion in the prototype. The used devices for immersion are head mounted displays, sensorial gloves and suits with movement. These devices make feel the user all real sensations inside virtual environments.

The conceptual map of virtual reality is showed in Fig. 1. The basic elements to develop a virtual reality application are the modeling of the reality, the simulation of the context and the interaction with the environment. These concepts are described as follows.

Modeling. There are several types of modeling when talking about virtual environments. In No-Immersive virtual reality, it is possible to create anything from the real world, such as: houses, cars, people and animals. Due to these things are own creation, the sketches must start at ground zero for being more original. Modeling determines the scale of the project, the delimitating area, the supporting devices and the features of the computer for supporting the developer and the user.

When the project includes a three-dimensional structure as a house, mall and building or in our case the Palacio de Bellas Artes, we need to take reference photos and to have a map of the structure to be modeled. The process of modeling is like the process to make a plasticine figure, i.e., we start with a cube which is shaped until the desired structure is achieved. After this, the figure is decorated with textures and realism details.

Simulation. Concerned with virtual reality, simulation consists on representing real or very similar situations to the scenario to be modeled, as example:

Virtual Reality

Basic elements	Development tools for VR	Components of virtual view
Modeling Simulation	BLENDER VRML	Palacio de Bellas Artes
Interaction Perception	3D Studio Max	Descriptive Audio and Text

Fig. 1. Conceptual map of virtual reality.

flights, driving or games. These situations can be very expensive or dangerous to accomplish continuously. Simulation pretends to imitate real life aspects in order to make feel the user an almost perfect experience in a parallel world to the real world. In the case of a virtual tour, the pattern of the path, the access and the displacements of the user are set. Simulation is the first phase of the tests of virtual reality project because is the main base of what will be the final result.

Interaction. In this point is where the specific behaviors of the scenarios are defined, besides the way the user interacts with the objects. The system should offer the possibility to exert control over certain objects of the virtual world. The programmer has to assign specific functions to relevant elements inside the virtual world to allow the user to experience a deeper exploring and to develop the sense of the curiosity inside the new environment. Today, visual and aural media are integrated to make the experience more dynamic as with tools such as: mouse, keyboard, helmet, jackets with sensors and virtual gloves.

Perception. The main sensations which are created by the perception are: depth, vertigo, movement, wind and even weight. Perception is a touch of transcendence which began in the 90's years when devices that make feel sensations to the user were created. These devices are still simulators but by the means of robotics and the creativity of designers and engineers, virtual visits begin to show sensations.

2.1 Development tools for virtual reality

There are many tools to develop virtual reality applications, such as: BLENDER, VRML, PAD, Cinema 4D and 3D Studio Max. Some of them are free software as BLENDER and others cost from 50 dollars to 2000 dollars as Cinema 4D. The cost depends on the quantity of functions implemented or the brand of the product.

At present, there are several software packages with modeling and simulation tools as well as interaction with scenarios in 3D. Some of the main features of these programs are:

- Routing of maps.
- Automatization of processes.
- Creation of individuals nodes.
- Capacity for a great variety of geometrical primitives, including curves, polygonal frames, NURBS (non-uniform rational B-spline) and metaballs.
- Inverse cinematic.
- Audio edition and video synchronization.
- Interactive features for games as collision detection, dynamical and logical recreations.
- Radiosity.
- Internal render.
- Python language to automatize or controlling several tasks.
- 3D game engine.
- Dynamical simulations for softbodies, particles and fluids.
- Illumination.
- System of static particles to simulate heir and pelage.

2.2 Description of Palacio de Bellas Artes

The Palacio de Bellas Artes shelters the following spaces:

1. Esplanade.
2. Low vestibule.
   - Time corner: it is a space where documents and objects related to the history of Palacio de Bellas Artes are exhibited.
   - Gift shop.
3. High vestibule.
   - Halls of museum of Palacio of Bellas Artes: Paul Westheim in West side.
     Justino Fernández in East oriente.
   - Main hall (under renovation).
   - Adamo Boari hall (under renovation). In this hall, activities of literature, press conferences and exhibitions are accomplished.
4. First floor.
   - Manuel M. Ponce hall (under renovation) is a place devoted to chamber music, recitals, book talks and music and literature series.
   - Halls of museum of Palacio of Bellas Artes: Diego Riverain West side.
     Nacional in Center.
   - Murals area (Rufino Tamayo's Works of art).
   - Terraces
5. Second floor.
   - Halls of museum of Palacio of Bellas Artes: Rufino Tamayo and Jorge González Camarena in West side.
     José Clemente Orozco and David Alfaro Siqueiros in East side.
   - Murals area (Works of art of: Diego Rivera, Jorge González Camarena, David Alfaro Siqueiros, José Clemente Orozco and Roberto Montenegro).
6. Third floor.
   - National Architecture Museum.
7. Parking.

