3D Digitized Romanesque Ermita
Iglesia de Nuestra Señora de la Anunciada in Virtual Reality

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“3D Digitized Romanesque Ermita in Virtual Reality” is a digital exploration of the historical, architectural, and cultural significance of a medieval Romanesque church in Valladolid, Spain. In this project, I recreate Iglesia de Nuestra Señora de la Anunciada, a reconstructed Catholic monastery that I frequently visited with my grandfather as a child in Spain. A digital replica of the church, produced by photogrammetry in the summer of 2014, has been created in a virtual environment and is experienced through immersive technologies. The use of a head-mounted display is a wearable device in which users view environments three dimensionally, while a Qualisys motion tracking system allows users to physically walk through the virtual world. Additionally, this project explores the potential for the use of virtual reality as a learning tool in classroom and museum settings.
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Each summer of my childhood, I visited the Basque and central regions of Spain to spend time with my Spanish relatives. During these trips, my grandfather, abuelo Laureano, took me on day-long excursions into various nature reserves in the wilderness of Castile and León. While exploring the canyons of Río Lobos and the Alpine juniper forests of Soria, which were thrilling, the most exciting aspect of these trips would be the discovery of hidden ermitas.

Ermitas are isolated rural churches, buried within natural environments. As we walked toward these churches, my grandfather would explain in depth the historical and cultural importance of ermitas in Spain. Ermitas, or hermitages, were the dwelling place of Catholic holy men from the Medieval times who lived in complete isolation, dedicating their lives to prayer, contemplation, and the study of scripture.\(^1\) Leftover edifices from the early Medieval times, these buildings and their unique history were a great fascination that I shared with my grandfather.

While studying Creative Technologies at Virginia Tech and 3D Digitization at the Smithsonian’s National Museum of Natural History, I became interested in the potential of using digitization and virtual reality as educational tools. I quickly began to design a pipeline, for my MFA thesis project, by which I could digitally reproduce an environment that holds both personal and historical significance; the ermita La Iglesia de Nuestra Señora de la Anunciada de Urueña. In order to recreate this environment I planned to achieve an accurate model of the edifice through photogrammetry, a method in which I was trained during an internship at The Smithsonian’s 3DX Digitization Lab. In June of 2014, the day after my internship was completed, I flew to Spain and ventured to the isolated town of Urueña in the region of Valladolid. Outside of this Medieval town is the ermita Nuestra Señora, a location I vividly remember visiting with my grandfather. After taking over five hundred images for photogrammetry, I began to process the images and build a 3D virtual environment for the church.
The ermita “Nuestra Señora de la Anunciada” is a Lombard Romanesque church built in the 11th century with the remaining materials of a Mozarabic monastery. The monastery, known as San Pedro de Cubillas, was destroyed by the Moors during the previous century and reconstructed into this Catholic hermitage by the commission of Princess Sancha of Urgel.[1] Sometimes mistaken as Islamic or Arabic, the Mozarabes were the remaining Christians living under Islam and paying a religious tax called Jizya. By the time the Castilian King Alfonso VII completed the construction of the ermita, the Moors had been defeated and retreated to the south of the Iberian peninsula.[2] From its construction in the XI century to the small Neo-Classic addition (XVIII century) in the back of the building, a continuous lineage of holy men lived in solitude on the grounds of the church as recluses. [3] This eremitic existence was a model for Christian monasticism, a life of renunciation. Anchorites were known in Ancient Greek as “ones who have retired from the world” in order to pursue a prayer-oriented life apart from secular society.[3]

Two primary factors led to the construction of these small hermitages in Spain. The first being the realization that the world was not ending on December 31, 999, as was widely believed. In order to celebrate and express appreciation to God, the Catholic monarchy of the time commissioned the building of many churches. The second factor was the religious fervor around the Camino de Santiago, a place of pilgrimage to Galicia to visit the alleged grave of one of Jesus’ disciples: Saint James.[1] From France, Flanders, Germany, and Italy, thousands of devotees walked an established path through Western Europe in order to reach the cathedral of Santiago de Compostela, located in the Northwestern corner of the Iberian Peninsula. Many ermitas were strategically constructed close to the path of Saint James.[1] Ermitas such as this one, Nuestra Señora de la Anunciada, were built with remaining materials from the Mozarabic monastery, as well as from elements surrounding the church.[2] The color, texture, and stone composition blend in notably well with the natural surroundings. It is not uncommon for hikers to come across semiabandoned ermitas deep in the canyons and forests of Northern Spain, slowly becoming reclaimed by the woods.

