An experience using X3D for Virtual Cultural Heritage

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Abstract

In this paper we present our experience in using Virtual Reality Technologies to accurately reconstruct and further explore ancient and historic city buildings. Virtual reality techniques provide a powerful set of tools to explore and access the history of a city. In order to explore, visualize and hear such history, we divided the process in three phases: historical data gathering and analysis; 3D reconstruction and modeling; interactive immersive visualization, auralization and display. The set of guidelines devised helped to put into practice the extensible tools available in VR but not always easy to put together by inexperienced users. These guidelines also helped the smoothness of our work and helped avoiding problems in the subsequent phases. Most importantly, the X3D standard provided an environment capable of helping the design and validation process as well as the visualization phase. To finalize, we present the results achieved and further analyze the extensibility of the framework. Although VR tools and techniques are widely available at present, there is still a gap between using the tools and really taking advantage of VR in historic architectural reconstruction so that users might immerse themselves into this world and thus be able to consider various scenarios and possibilities that might lead to new insightful inspiration. This is an ongoing process that we think will increase and help current architectural development.

CR Categories: I.3.7 [Three-Dimensional Graphics and Realism]: Animation—Virtual reality I.3.6 [Methodology and Techniques]: Standards—Interaction Techniques J.2 [Computer Applications]: Computer-Aided Design—Computer Aided-Engineering

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1 Introduction

The aim of this work is to report our experience in creating and visualizing a large 3D environment that accurately represents an old historic city of Brazil in the year of 1911 utilizing Virtual Reality tools and techniques. Our goal is to model the whole environment as accurately as possible, with both visual and audio fidelity. This

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3D Virtual Environment will be useful to explore different aspects of the old city such as: position of the buildings, the relationship between different aspects of economics and politics, analysis of how the architecture influenced people in such context, discussion of ideas and insights for future developments and comparison of the current existent buildings with how they looked in 1911.

This task is challenging in several aspects, especially in scaling and integrating all levels of details: gathering historical documentation of the visual objects/buildings/people; virtually recreating the environment sound scene; modeling the gathered data with accuracy; and integrating all this data coherently with both audio and video projection systems. All this tasks are required in order to achieve the level of realism desired.

In order to accurately reconstruct a virtual city, a team of architects and historians actively participated in the process. They gathered the most relevant data and carefully accompanied the 3D modeling phase. The feedback in this case is crucial: reconstructing no-longer existent buildings is a difficult task and expertise for such task is an ongoing demand, influencing every step of the process.

Both the modeling and visualization phase used the X3D standard: architects and historians were able to analyze the 3D data through the web during the modeling phase, providing almost instant feedback and leading the way for an accurate 3D representation; in the visualization phase, we used our X3D immersive browser, which is capable of displaying X3D models on a CAVE environment.

This provided an in depth view so that specialists and architects could analyze different aspects of yore, that were not visible in plain photographs. Virtual models can expose different panoramas, providing a brand new perspective of different aspects of that time.

2 Motivation

The field of Virtual Cultural Heritage refers to the use of virtual systems to generate, navigate and explore reconstructed environments that are of cultural interest.

Historic reconstructions using 3D representations are usually based on data from architectural plants, old photographs, paintings, and postcards. But the most important data come from the knowledge of experts that are used often to gain further insight. The 3D modeling is not a straightforward task due to the lack of standardized tools and methodologies, the requirement of specialists and programmers to create and operate such tools and finally the high cost of most VR Visualization Systems.

According to Bocchi [1999], a city is represented by a synthesis of its material structures and activities, which constitute the product of its culture, economy, research, science and the arts. Therefore, the ability to reconstruct, explore and visualize how the city looked like is an important part of the process of understanding the politics, economics and mutual relationships of people. This initiative is of significant importance given the possibility to visualize city regions that due to the long process of intervention occurring during the past years were previously not possible to understand and explore its functions throughout time as well as the comprehension

of the respective urban relationship quotidian model. This work is inserted in the context of iconographic urban history, therefore, subject to criticism and open to new ideas and concepts. It is our opinion that this project can stimulate and generate a series of studies and more in depth discussions about our history and urban culture through the improvement of the utilization of Virtual Reality techniques. It is up to us, users, to put into practice our experience and push to limits our efforts in transforming the VR world into a tool widely available to the population.

3 Historical Data Research

The process of gathering and acquiring historical data to this project was achieved through a partnership and full support of the Department of Historical Patrimony (DPH/SMC/PMSP - Departamento do Patrimônio Histórico da Prefeitura da Cidade de São Paulo). The DPH is responsible for the permanent guard, organization and preservation of documents produced, received and accumulated through out the years, in a natural process, by the organizations that constitute the Municipal Public Administration since the XVI century until the first half of the XX century.

