AN ELECTRONIC LIBRARY FOR TEACHING ARCHITECTURAL HISTORY

CHIU-SHUI CHAN, JOHN MAVES, and CAROLINA CRUZ-NEIRA*
Department of Architecture
Iowa State University, Ames, Iowa, 50011, USA
**Department of Electrical and Computer Engineering*
Iowa State University, Ames, Iowa, 50011, USA

Abstract. This research project developed an electronic library of significant buildings chosen to represent seven selected periods of Western architectural history: Egyptian (Mortuary temple of Queen Hatshepsut), Greek (Parthenon), Roman (Pantheon), Romanesque (Speyer Cathedral), Gothic (Notre Dame Cathedral), Renaissance (Tempietto), and Modern (Des Moines Art Center). All buildings were reconstructed in their original or intended forms based on plans, drawings, photographs, and historical texts. Two products were generated by this project: (1) materials to be displayed on the World Wide Web, including rendered still images for perception, movies for a visual guide, and Virtual Reality Modeling Language (VRML) models for user navigation; and (2) virtual reality (VR) models to be displayed in the C2 (an improved version of the Cave Automatic Virtual Environment or CAVE facility). The benefits of these VR models displayed on the Web and in the C2 are their easy accessibility at any time from various geographic locations and the immersive experience that enhances viewers' understanding of the effects of spatial proportions on form and of colors on materials.

1. Introduction

One mission of architectural history courses is to provide a historical perspective of architectural forms, features, and the characteristics of spaces. Traditionally, course materials include textbook reading assignments and a wide variety of images. The reading material provides information on the socio-cultural context, constructional concepts, impact of local materials, influence of climatic factors, and technology related to form generation. The accompanying images include slides, drawings, photographs, and models that provide visual information on color, material, texture, and shape of features as well as clues to certain interior and exterior appearances. Combining text and images offers the background necessary to understand forms and to appreciate features. However, these two instructional media cannot fully communicate the characteristics of three-dimensional spaces, which is why many architecture schools offer study-abroad courses in Europe to offer students first-hand information. In some instances, however, even a field trip will not offer the opportunity to visualize the original buildings because they have been ruined by time or have been remodeled or changed in some way. With advances in information technology, these barriers

can be overcome.

One such advance is virtual reality (VR) technology. VR represents a revolutionary way of interacting with computers. The synthetic Cave Automatic Virtual Environment (CAVE) provides an immersive experience in which images can be visualized in full scale and viewers can navigate and project themselves into the atmosphere to create the perception of being in those surroundings. To take advantage of this high-tech development and to apply information technology in teaching, this project combines information technology and the C2 virtual reality system (the second generation of the CAVE) to build an interactive VR environment for perceiving architecture. Inside this virtual environment, buildings that existed in the past but have since been destroyed or altered can be visualized in full scale in their original form, overcoming the limitations of time and space.

Using VR to see numerous buildings in different locations around the world, this research has created a new tool for teaching architectural history. Viewers can experience the changes in architectural forms over time and across geographic boundaries without having to visit the actual sites or piece together old drawings and texts. In this way, a virtual library is created. This virtual library consists of significant buildings of Western architecture in their original or intended forms. Seven buildings representing seven major historical periods are completed at present. They include Egyptian (Mortuary Temple of Queen Hatshepsut), Greek (Parthenon), Roman (Pantheon), Romanesque (Speyer Cathedral), Gothic (Notre Dame Cathedral), Renaissance (Tempietto), and Modern (Des Moines Art Center). The final product is a three-dimensional model with animation that creates the psychological sensations of "immersion" in the environment, allowing viewers to perceive each building in full scale. The sensations are extremely convincing and much more informative than two-dimensional images.

2. Methods

Two fundamental methods were applied in the process of modeling the seven buildings. The first, termed the solid geometry method, used working drawings as guides and utilized a computer modeler to construct solid models. Each object was modeled by measuring exact dimensions on drawings. After all the geometry of objects was completed, major pieces of textures and colors were applied from still images onto the surfaces of each object. This method generated accurate geometry of the model but was consumed an enormous amount of memory as thousands of polygons were created. Consequently, it took a long time for the CPU to process rendering and animation.