Once the setting for Iberian Pagan celebrations, many of these small churches still are the sites for annual celebrations known as romerías. The romería of this particular church is held on March 25th, the Day of the Annunciation--one of the Twelve Great Feasts celebrated in the Catholic calendar. The word “romería” originally refers to “romeros”, the people who took long trips to Rome, the ultimate destination of medieval pilgrimages.[1] During the romería today residents of nearby Urueña travel to the ermita to enjoy elaborate feasts, drink wine, and dance in celebration of the annunciation of Mary.[1]

Situated in the Duero Basin, this ermita is located in the high plane of the Valladolid province, right at the center of the north plateau called la Meseta. The stone makeup of The Church of Our Lady of the Annunciation was made of the abundant limestone and granite in this region.[2] The church was built in the Ashlar stone masonry unit, which, unlike polygonal or rubble masonry, contains smoothed and meticulously organized cubic units.[2] The ermita was built less than two miles from the beautifully walled town of Urueña. This wall was erected during the war between the medieval Christian kingdoms, Leon and Castile. Later united into one, Castile came to exist as a separatist region of Leon. Soon after the construction of the ermita both kingdoms became one, Castilla-León.[4]
While Urueña’s ermita contains traces of materials and features from the neoclassic period, its Romanesque aesthetic has remained unchanged. The immigration of Catalan workers to Valladolid greatly influenced the region’s architecture. \[1\] As a result, the Iglesia de Nuestra Señora de la Anunciada was constructed in the style adopted by Catalonians, the Lombardan style of Romanesque architecture. Primary Lombardan architectural features include both internal and external pilasters, vertical bands carved into the walls that create an elongated appearance. \[2\] Narrow windows of early the Romanesque style appear throughout the edifice, providing a reduced light source within the chapel. Additionally, ornamental blind arches called Lombard bands of are decoratively placed along the building’s exterior. \[2\]

The overall architectural form of the ermita was built according to the cross design with the Roman basilica as a basis. \[3\] The portal leads into the longer end of the cross, called the main nave, a barrel vault corridor ending in a XVII century Baroque altar. \[4\] The vertical ends of this cross formation, also known as the patibulum, form the projecting transepts which contain additional seating space. \[5\] At the intersection of the cross formation is the crossing and directly above this is a dome-like hemispherical structure called the cupola. \[5\]

**Figure 5.1:**
Above: Simplified Romanesque interior of the ermita. Below: Closeup of the XVII addition of a Baroque altar within the church. (Both images provided by: http://www.provinciadevalladolid.com)

**Figure 5.2:**

Romanesque churches of this style typically have internal Corinthian based columns with decorative capitals and jambs. However, this particular ermita is limited in complexity and contains wide, elegant piers. The entryway, or portal, faces the west towards Jerusalem. On the sides of the interior walls are the pilasters, rectangular columns protruding from those walls that appear to be supportive columns.

At the east end of the portal is the ambulatory, a wide corridor which encircles a large rounded chancel, also known as a presbytery. The chancel is the structural site for the sanctuary’s focal point where the altar is also located. At the very end of the liturgical east of the church is the apse, a semicircular recess appearing as a semi-dome. Located tangentially to the apse are two protruding apsidal chapels, treated as secondary sanctuaries.

Below: The west end of the ermita facing Jerusalem. (Image by Emilia Munoz). Right: Illustrated diagrams of the interior and exterior of the ermita Nuestra Señora de la Anunciada de Urueña. (All images provided by: http://www.provinciadevalladolid.com/)
I traveled to the Valladolid region of northern Spain to digitize the ermita of Uruña Iglesia de la Señora de la Anunciada. During the previous month I received training at The Smithsonian’s National Museum of Natural History in the 3D Digitization Lab in the skill of photogrammetry and data processing in Geomagic and Artec software. Photogrammetry involves the procedural photographing of an object in which the measurements of surface point distances and RGB texture information are processed and combined to generate a 3D digital object. In order to preserve accurate texture information it was vital that I conduct the photogrammetry at precisely 6:30pm, the time of day in which there are the fewest shadows and most even lighting. (See image to the right).