The city of São Paulo has a lot of different important sites and buildings. Some of them have witnessed a myriad of changes through out the century due to the industrial revolution, the advent of electricity and the economic growth the city has faced. After the year of 1880, drastic changes occurred in the city of São Paulo, altering the city's architectural appearance and its relationship to native residents. During the years of 1880 and 1935, the implantation of new infrastructure urban services such as public transportation, water treatment and public illumination served as a start point for such drastic and rapid transformations. Between the years of 1890 and 1910, the city population expanded four times, growing from almost 60.000 people to 238.500 according to the records found.

These factors contributed to processes of city architectural remodeling and the construction of new buildings.

Due to this scenario, the 3D reconstruction focused on the year 1911, which represented a differential point from the evolution faced by the city. The 15 most important buildings were chosen to be modeled. Only 3 of these 15 buildings are still standing today.

Specialists of the DPH gathered data from 1893 and 1930. Documents such as iconographic sources, cartography plants, architectural plants, technical procedures, plumbing plants for those constructions, power line plants, photographs and postcards were gathered and arranged in different portfolios.

Although this research phase accomplished almost its objectives completely, it actually extended itself through out the project due to the constant re-evaluation of the 3D modeling and requirements for data to fulfill missing spots in the modeling. We are currently looking into introducing features like this in our next projects.

4 3D Modeling and Reconstruction

The modeling phase consisted of carefully analyzing the data collected and distributing them to expert modelers. Our goal was to accurately depict the city as it really looked in the year of 1911. The experience should be complete, fulfilling the immersiveness required for VR Environments.

In order to accomplish this, the models should have enough geometric details for a close-up view of the user. The buildings chosen
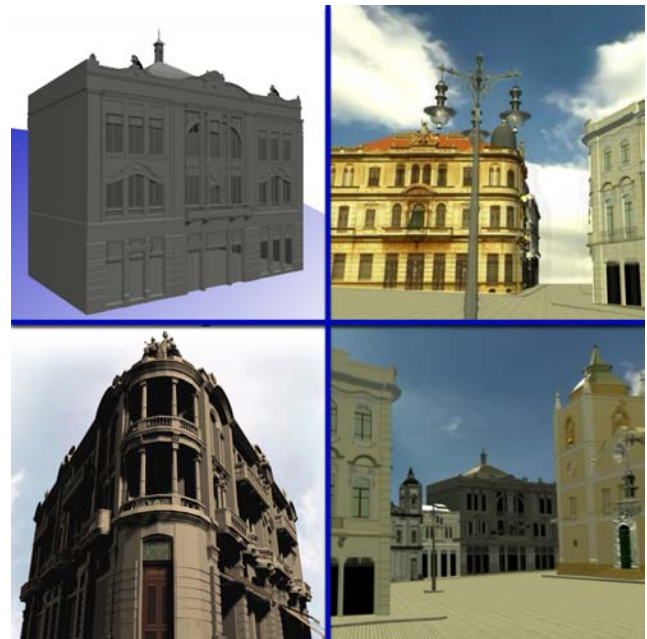

Figure 1: *From top-left in clockwise direction: 3D models of Germania building; Casa Baruel; Palacete Tietê; perspective view of other 3D models.*

to be modeled contained a high level of geometric details in it such as the "Casa Baruel" or "Palacete Tietê". Look carefully at the details on balconies, double windows and the cupola [1] of the "Casa Baruel" (see figure 1). The balustrades [2] of "Palacete Tietê" also shows how far our modelers had to go in order to accurately represent this buildings.

The design and review process was an extenuating phase where every week the DPH experts would analyze and compare our models to the actual buildings data collected, in order to certify the 3D models.

The software Maya from Autodesk [Autodesk 2006] was used to model the environment. Maya does not natively supports exportation to the X3D format standard. However we were able to use an open source Maya exporter called Rawkee [Archaeology Technologies Laboratory 2006]. The export phase was not successfully achieved at the beginning due to problems in the Rawkee exportation. Texture coordinates and normals would get mixed up in the process, affecting the overall look of the model. This had to be manually corrected using the X3D-Edit tool. Another approach that reduced the time-consuming design review process was the utilization of the X3D standard.

Using the X3D standard, we were able to post on a web page the weekly results of our modeling work. Instead of creating high-definition renders and the time consuming lighting process, the X3D files provided an easy and accessible alternative to the design process of our work. With this web-page setup, the DPH specialists were able to interactively analyze our work from the comfort of their offices. The possibility provided an interactive visualization that greatly improved the analysis process. The interactivity depicted an unforeseen feature for comprehension of the work be-

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[1] A cupola is a dome-shaped ornamental structure placed on the top of a larger roof or dome.

