X3D Modeling of a Historical Building: San Carlos Cathedral Case Study

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Figure1: *The San Carlos Cathedral in Monterey, CA,USA, modeled using X3D*

Abstract

Between 2011 and 2015 we created an X3D reconstruction of the San Carlos Cathedral, standing in Monterey, CA, USA, from 1791. This paper focuses on techniques and practices for modeling a major cultural heritage site. We illustrate the phases of our work: gathering sources, modeling, texturing, creating navigation and interaction features, adding sources, resources and metadata to our model and building the user interface. We then introduce various suggestions on procedural use of the declarative Web language X3D in the Cultural Heritage field. Instead of considering our model strictly as content, we considered it as a web portal or access point to other content. The role of animation/interaction/scripting is crucial to an innovative communication for Cultural heritage. A sophisticated and innovative use X3D for Cultural Heritage (with its animation/interaction/scripting feature) can be reached only if the author can control the geometry nodes of the model.

CR Categories: I.3.3 [Computer Graphics]: Three-Dimensional Graphics and Realism—Display Algorithms I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Radiosity;

Keywords: Cultural heritage, 3D modeling, X3D, prototypes.

1 Introduction

The work presented started in the context of an internship held at Naval Postgraduate School in Monterey, CA, USA, from December 2011 to February 2012 and evolved in the following years. The aim of the project was to show how using X3D it is possible to create a virtual environment, made of the 3D model of a Cultural Heritage artifact and connected resources. We wanted to consider the 3D model not only for his visualization properties, but as an access point to knowledge and information. The user can explore and gain information; resources are maintained and preserved in a digital context[1]. The selected site is the San Carlos Cathedral of Monterey.

This work presents the 3D reconstruction of a building of historical importance still standing from 18th century using X3D. Will be described an approach for the creation of a 3D model for the Cultural Heritage [Ioannides and Quak, 2014]. From the preliminary historical and architectural research, to the planning and building of the user interface and the exploration and narration strategies.

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[1] A virtual museum, in a real or virtual space, exists if there is a focus on tangible or intangible heritage, real or virtual, linked by a communication system, and it's used in various forms of interactivity and immersion, by a public for the purpose of education, research, enjoyment, enhancement of visitor experience or promotion. *State of the art on Virtual Museums in Europe and outside Europe*, Deliverable report D.23, 03/03/2014, CNR, http://www.v-must.net/sites/default/files/D2.3_StateArt_VirtualMuseums_V2014_FINAL.pdf

Section 2 presents all kinds of sources we used for modeling and making up the whole information environment. Starting from the searching for books in the local library, searching for maps of the building, historical records and pictures, to the on-site inspections where we took measurements and photographs.

In section 3 we deal with the modeling and texturing process. We will focus in all the operations, problems and difficulties we encountered.

The user interface is the main access to all navigation/animation/interaction features and to the digital archive and the information environment we created. Our proposed user interface is presented in section 4.

Section 5 presents future works, how the model should be added in a web page, the importance of links, bibliography and connections with related 3D models. Possible future directions of the use of a procedural language as X3D for Cultural Heritage will be introduced.

Figure 2: *A Picture of San Carlos Cathedral, exterior*

Figure 3: *A Picture of San Carlos Cathedral, interior*

2 Gathering sources

The Cathedral of San Carlos Borromeo is the oldest continuously functioning church and the first stone building in the State of California. Also known as Royal Presidio Chapel, it was funded in 1770, made by adobe, and rebuild between 1791 and 1794 by sandstone. From that time a few changes has been made and it is still standing in the city of Monterey [Mendoza, 2009; Casabianca, 2009]. The church has been listed on the National Register of Historic Places as a National Historic Landmark[2]. It has a latin cross shape, his dimensions are 49 x 23 (at the transept) meters. The church, with his carved façade, has been built in the Spanish colonial style and we know that native indian labour contributed to the church decoration [Schuetz-Miller, 1994].