The second method involved importing the scanned floor plan into the modeler and matching the plan with the section and elevation drawings to achieve accuracy. Geometries then could be modeled three dimensionally by extruding objects. The form of the objects could be very schematic with as few polygon as possible. Afterward, details were texture mapped from scanned images from photos to create an illusion of realism. For instance, the number of the polygon representing a circular column can be reduced to eight sides and texture mapped with a photo image to create the illusion of a round column. This method is termed the mapping method. Models generated by this method have fewer polygons and smaller file sizes, which allows faster running time than the models generated by the solid geometry method. The Pantheon model was created by this method, whereas the Tempietto and Matuary Temple were generated by the solid geometry method. Other four models were constructed by mixing the two methods.

All seven models were completed in Multigen, navigated through Performer, and transformed to C2 for CAVE display. The scanned images were photo-retouched in PhotoShop before being attached to the model. For the Internet version of the virtual library, all buildings were rendered to get still images, a minute-long movie of each building was created, and all models were simplified by reducing the number of polygons before converting them into VRML format for easy download and quick display on the Web.

3. Historic buildings of seven periods

The oldest building of the seven in the library is the Mortuary Temple of Queen Hatshepsut near Thebes, Egypt. Dated to 1570 BC, the Mortuary Temple is a remarkable piece of architecture. Sitting at the foot of a mountain cliff, it rises from one platform to another connected by a series of huge axial ramps. The temple, unique in its design, sits at the highest level at the base of the cliffs. It was selected as one of the major components of the library because it represents ancient Egyptian culture and currently is in ruins, so this provides an opportunity to view the structure as it originally appeared.

At this temple site, an axial avenue of sphinxes once ran from the Nile River to the foot of the first ramp. On the second ramp, the sphinxes were carved of red granite (Jordan, 1970). However, the sphinxes and the cedar trees originally planted on the terrace were not included in this reconstructed model. Incised figures and hieroglyphs on the walls of the second floor were scanned from drawings and texture mapped on the surfaces of the model. Architectural historian Edouard Naville (1895) has indicated that the entire building was at

one time covered in a white plaster to create the illusion that the temple was carved from a single, massive piece of stone. Rays from the sun would be reflected by the plaster and cause the building to shimmer and glow in an almost blinding white light. Based on this information, most of the walls in the model were given a light, sandstone-like texture. A few walls in the lower colonnade were textured to simulate the appearance of the stone pillars and columns before they were plastered over.

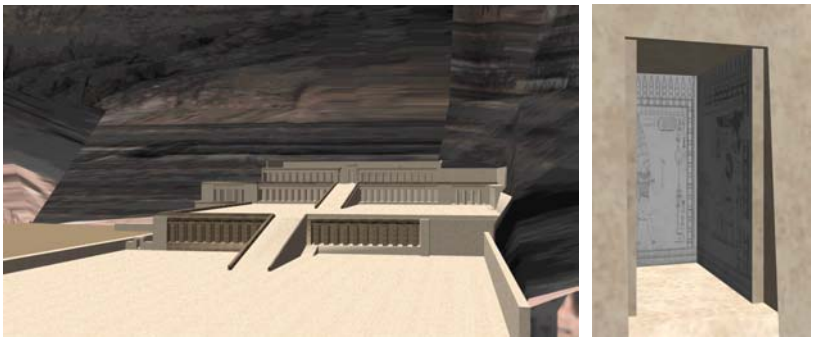

Figure 1. Egyptian architecture: the exterior and interior of the Mortuary Temple of Queen Hatshepsut.

The Parthenon in Athens, the most famous of Doric temples, was selected as the virtual library's example of Greek architecture. Dedicated to the goddess Athena Parthenos, patron goddess of the city, the temple was begun in 447 BC and completed in 432 BC. The building was badly damaged in an explosion in the 17th century and exists in a partly restored state today. This model restores the building to its 5th-century BC appearance.