Four scenarios will be modeled among the seven scenarios previously described: the front, the hall and the first and second floor. These scenarios will

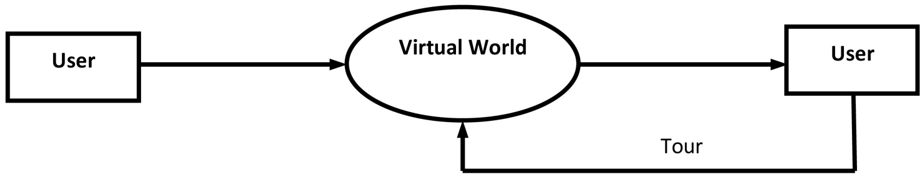


Fig. 2. Data flow at conceptual level.

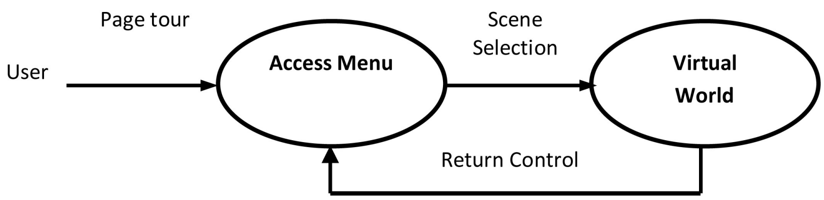


Fig. 3. Data flow of Level 1.

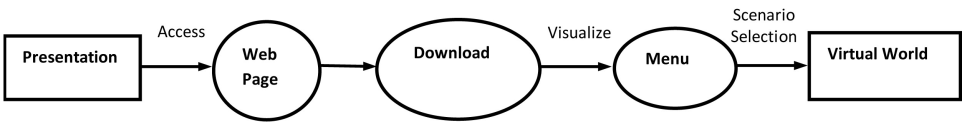


Fig. 4. Data flow at presentation level.

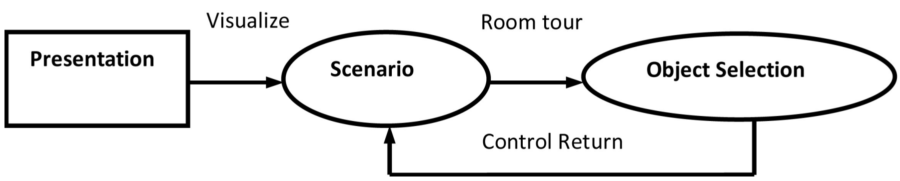


Fig. 5. Level of the virtual world.

contain halls, sculptures and interactive objects which will be modeled in 3D.

Photos and engineering design of the building will be the two elements used as guide for modeling and for creating the general virtual structure of the Palacio de Bellas Artes.

3. Description of the model

In this section the formal description of the software design [12] is presented.

3.1 Diagrams of virtual visit

Figure 2 shows the data flow at *Conceptual Level.* The user loads the application which shows the virtual world, inside it there are options for moving along the scenarios, the user selects one option to change the scenario. The user will take the complete tour and will exit the application.

Level 1 is showed in Fig. 3 and illustrates the interaction between the user and the virtual visit.

The *Presentation Level* is showed in Fig. 4. In the first step, the web page is accessed, then the application is loaded and the user can observe the menu. When the user selects one option then he can access to the virtual world.

Level of the Virtual World which illustrates the interaction between the user and the objects of the virtual world is showed Fig. 5.

Figure 6. shows the flow chart at User Level.

3.2 Use cases

Typically, a Use Case defines the interaction between a role (actor) and a system to achieve a goal. In this section we will describe the behavior of the virtual visit (system) in different conditions when responding to the user (actor) requests.

The basic case is described as follows:

1. The user connects to Internet thru the computer.
2. The user enters the web page of the application of the virtual visit.
3. In the main page, a link for the virtual visit appears and the user has to click in that link.
4. The web page where the user can download the application is loaded.
5. Once the application is downloaded, the user executes the application.