The city of Monterey was the capital of the California province from 1777, during the Spanish Empire period. In 1821 California became part of the independent Mexico and in 1850 a new state of the United States of America. Native Americans, Spanish colonialists, Mexicans and white Americans "encountered" and "struggled" at the shadow of the façade of our Cathedral. We designed this 3D model to be the access point to a lot of histories, to a great number of resources, to the History that we usually find in books.

This is the reason because our modeling project started from the Monterey public library and the C.S.U.M.B university library, searching for an exhaustive bibliography on the site selected[3].

In the Monterey library we found in the same book a great number plans drew in two different moments: an architectural survey by E. E. Kimbro and another survey made in 1934 in occasion of the Historic America Building Survey (images n°4 and n° 5) [Kimbro, 1999]. We found as well several drawing representing the church on the past and we used some of them to create a model of the building in the 19th century (more on section 3).

We took several on site measurement in order to render various architectural structures like, for example, niches not drawn on our plans.

During our on-site inspection sessions we took many photographs of every room we decided to model. We photographed general views of each part of the church as well as pictures of particular objects (carved structures, objects, furniture). It is important to say that during this preliminary inspections long distance and general view picture were very important, because usually maps and plans lack of information and we needed pictures on our computer during the modeling operations. These pictures has been a necessary instrument to decide what to model and what not to model during the design of the modeling phase. We didn't care about the quality of pictures, their primary use has been to design and recreate an environment (an atmosphere) that should be reliable, economical in terms of time and created for the purpose of our general motivations.

A different kind of photos we took when we were going to start the texturing process. Pictures must be very detailed, high quality and taken near the object or the decoration we wanted to add to our model. A clear example are painting on the wall.

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[2] Added 1966, #66000216

[3] See bibliography at the end of this paper

Another kind of pictures are those for documentation. They has been made with the aim to be published and added to our information system. Because a model is always a selection of element, the user should always be able to watch the church in pictures, that represent reality much better than 3D (we will insist on this point in the following sections and in the conclusions of this paper).

Figure 4: *San Carlos Cathedral: elevation of façade. From a survey made in occasion of the Historic America Building Survey (1934)*

Figure 5: *San Carlos Cathedral: a plan by E.E. Kimbro*

Figure 6: *A 1856 drawing by Henry Miller. Kept in the Monterey Public Library, California History Room*

Figure 7: A *Drawing of San Carlos Cathedral limits in different ages by archeologist R.G.* Mendoza, 2009

3 Creating our church: Modeling and texturing

We modeled the San Carlos cathedral using the open source editor X3D-Edit. Modeling and texturing operations lasted two months and half.

A general problem of modeling in X3D is how to render an irregular or a curved shapes. In practical, for the majority of irregular shapes we used the IndexedFaceSet node. Besides, we used the extrusion node for the bells, for the facade window and for the circular shaped decorations of the exterior of the church. All of the curves and arcs in the San Carlos project are the modification of only one arc created with the IndexedFaceSet node. This arc was created one time and then copied, put into a transform node and stretched or shorten in one or all of his dimensions (x, y, z) thanks to attribute scale of the node transform. As you can see from the image n°10 it was a very helpful to use a section (or a photograph taken from a frontal point of view, for other structures) in order to recreate a curved shape. We put the section on a box as a texture. Then we put the original arc above the section and we started to stretch and shorten it (with the Transform > scale attribute) until it is superimposed with the curved line we wanted to render. The way we did that is the trial and error method and a bit of patience. Only the design before to start each one of these operations saved us time.

The fact that the same arc has been used hundreds of times during the modeling of the San Carlos Church, each time copying and modifying small parts of it, convinced us to the opportunity to create an arch prototype. The aim of this prototype is to do all this kinds of modifications using a single interface, a single prototype, without modifying the forest of points and indexes, only adding and modifying values to the fields of the prototype. Stairs are another very common shapes in buildings. A stairsteps prototype

has been created after the San Carlos modeling, allowing the user to insert dimensions of one step and the number of steps.

Lining up one shape to another is one of the more time consuming problems of modeling in X3D. As you can see in the image n°8 a trick that helped us during the trial and error method (in the moment of lining up two shapes) is to change the color of one and then modify dimensions with trial and error until "aliasing" artifacts disappeared and the geometry rendering demonstrated that polygons were perfectly aligned.