[2] A balustrade is a row of repeating balusters – small posts which support the upper rail of a railing. Staircases and porches often have balustrades.

ing done. The DPH specialists could verify our models beyond the static pictures rendered at the beginning of the process. However the review process still had to be written down in the form of reports since our X3D web page did not provide an annotation/comment feature.

5   Interactive Visualization

The final phase of our project consisted of using Virtual Reality tools and techniques to add interactivity and immersiveness to visualize the modeled 3D dataset. The very concept of virtuality implies three dimensional visualization and interactive systems aimed to create immersion environments generated by computers in real time.

Our approach in this project was to combine widely used tools for VR with custom solutions developed by us. Our custom developments aimed at solving and providing features not available by most of those tools. The features desired in our VR visualization tool are: full support to the 3D data (scenegraph and data loader), photorealistic rendering (support for programmable shaders), support for cluster (Immersive Environment) and good usability These features and many others are desired not only in our tool but also in all VR visualization tools in general. We tried to address each one of these features by either developing or using already developed API's available. In the next sections we will cover in more details each one of this specific features.

Building a scenegraph from scratch was not under the scope of our project. In fact, there are a handful of initiatives that deals with this issue. We analyzed several of them including OpenSG, OpenScene-Graph, Coin3D and Ogre3D, taking into account their characteristics in the following aspects: object oriented approach and design, easy programmability learning curve, platform independency and, most importantly, overall performance for millions of polygons.

Ogre3D does contain several features that we wanted our tool to posses: programmable shaders support (Cg); animation and scripting support; high-level hierarchical scenegraph organization (Octree and BSP); compatible with Linux, Windows and MAC OSX.

Although Ogre3D supports many 3D file formats, one of particular interest to us is not yet supported: X3D. Given our usage and experience in the previous phase, we wanted to maintain this format as a default for our visualization tool. We needed to develop a custom data loader from X3D to the Ogre3D scenegraph structure.

The main objective for the loader is to correctly associate the X3D scenegraph structure with the Ogre3D scenegraph, which is not an easy task. To accomplish this, a deep study on the internal object structure and functions of the Ogre3D was necessary. Then, we had to carefully map the structures available in the X3D standard to the appropriate classes available in the Ogre structure.

In our case, we have concentrated our efforts to accurately load the main primitives described in the X3D standard: Lighting (DirectionalLight, SpotLight, PointLight), Appearance (Material, ImageTexture), IndexedFaceSet (Coordinate, Normals, TextureCoordinate), Transform Operations, and Grouping nodes.

The light representation in both scenegraphs are different. The X3D standard takes only one argument to describe distinct values of light reflection: diffuse and specular. In this case, we had to duplicate the value, which caused no apparent difference between the visualization of the 3D scene in both worlds.

The X3D defines a node in the scenegraph that holds material information of such node, called Appearance node. This node can hold information of only one Material instance while in the Ogre3D scenegraph, every Appearance node can hold several different instances of Materials. In this particular case, we chose to export the X3D with separate Material properties for each different Appearance node. However, this introduced an overhead due to the extra time required load.

The geometry in Ogre3D is described through a scenegraph node called ManualObject. This node works similar to the OpenGL state machine when building elements that compose a scene and it allows different primitives to be passed to it in order to describe an object.

Although we would like to implement event manipulation and routing, this have shown to be a very complex subject and we were not able to implement that in the time available for the project. Event manipulation and routing could be nicely explored in user interaction and animation as a whole and we are considering that as a future work.

5.1   Cluster support

The cluster approach we used was to assign every screen to a single VRCluster node. The Ogre3D does not support this feature so we implemented ourselves a library, called Ether, to synchronize data, events and barriers among cluster nodes. The Ether library is a framework for distributed computing that provides synchronization over cluster applications. Ether was built in C++ and it implements Barriers, Semaphores, Events and Shared Variables classes.

Ether has a centralized controller (server), which is responsible for managing all remote client applications. This server entity can be set with a single flag on parameter line. Ether allows that remote applications joins and leaves dynamically, as long as the server has been specified. For example, `etherServer -h server -s 2 -t 5` mean that the instance is a server, it needs at least 2 and at most 5 clients to run. It is important to notice that Ether supports both the Unicast and Multicast IP. Using multicast, the network resource usage can be optimized due to the fact that the server frequently sends the same packets to its clients. However, the use of Multicast is only possible over local area network. In order to extend its use to wide areas network, it is necessary to activate Multicast support on all routers of the network.

Our improved cluster version of Ogre3D is called caveOgre. CaveOgre uses the Ether library to render the models in the VR-Cluster. CaveOgre uses basically two Ether objects: Barrier and Shared Variable. The Shared Variable class allows the CaveOgre application node to share information with each other. For example, the position of the avatar and viewing direction are established with shared floating-point variables between each node of the cluster. The Barrier class is responsible to synchronize the data write/read as well as maintaining the FrameLock [3] of the system.