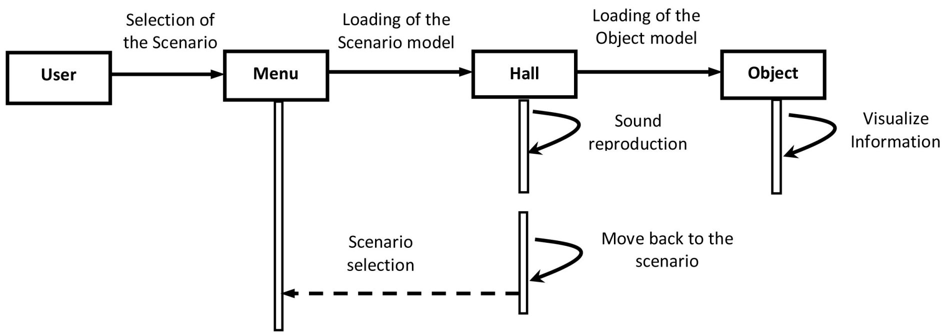


Fig. 6. User Level.

6. The user decides the scenario he wants to visit.
7. The user starts the virtual travel.
8. Finally, the user exits from the application.

Exceptions

1. Web page cannot be loaded: the user should verify the internet connection.
2. The user cannot download the application: the internet connection is not optimum.
3. The application is not operational: the elements of the computer viewer (hardware) are not suitable.

The use cases for other interactions with the user are developed in a similar way.

4. The design of the software

In this section, we describe the modeling of the different objects that integrate the virtual visit of Palacio de Bellas Artes of Mexico. First, we present the modeling and construction of the building, sculptures and objects with BLENDER as a development tool. Then, the texturing and illumination processes are described. Finally, the animation and navigation process are presented together with the implementation of the interactive and descriptive audio and text.

4.1 Description of blender

The process of modeling is like the process to make a plasticine figure, i.e., we start with a cube then the cube is shaped until the desired structure is achieved. BLENDER models a figure in a similar way. The geometry of a scene of BLENDER is achieved working from one or more objects: lights, curves, surfaces, cameras, meshes and the basic objects (Fig. 7a) which are shaped from three structures (Fig. 7b): vertex, edge and face.

BLENDER models complex objects by taking actions over the basic objects such as: erasing, joining, connecting nodes shared by other objects, duplicating and grouping objects, rotating, scaling and cutting.

Besides, BLENDER has very important elements as Booleans which are actions that can be applied over basic objects. These actions are: intersection, union and difference.

Other operations are Smoothing and Extrusion. Most of the objects of BLENDER are represented by polygons with plain faces therefore, the operation of Smoothing allows to obtain curved faces. Extrusion allows creating cubes from rectangles and cylinders from circles. When we are working with vertexes, edges and faces of objects, this operation expands the faces of the figure.

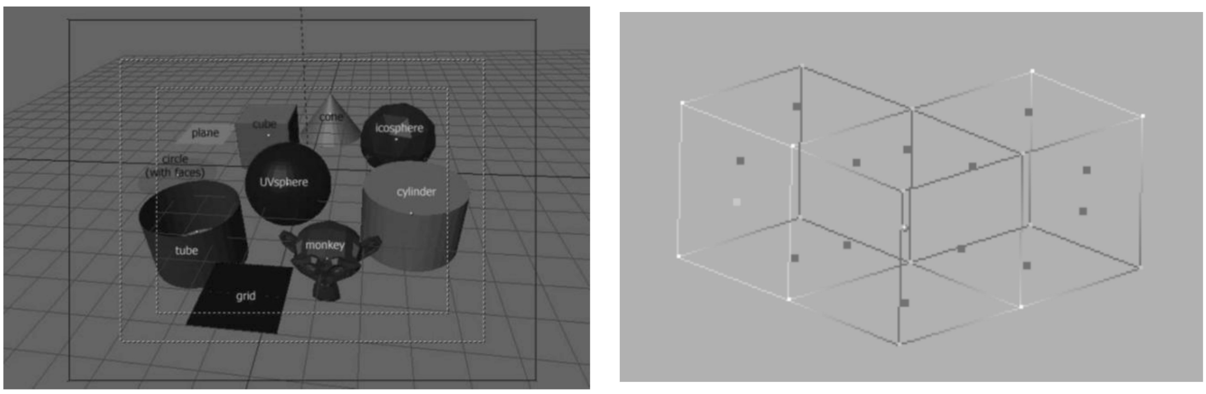


Fig. 7. (a) Basic objects in BLENDER, (b) Structures for shaping basic objects.