A way to skip the problem of lining up shapes is to use huge IndexedFaceSet nodes. We often used quite big IndexedFaceSet, like for the walls and for the roof of the church, but we decided to use boxes or small IndexedFaceSet shapes lined up to each other in order to create other shapes. The reason we did that is because we think that the bigger the IndexedFaceSet shapes are, the more you lose the control of the model geometry and, as a consequence, the more you lose the possibility to edit it, to add texture and links, to create animations and interaction features, so important, as we will see, for Cultural Heritage. We liked to call this method Divide et impera (Divide and Rule, from Machiavelli).

Once finished the modeling of the present church we modeled the church in 19th century by following past documentation. The model came up merging mainly two sources: a 1856 drawing by Henry Miller[4] and a plan made by dr. R.G. Mendoza based on his recent archeological surveys (images n°6 and n°7) [Mendoza, 2009]. We created different files for different parts of the church. All files has been linked together thanks to a large use of the Inline node. At the end of the modeling phase our project counts twelve X3D scenes: one for the user interface, one for the church geometry, three for pieces of furniture (altar, benches, chandelier), one for bells, two for scaled models of the user interface, four for the 19th century model.

Talking about texture it is important to say that our goal was to use the least possible number of images. This was designed for two reason: 1) it is a web project and texture files is what increase the weight of the scene; 2) we wanted to take advantage of the lighting and shading capabilities of X3D. Walls and various objects of the church (benches for example) have a material color instead of textures. Various church decoration and other church textures (as the front of the organ) has been added as png file with a transparent background to the walls of the church, the latter rendered with the material node. The result is that the whole church seems more "live" and, in a certain way, more "real" than a very detailed, high quality, but still photograph. And the ten lighting variants we created wouldn't have been exploited. Anyway, various details, as the stone stair steps, the floor and the roof of the church, the crucifix and the paintings have been full textured. At the end of the texturing phase 69 images has been added to our geometry nodes, including 22 paintings and 26 irregular stone stair steps.
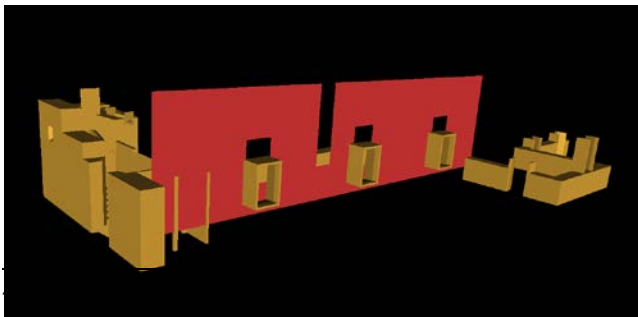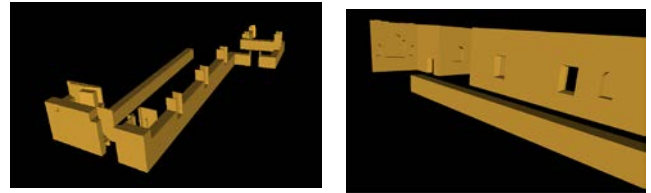

Figure 8: *A trick to line up to x3D shapes: change color to one shape, gradually modify dimensions with trial and error until*

tearing/aliasing artifacts disappear and polygons are aligned.

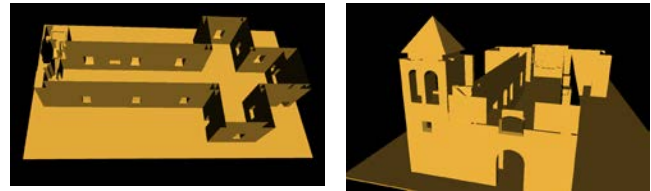**Figure 9:** *Snapshots taken during the modeling phase.*

Figure 10: *A trick to create curved shapes with the IndexedFaceSet X3D node: a section is attached on a box as a texture, the box is positioned above the façade, the IndexedFaceSet arc is shorten and stretched till it is superimposed on the corresponding arc on the section image.*

4 Making our model usable

Communication and fruition are key elements of every Cultural Heritage project[5]. With this in mind, we started to develop all features regarding the user interaction. We started from the X3D tools related to navigation, animation and lighting, arriving to the creation of an information system where digital resources and textual information are digitally preserved and available to the user.