5.2   Usability

Usability [Nielsen 1993; Nielsen et al. 2003] is mainly concerned with 5 main topics: learnability, efficiency, memorability, errors, and satisfaction. Therefore, an interface with good usability should be easy to learn (learnability), allow expert users to efficiently perform their tasks (efficiency) and casual users to reuse the interface

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[3]Frame-lock, also called swap-lock, ensures the images computed on each PC node are released at the same time, i.e. the buffer swaps are synchronized. Failing to ensure a proper frame-lock results in discrepancies. More details in Raffin *et al.*[2006]

without the need to learn the tasks again (memorability). The number of errors should be small, and when they occur, they should be easy to correct. Subjective factors, such as trust and comfort, are also important for usability, and they are included in the satisfaction item.

We tried two different approaches in our visualization tool: a joystick that simulates a well-known game like interface and a 3D mouse (tracked by a Flock of Birds device [AscensionTechnologies 2006]. The 3D mouse interface worked with a simple point-and-go simulation: the user would use the 3D mouse to point where to go (controlling the viewing direction of the camera) and the click the left button to go forward and the right button to go backwards.

Subjective analyses of users using the joystick interface provided us good results on learnability and efficiency. We believe this is due to the current knowledge people have nowadays using video games. However, efficiency greatly varies among users, most of the times favoring those who are usual video-game players. On the other hand, the level of satisfaction people showed when using a 3D mouse to navigate was impressive. Almost every user found the 3D mouse interface easy to use and also pleasuring to utilize.

Our time to test the overall system's usability was short and beyond the scope of this project. However we intend to do more intensive tests in future projects in order to gather more data and effectively evaluate Virtual Reality interaction techniques.

6 Results, Conclusion and Future Work

The development phase of the data modeling was accomplished using Intel Dual Core Systems with NVidia Quadro 1400 machines. The final 3D model contains approximately one million triangles. The texture files take over 300 megabytes of data. This model was then visualized on a CAVE and powerwall environment using the developed X3D browser based on Ogre3D.

However, one of the major achievements in this work was the use of X3D to effectively improve the design review process. It helped consuming less time for developers, users and specialists. Moreover, it allowed specialists with no background in 3D graphics to interactively and effectively make use of such technologies, introducing novel working models to this area of work.

In the future it is desirable to model and interact with the ongoing life at that moment: watch the cars passing by, the citizens walking on street, pause and resume their movements and change their destinies would be a great experience and a powerful instrument to reconstruct not only the buildings, but a life like situation. In the X3D standard, this level of interaction can be achieved by using a set of device and pointing sensors, together with a scenegraph capable of manipulating and routing events. Unfortunately, the Ogre3D scenegraph is not able to associate events to objects and handle these events at runtime. As a future work, we intend to implement an extension to the Ogre3D scenegraph to do event routing.

Parallel rendering algorithms like sort-first and sort-last are not yet available in the Ogre3D engine. Although sort-first configurations can be set up with the Ether library, support for sort-last on each screen of a multi-display system would greatly improve performance, allowing more complex models.

The project was considered to accomplish its purposes and undoubtly enriched the reproduction and analysis of the days of yore of the Sã Paulo city. All the models were periodically submitted for the approval of the DPH specialists. The architecture as well as the
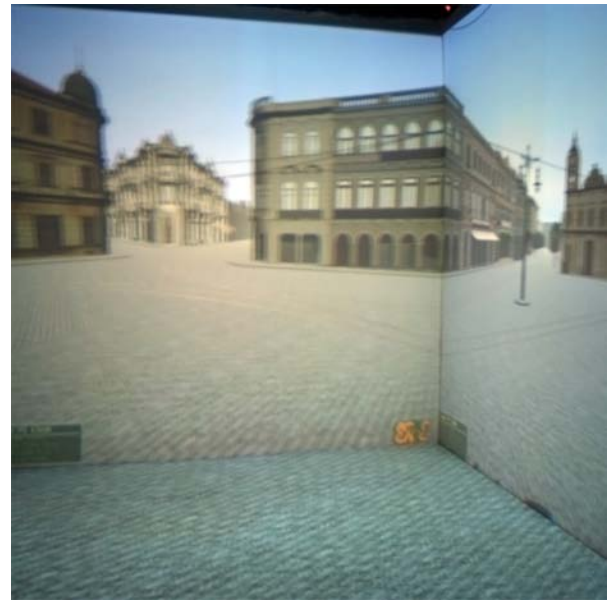

Figure 2: *3D model running in a CAVE like system*

colors of the buildings were considered realistic, presenting X3D and VR as a powerful instrument for historical reconstruction.

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