4.2 *Constructing architectural models*

In the construction of each of the four scenarios we carried out the following steps:

1. Taking photos of the Palacio de Bellas Artes. We took several photos from several angles of the front, vestibule, first and second floor.
2. Constructing the floor plan of Palacio de Bellas Artes. We could not get the original plans therefore we constructed a floor plan by assessing the measurements. A plan was constructed for each scenario.
3. Constructing the scenario. The front was modeled based on a geometric figure called Plane.

Figure 8 shows the photo and the model of Palacio de Bellas Artes.

4.3 *Constructing sculptures and objects*

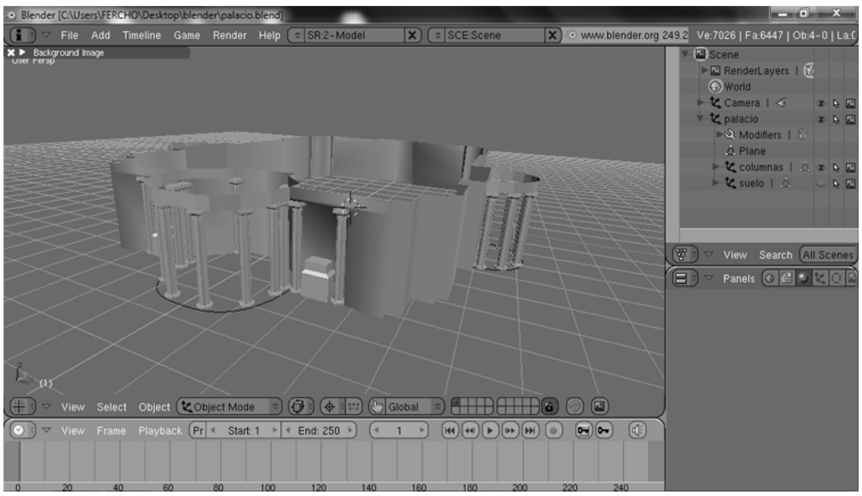
In a similar manner, the steps for modeling the sculptures decorating the front are the following:

1. Taking the photo of the sculpture.
2. Constructing the sculpture with BLENDER. The photo was exported to BLENDER. With the paintbrush tool, we drew the lines that delimit the contour of the sculpture (see Fig. 9). The model of this object was built from the geometric figure called Cube. Finally, the smoothing is applied.

4.4 *Texturing process*

For illustrating this process, we will take as an example the Fig. 10(a). Once we have the image for texturizing, we select the image which will be the

(a)



(b)

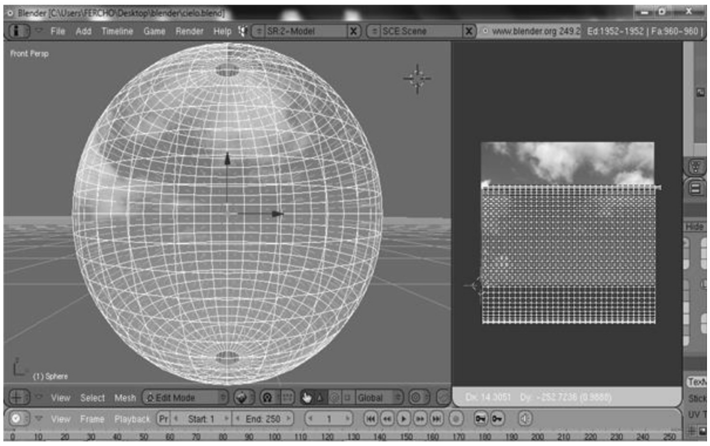
Fig. 8. (a) Original photo of Palacio de Bellas Artes, (b) Model from the photo.

Fig. 9. Drawing the lines for delimiting the sculpture.

texture; in our case is the sky. This image is incorporated to the 3-D object by the BLENDER command *unwrap*. Finally, the frame of vertexes of the image is edited for covering completely the 3-D model. Fig. 10(b) shows the textured scenario.