In renovating the Parthenon to its original state for this virtual library, major sources of information used were from archaeological measured drawings and restoration drawings (Balanos, 1938). Based on the drawings, the center of the naos was set one step down from the surrounding aisle (Loviot, 1994). The ceiling, roofed by a beam structure, was assumed to be solid. Both the roof and ceiling were modeled as timber structures (Fletcher, 1987). The floor was marble and the surface reflections are shown on the model. Light enters from the eastern door. The statue of Athena was based on a reconstruction provided by the United Nations Educational, Scientific, and Cultural Organization. The appearance of the statue can be found on the organization's Web page at www.unesco.org/webworld/worlds/particon.htm.

Figure 2. Greek architecture: the exterior and interior of the Parthenon.

Roman architecture is represented by the Pantheon in Rome, Italy, a domed cylinder with an attached portico. The building, dated to 120 AD, was dedicated to the sun god and the deities of the seven planets. The spherical form symbolizes the cosmos, the opening in the center of the dome symbolizes the sun, and the bronze stars set in each coffer represent the stars of heaven (Fletcher, 1987). The dome sits on top of a rotunda with thick walls. The walls are hollowed out at their lower level by niches and recesses for altars or statues.

The Pantheon remains largely intact. This model attempts to recreate the original interior and exterior as well as the forum that once stood in front of the building (MacDonald, 1965; 1976). It is possible for visitors in this VR environment to enter the model through the main entrance from the forum and leave through the 27-foot opening at the top of the dome.

Figure 3. Roman architecture: the exterior and interior of the Pantheon.

Speyer Cathedral in Speyer, Germany, represents Romanesque architecture. Having gone through several reconstructions over the last 900 years due to

flooding and fire damage, the exterior and interior forms have been changed dramatically.

The original construction of the cathedral began in 1030 on the ruins of a much older temple. It was founded by Emperor Conrad II, who had intended the building as a burial place for himself and his descendants. This model reconstructs the original form built by the emperor with a wood truss roof and wooden ceiling. A series of 18 plan and section drawings of the cathedral in its current state with designations of previous construction were the basis for the model. These drawings were supplied by the cathedral architect.

The modeling process started with building the cathedral walls. Then a groin vault was created and repeatedly applied throughout the crypt and side aisles. On floor plans, it was found that the building is askew in several places (Gall, 1963). Because the differences are slight and virtually unnoticeable, the askew parts were ignored in this model. According to the information provided by historian Hans Kubach (1976) the area of interment within the nave was enclosed, but probably not until the time of Henry III or Henry IV.

The textures of the building materials were scanned from photo images and mapped to the model (King, 1868). For instance, the color and materials of the nave's piers were taken from a photo of the side aisle. The plaster-like texture surrounding the windows along the side aisle was copied from a postcard image of the crypt. Much of this building is more textured in the model as a way to delineate differences in all of the articulations along the walls and engaged columns.

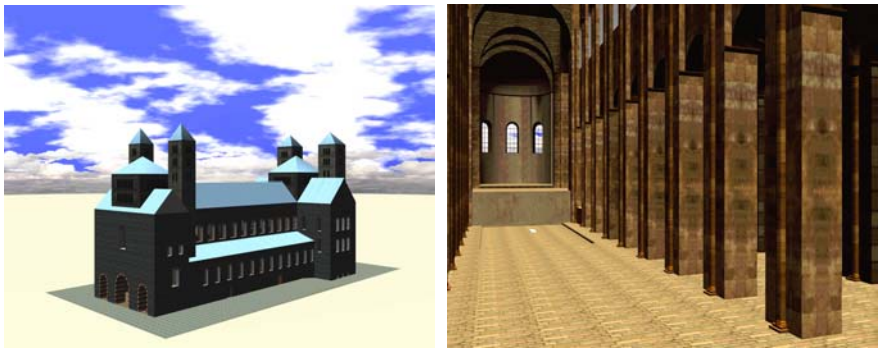

Figure 4. Romanesque architecture: the exterior and interior of the Speyer Cathedral.