Exploring the church at run time is a very important experience to the visitor, but usually, like in a real monument or museum, he needs something more. Therefore, we created a map, guided tours, and quick links to go to places of interest.

We will talk about the map at the end of this section, dealing of the user interface panel. Talking about tours, we created a large number of Viewpoint nodes. The user can change viewpoint pressing the pageUp and pageDown keys or can watch the tour thanks to the ViewpointSequencer prototype. We implemented a complete visit of the church (outdoor and indoor, starting from the facade and ending at the top of the bell tower) and a thematic tour showing all painting and the most important sacred furnishing of the church. The user can go to a place of interest and the related viewpoint by pressing buttons of the user interface. Some places of interest, like an interesting room, deserves more than one point of view, therefore we implemented a 360° camera tool using X3D features[6].

Ten lighting alternatives of the church have been proposed to the user. The latter can switch from one to another clicking on buttons of the interface panel. Examples of effects that can be created with these alternatives are: artificial illumination coming from chandeliers; morning beams entering from left windows and so on.

We added to our model various animations. Bells moving and ringing are an example. Real sound of the San Carlos Cathedral can be recorded and reproduced when clicking on the 3D bells. This feature that uses an audio file of cultural interest regarding our church introduces us to the important topic of digital archives.

We said in the introduction that we created our model as an access point to an information system. Resource files have been stored on a server[7] and linked to the model adding to the latter metadata

descriptions. We followed the ISO standard Dublin Core Schema. X3D-Edit permits a simple and straightforward creation and editing of metadata nodes. Following the Dublin Core Schema, we added metadata such as authors, date and various types of references: screenshots, pictures, and bibliographic references[8].

Beside of images (pictures and plans), screenshots, texts and multimedia files, we added to our system html files that contains text, images, video, audio, 3D content of various nature. In these files can be visualized sources of reconstructions, links, book references, comments, thorough annotations, images and animations to explain something. In short these files has been designed to have the same function of footnotes of a text.

Lastly, here we present a description of our user interface panel. It is a rectangular shape that appears in front of the user when he clicks on the word Menu. The latter is always on the upper right part of the screen during exploration of the model. The panel is composed of two parts. On the right of the panel there is the "map" of the model that completes our navigation system. It is a X3D model of the church made smaller with scale (see picture 11) and added to the panel thanks to the Inline node. It permits the user to have an overview vision of all the rooms of the model he is going to explore. Thanks to the ProximitySensor node the user is aware in witch room is located, thanks to a reference that appears inside the scaled model of the church. On the left part of the panel there is a menu, the list of items and actions the user can perform[9]. Here the user can find links to visualize on a web page all digital resources and information related to the church.

We want now to focus on the menu item called "Show references" (the second from top). Clicking on it the user faces another list of items:

Navigating; Historic model; Pictures, images, maps; Multimedia files; Reconstruction sources; Lighting; Animations; Other

It seems that the menu has been doubled, but it is not so[10]. Items on this list are layers of information. Clicking on one of them make a set of colored references (small pyramids) appear inside the scaled model and/or inside the main model. These pyramids are links to a place of the model, to a digital resource, like a map or a drawing, to other features like animations and the position of light sources. This mechanism permits the user to easily move to a specific room, place of interest or the viewpoint where an animation is visible. More important is the fact that reconstruction,

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[5] By communication we mean the ability of the VM to disseminate culture and turn "raw" data into information, regardless of who the final user is. By fruition we mean the way in which the user visualizes and interacts with the contents presented. The system of communication/fruition in fact, will not work unless the "raw" data comes across clearly to the user. This is achieved using a system of diffusion made up of, on the one hand, an interface, behaviour and devices (technology), and on the other hand by a narrative and communicative scheme (contents). State of the art on Virtual Museums in Europe and outside Europe, cited.