4.5 Illuminate process

In the following example, we used the BLENDER lights Hemi and Lamp. The lamps were placed in such form as the 3-D object had enough light to correctly visualize its texture and it could screen a



(a)

(b)

Fig. 10. The edition of the texture. (a) The original image. (b) The textured image.

shadow. In Fig. 12 we can observe the original object (Fig. 11(a)) and the illuminated object (Fig. 11(b)).

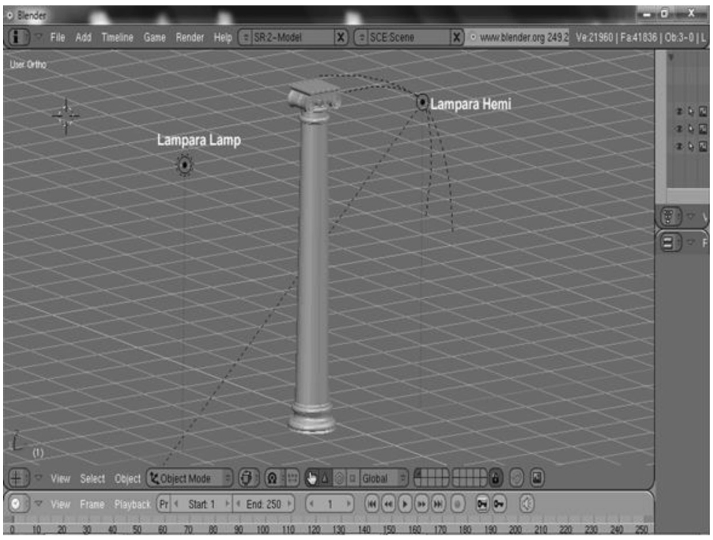
Blender has five types of lamps: lamp, sun, spot, hemi and area, each of them with similar parameters of distance, brightness, and incidence angle. The illumination for each scenario is:

- *Sun*. For illuminating the exterior front. This type of lamp resembles the sun light.
- *Hemi*. For illuminating most of the objects and sculptures. This lamp does not require many hardware resources but it does not screen shadows of the objects.
- *Lamp* (standard lamp). It is a combination with Hemi lamp and it was used for illuminating objects and sculptures screening shadows, however it needs many hardware resources.

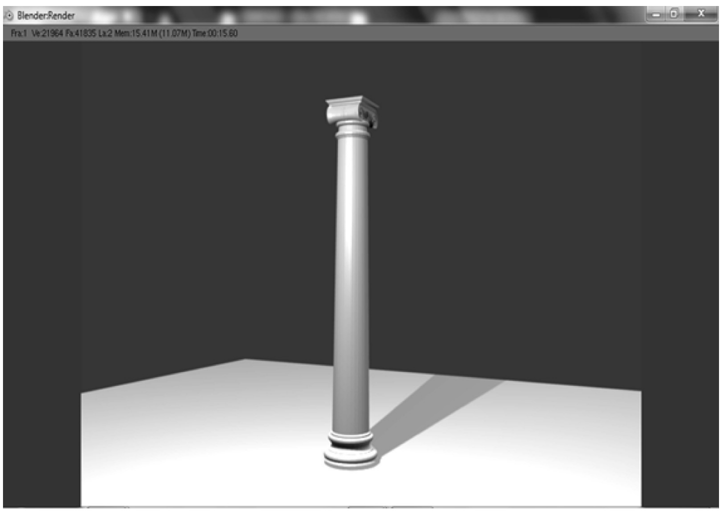
The main goal of the virtual visit is to navigate and to travel across the model of Palacio de Bellas Artes with the most possible real view. This purpose is accomplished by animation and navigation of scenarios. Therefore, once all the objects were modeled, illuminated and texturized, it is necessary to animate the objects and to allow the user to travel across the scenario. The animation is implemented with BLENDER tools, and navigation is implemented with Phyton. These features show to the user a more real view and allow the user to interact with the virtual world more than just a panoramic view.

4.6 Animation process

BLENDER animates objects in many manners. The objects are animated by changing their position, orientation or size over time. Also, objects can be animated by deforming their vertexes or control



(a)



(b)

Fig. 11. Illuminate process

points. Another manner uses an interaction with an especial object: the Skeleton. The other tool is the game engine which is and editor for creating games that it is integrated to BLENDER from 2.x version. The game engine has:

(a) An IDE with modeling, animation and game-player.
(b) Rigid body dynamics and collision simulation.
(c) Sensors and other predefined logical devices.
(d) Phyton as an script for more complex games
(e) A Camera which allows the user to follow the scenario and to take photos.