Notre-Dame Cathedral in Paris, France, represents Gothic architecture. The challenge of this project was to reconstruct its original, 12th-century state (Bottineau, 1967; Mark, 1990). The upper part of the nave walls in the 12th century had two layers of clerestory windows and triforium (blind story). Because of the low level of light reaching the nave floor and problems with wind

loads, the upper nave wall was later remodeled. The triforium was eliminated and the clerestory enlarged downward in its place. The appearance of the building at this time was much "less Gothic" when compared to the current landmark, a product of 19th-century restoration.

During modeling, much use was made of the sketches and notes by Viollet-le-Duc, who was responsible for the 19th-century restorations and additions that transformed the building into what it is today. By far, the most beneficial reference used in the process of modeling Notre-Dame was *Notre-Dame de Paris* by Marcel Aubert (1928). Although many key features of the building have changed since the 12th century, the use of photos in Aubert's book provided the foundation for creating textures representative of the building in its original form.

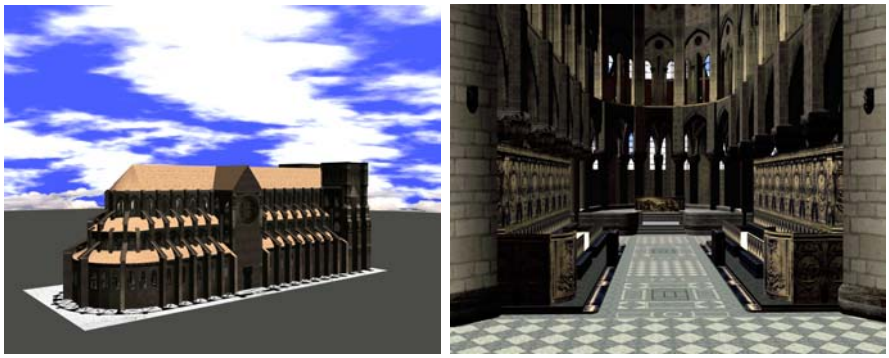

Figure 5. Gothic architecture: the exterior and interior of the Notre-Dame Cathedral.

Renaissance architecture is represented by the small shrine of the Tempietto in Rome, Italy. The Tempietto was built by Bramante in about 1502 on the supposed site of the crucifixion of St. Peter. The focus of this model was to recreate the unbuilt circular courtyard which was to surround the Tempietto. Information was based on the reconstruction drawings of the courtyard done by Portoghesi (1972) and Serlio's plan drawing. The Tempietto and its courtyard, based on classical architecture and a concern for proportion, balance, and gravitas, represent the qualities of the High Renaissance.

The process of modeling the Tempietto was drastically simplified by the building's symmetrical shape, which allowed the modeler to revolve surfaces and create a shell that would become the basic shape of the structure. Details including the metopes, triglyphs, and interior plaster were texture mapped to show trivia (Letarouilly, 1928; Furnari, 1995). The geometry that makes up the Tempietto and courtyard is very schematic, thus enabling detailed texture mapping to create the illusion of three-dimensional elements.

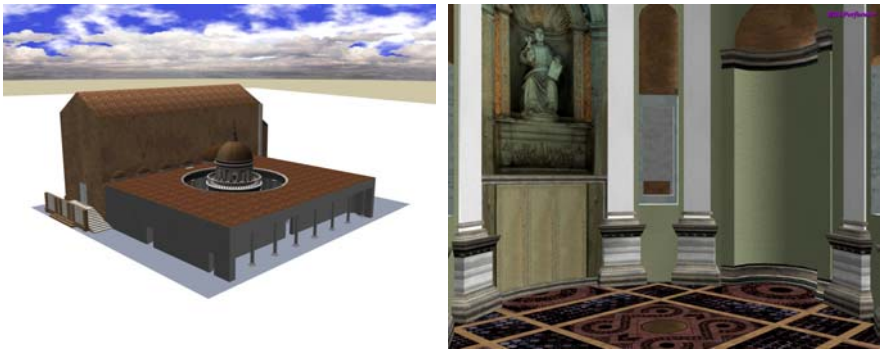

Figure 6. Renaissance architecture: the exterior and interior of the Tempietto.