[6] 1) the user is taken to a viewpoint, typically on the center point of a room; 2) a pointing left and a pointing right arrow appear on the screen thanks to the HUD prototype; 3) clicking on one of them, the current Viewpoint > orientation field changes at runtime.

[7] At the moment X3D files are stored on a SourceForge repository http://sourceforge.net/p/x3d/code/HEAD/tree/www.web3d.org/x3d/content/examples/X3dForAdvancedModeling/SanCarlosCathedral. In particular we created five folders

to store references: 1) Pictures_Images_Maps; 2) Multimedia files; 3) Text files; 4) Past documentation.

[8] To have an idea of how many types of file resources related to a Cultural Heritage object can be added to a 3D model, is presented here a not exhaustive list taken from Europeana, one of the largest european digital collections: Images - paintings, drawings, maps, photos and pictures of museum objects; Texts - books, newspapers, letters, diaries and archival papers; Sounds - music and spoken word from cylinders, tapes, discs and radio broadcasts; Videos – films, newsreels and TV broadcasts. http://www.europeana.eu/portal/aboutus.html

[9] Here there is the list of the highest level of this menu: Navigating; Show references; Historic Model; Archives; Lighting; Animations; Bibliography; Links and online resources; Other

[10] Corresponding names on the highest level are direct link to an action, like "Start the tour" or a digital resource, like "Map of San Carlos Cathedral in 1857" that will appear on a web page.

information and historical sources, and html "footnotes" have a physical location, that is the part of the building their content deals. These will be shown in the scaled model and in the main model. We think this implementation is the ideal solution to show the presence of alternatives, hypothesis and comments concerning reconstruction of building in past ages. One or more layers can be activated at the same time, each layer shows references/small pyramids of a different color. We designed this section to make the user decide when and what kind of information, what kind of stories or links to look at.
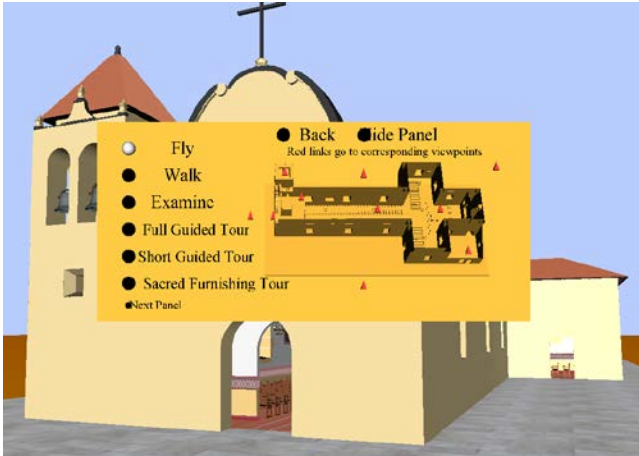
Figure 11: *Our proposed user interface panel. The Navigating panel is selected*

Figure 12: *Interior of San Carlos Cathedral. Screenshot of the 3D reconstruction*

Figure 13: *Interior of San Carlos Cathedral, Back of the church. Screenshot of the 3D reconstruction*

5 Links, Future Directions and Conclusions

We then prepared the "Bibliography" and "Links and related resources" pages, both reachable from the interface panel. The first is an html file and follows the conventions and rules of bibliographies found on books. The second is an html file as well and matches the "Further readings" in books, and "See also" or "you may be also interested in" in webpages. In this second file the user interested in investigating the topic thoroughly, can find: related issues or related 3D models, links to the Wikipedia page of the church, the official web page maintained by the Diocese of Monterey, similar projects, such as those dedicated to history of California missions or mission chapels (the Carmel Mission is distant only a few miles from San Carlos Cathedral[11]) and so on.

Future directions of our project are to put the model of San Carlos Cathedral on a web page and then to build a web site, where our model occupy the home page. This site will be navigable in two ways. The first approach is the classical one, following links from a menu in the homepage. The second approach is to start the exploration of the 3D model and then following links to web pages from the user interface panel. Web pages of this site will contain digital resources like pictures, maps, past documentation, texts narrating the history of the church and other information, videos, snapshots and other 3D models and 3D animations/interaction features. In the case the user follows the second approach, a back button permits the user to close the internal web page and continue the exploration of the church.