4.7 Navigation process

The navigation process was implemented with two objects: a Camera and an Empty.

(a) Camera animation. Inside the BLENDER 3-D space, the camera was rotated by using an IPO curve (interpolation system).
(b) A Phyton script was created with the BLENDER text editor. The script allows the camera to follow the movement of the mouse pointer in the virtual visit.
(c) The camera animation and the script were incorporated by the engine game.

4.8 Creation of audio and text for a hall

The user will interact with some elements in the halls thru descriptive audio and text which give information about sculptures and paintings. For this purpose, BLENDER has an audio sequencer (*Cubase Le*) to edit and incorporate audio in wav format; also, it has a text editor for inserting text in a 3-D space.

5. Discussions

A virtual visit at Palacio de Bellas Artes of Mexico was presented. The view is more real than the current virtual visits in Mexico. The three-dimensional movements of the user and the illumination techniques are unusual features in other views. Our virtual visit is not panoramic like others.

BLENDER is free open source software which allows designing virtual visits with a great grade of realism.

Although the software presents a very attractive view, the administrative politics of the Palacio de Bellas Artes do not allow the application to be immediately installed and we are waiting for the formalities to finish. The installation will be in the near future.

Finally, it should be established some standards for virtual visits to be consider as such.

The application was developed with the bases of Computer Engineering and it is an important contribution for Education because allows users to take a virtual visit to one of the most important cultural center in the world just by the use of a computer with Internet, and it can increase the cultural pool of every virtual visitor.

6. Conclusions

Culture is a fundamental part of education and it can be learnt from many sources. Virtual places are a viable option. There are several tools for designing and implementing a virtual place, and BLENDER has demonstrated to be a suitable tool. By the use of this software, we could create virtual places representing some of the principal halls of the Palacio de Bellas Artes from Mexico City. The result is a friendly software which facilitates the knowledge of part of the culture in Mexico just by a click.

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References

1. A. Druck, When will Virtual Reality become a reality?, *TechCast: A virtual think tank tracking the technology revolution*, TechCast LLC, 2006.
2. S. S. Fisher, M. McGreevy, J. Humphries and W. Robinett, Virtual environment display system, *I3D '86: Proceedings of the 1986 workshop on Interactive 3D graphics*, January 1987.
3. T. M. Rhyne, Computer Games and scientific visualization, *Communications of the ACM*, **45**(7), July 2002, pp. 40–44.
4. C. Scharver, R. Evenhouse, A. Johnson and J. Leigh, Designing Cranial Implants in a Haptic Augmented Reality Environment, *Communications of the ACM*, **47**(8), August 2004, pp. 32–38.
5. T. S. Sørensen, J. Mosegaard, D. Ballisager, B. Carstensen and A. Rasmusson, Virtual Open Heart Surgery: Training Complex Surgical Procedures in Congenital Heart Disease, *SIGGRAPH 2006*, Boston USA.
6. A. M. Kunz and T. Nescher, Future Entertainment Technologies, *ACM Computers in Entertainment*, **9**(3), November 2011, 11: pp. 1–4.
7. J. Gurri and C. Carreras, Realidad virtual en nuestros museos: experiencias de la colaboración entre Dortoka y el grupo Òliba, Internet Interdisciplinary Institute, 2003, available at: http://www.uoc.edu/in3/dt/20287/20287.pdf, Accessed September 13th 2012.
8. Virtual visit at Museo del Templo Mayor "Teopantli", http://aztlan.inah.gob.mx:8080/teopantli/index.html Accessed September 13th 2012.
9. Palacio Nacional de México, http://www.hacienda.gob.mx/cultura/museo_virtual_pal_nac/shcp_mv.htm, Accessed September 13th 2012.
10. Asociación Yad Vashem de México, http://www.yadvashem.mx/conmemoracion-de-los-nombres.html, Accessed September 13th 2012.
11. J. E. Labra Gayo, P. Ordóñez de Pablos and J. M. Cueva Lovelle, WESONET: Applying Semantic Web Technologies and Collaborative Tagging to Multimedia Web Information Systems, *Computers in Human Behaviour*, **26**(2), 2010, pp. 205–209.
12. R. S. Pressman, Software engineering, Ed. McGraw Hill. Sixth Edition.

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