The Des Moines Art Center in Des Moines, Iowa, represents Modern architecture. Located in the city's Greenwood Park, the art center was designed by Eliel Saarinen in 1945, with additions by I. M. Pei in 1968 and Richard Meier in 1985. Each architect's design represents a period of contemporary architecture. This model reconstructs the original phase designed by Saarinen, who is an example of the first generation of the Modern architects.

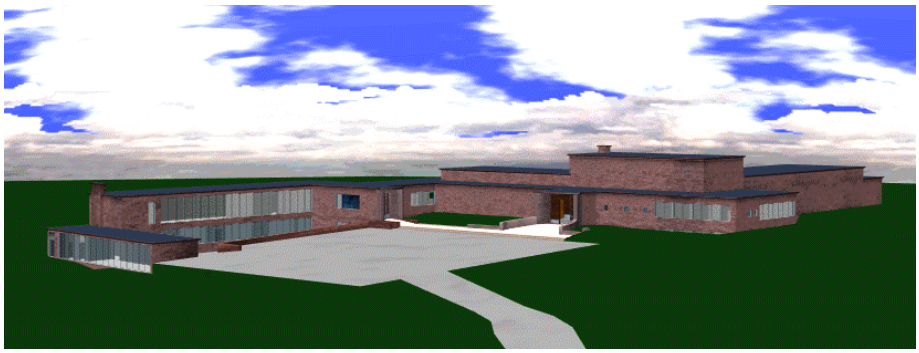

Figure 7. Modern architecture: the exterior of the Des Moines Art Center.

Saarinen's original design consisted of a U-shaped museum of foyer, galleries, an auditorium, and a straight educational wing off one end of the U consisting of classrooms and studios. The museum courtyard looked south to the existing Rose Garden and its pylons of lannon stone, the material used to clad the building. Saarinen's initial design is intact except for the auditorium, which was converted into exhibition galleries when a new auditorium was built in the Pei addition. Information used to construct this model was drawn from the original working drawings done in 1945. Colors and textures were applied based on current photos taken on site.

5. Conclusions

At present, all the architectonic components of each building in the project have been completed, and the virtual library already has been visited by students, faculty, and practitioners. These VR reconstructions also have been captured to provide access by viewers via the World Wide Web. Web users are able to view still images, watch a guided movie tour of each building, and navigate the building models using VRML. Additional information on this virtual library can be seen on the Web at http://archvr.design.iastate.edu/miller.

The main advantage of this library is that it provides immediate visualization of famous buildings in various countries. This provides viewers with an instant perception of the differences in colors and materials used on different sites, and the changes in spatial proportion of forms associated with the cultural beliefs at different periods in time. It is a valuable new tool for teaching architectural history, as it allows viewers to experience various historic buildings and periods in a much fuller way than through text, photos and drawings alone.

Additional efforts to reconstruct the surrounding landscape and "plant" specified trees are needed to restore the geographic character of each building in the library. For example, in the Des Moines Art Center model, it is necessary to put trees on the exterior and to exhibit some art works inside the building. Then its "art center character" will be clearly expressed and comprehended. Demonstrating the effect of light and shadows in and around buildings at various times of the day is also important to enrich the sense of realism.

Similar methods of constructing this virtual library can be applied on workstation and visualized through head mounted display (HMD) to provide the same VR experience. For instance, utilizing solid modeling to construct the model, applying texture mapping to the faces, and importing the model into a VR workstation setting can achieve similar immersive results as in C2. Thus, it is feasible for a design school to install less expensive VR equipment and start a visual exploration to get the same effect as implementing VR in the synthetic environment. By the same token, VR technology is also valuable for the fields of archaeology and social studies to reconstruct historical objects, hidden figures, underground buildings and lost cities as tools for visualization and perception by students and practitioners alike.

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