As we saw in section 4, we added to our system html pages that contain information like sources of reconstructions, links, book references, comments, thorough annotations, images and animations to explain something with function of "footnotes" of the model. Such html pages will have in future the possibility to receive comments and contents from other researchers and people that found or own objects or documents related to the church, perhaps living in another part of the world. Therefore, interesting and valuable comments and sources may be received and, after evaluation, published. Such contents can be the source of future extension of our project or even modification of the existing content. Technologies permit a collaborative Cultural heritage opera that never ends and this mechanism fits the process and the concept of research.

In conclusion, after we have described our approach to create an historical web3D model, we want to make some considerations on the use of a procedural language as X3D in the Cultural Heritage domain. X3D is worth in this field not only for the possibility to the rendering on the web, but also for some internal capabilities of this language, like animation and interaction, run time navigation and modification of geometry and lighting. These behaviors, accessible online, can't be combined using other modeling approach, unless a massive use of an imperative programming language (as commercial video-games) is used. And procedural languages are much easier to learn and implement. The X3D author doesn't have to deal with low level programming aspects, but with high level problems, as animation, interaction and texturing. These can be considered and designed as "humanistic" features. This language encourages the cohabitation and

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[11] www.carmelmission.org; also see
http://archive.cyark.org/misin-de-nuestro-padre-san-francisco-de-ass-mission-dolores-gallery to watch the 3D reconstruction, made by a laser scanner of the San Francisco mission church

communication in the same environment between technical and humanistic skills and resources. Lastly, as a consequence of what we said, X3D permits low budget projects.

Furthermore, an exhaustive and sophisticated use of animation and interaction features is fundamental for Cultural Heritage. In this paper we wanted to underline that these kinds of features can be properly implemented only if you can control the model geometry. It means a modeling approach that use many nodes to create a shape, as we pointed out in section 3. Grouping and naming are other X3D feature that helps to control the model geometry (to "open" the roof of a building with a click, to watch what there is inside, for example, a switch node would easily not render the Group   DEF="Roof"). Animation is the key for interaction. The videogame industry is so prosperous because, while exploring a new world, there are monsters that quickly approach towards you, you can pick fantastic weapons up, open doors pulling chains of a mechanism and so on; things that move, using a few words. X3D lighting alternatives can be a future key issue of 3D Cultural heritage. They can be a background and contribute to create stories, narrative outlines and dramatic effects. We can consider, in fact, the role of light in other medium as theatre, paintings, movies and videogames. We believe that the focus on surprise, visualization, poor animations, poor interaction and poor hypertexts capture the user attention only for a while, without producing real culture. This is the reason because our church model is only a starting point where to add and experiment new kinds of animation and interaction features.

Clearly, the aim of quicker modeling tools or scanners is to approach the reality of the artifact is going to be reconstruct in 3D. Procedural languages limits emerge when reproducing irregular and curved shapes. But, we demand if approaching the reality is the aim of a Cultural Heritage reconstruction. A model (the word itself says it) is a selection of element of reality. Using a metaphor a model in the Cultural Heritage field is like a map to explore a land you don't know (a map do is a model). It is a tool. It is detailed as you need. You don't ask for realism at your map, you ask for arriving at destination, you trust on its content. Information, learning and interaction features and not visualization make the difference in the Cultural Heritage field.

These considerations about the relationship between selection and reality are much more important when talking about building that are no more existing or when you want to show a standing one how it was in the past. Approaching reality is not only impossible, but far away from knowledge. In the positivistic age, 19th century historians pursued the illusion to recreate the past society "how really it was". 20th century historians dropped that dream telling us that the history is the use of evidences of past to better understand present society. Building a 3D model of the past that focus on visualization risks to repeat the error of 19th century historians, and this risk is even dangerous, because they used texts, nowadays we can create figures, that affect even more people psychology. The use of 3D models to represent the past can be a powerful tool for creating culture and knowledge only if it is supported by sources and related resources, and if the user is conscious that they are the only reality and not the reconstruction visualized.

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