It was necessary to photograph the church in a method by which the camera remained parallel to the surface of the edifice. I encircled the ermita thrice and altered the angle at which I captured the surface data during each round. In order to achieve the most complete point cloud, it was important that I capture each surface point at the straight-forward, upward, and downward angle. This presented a challenge as I was unable to capture the downward angle. This resulted in the exclusion of the roof data from the initial point-cloud. Within one hour I had taken over 500 photographs with a Canon DSLR and began to process this data in AutoRecap360.

Figure 6.1:
Above: photogrammetry method: http://fad.ensg.eu/moodle/file.php/316/moddata/scorm/152/res/Figure%2052.jpg
Below: Initial model produced by AutoRe-cap360. (Image by Emilia Muñoz)

Figure 6.2:

Figure 6.3:
Above: Nuestra Señora de la Anunciada de Uruña
(Image provided by http://www.provinciadevalladolid.com/turval-client/cm/gallery/vistas_monumentos/anunciada_web/index.html)
AutoRecap360 generated a complete model within 24 hours of processing. While this model contained accurate texture and geometry, AutoRecap360 created five texture maps. The multitude of texture maps made RGB information incompatible with the next step of the process; retopologizing in Zbrush. Upon my return to Virginia Tech in the fall of 2014, I reprocessed the photogrammetry data in Agisoft PhotoScan, generating a point cloud with a significantly higher level of detail and a single texture map. I manually modeled areas of detail after importing the high poly mesh into Maya in order to delete excess terrain data. The cleaned model was imported into Zbrush in order to reduce the poly count through the process of retopologizing. Following its retopolization I exported the OBJ and created UV maps in HeadUS, allowing for a greatly improved texture. In Zbrush, I sculpted, Zremeshed and Dynameshed the 3D model, improving the overall exterior geometry. With the addition of high quality UV maps both the geometry detail and texture were projected onto the lower poly model. In Maya I modeled the ceramic Spanish style roof tiles. The total number of individually textured tiles exceeded five hundred. The roof model and surrounding terrain and vegetation assets, were based upon Google aerial view images of Urueña.
The method of photogrammetry created accurate geometry of the exterior of Iglesia de la Señora de la Anunciada, I was unable to access the interior to capture photographic data. With the use of blueprints of the building found online, along with the few existing photographs of the interior online, I modeled the inside in Cinema 4D and Maya. Initially laying out the traditional Romanesque cross plan, I extended the design to include the apse, cupola, chapel, and chancel. As the interior of the church is not available to be seen by the public, the ability to access the space through virtual reality is especially important. Additional assets such as minimalist pews, a rug, and candles for ambient lighting were included to provide a sense of environment and scale. A simple white, lambert material covers the interior, allowing the traditional lighting scheme to provide the primary sense of ambiance. Prior to lighting baking onto the UV’s in Cinema 4D I applied Ambient Occlusion and Global Illumination to the scene which allowed the lighting particles to bounce realistically onto interior geometry.

The exterior, interior, interior assets, and environmental assets were combined into one FBX file and imported into Unity. This is the final program through which the virtual reality scene would be completed and the Oculus Rift would function. The scene was lit in Unity using Physical Sky and a skybox added to contribute to the ambiance of the virtual world.
Once the Spanish 3D environment was finalized its application to virtual reality in Virginia Tech’s Cube proved to be a tremendous undertaking. This innovative process had not yet been pioneered. The Cube contains 24 cameras that track the motion of a rigid body form connected to the head mounted display. This tracking allows participants to move through the virtual world by walking, creating a more immersive and interactive experience. As the Director of ICAT, Ben Knapp states “The beauty of the space is that you now move through a virtual world by walking”. Virginia The Oculus-to-Cube setup involved ten primary steps, each of which included multiple sub-tasks.

The first two steps lead to the ability to build game scenes in Unity for the Oculus while the remaining eight steps explain connectivity between the HMD and motion tracking system in the Cube. This process began with accessing the Unity Integration 4 package that allows the main camera within Unity to be replaced with the OVG Camera Rig, creating the a split screen build for the Oculus DK2. The second generation Oculus contains low-latency positional tracking that requires disabling for The Cube’s motion tracking system to function properly. In order to disable the DK2 internal tracking and enable The Cube’s system the OVR Camera Rig Script was modified in Mono Script.
Following the completion of the virtual world, I organized a panel of five professors to experience, reflect on, and discuss the project. Professors in the School of Visual Arts, Creative Technologies department, included Thomas Tucker, Dr. Simone Paterson, and Dane Webster. The panel also included Professor Todd Ogle of Instructional Technology and David Hicks, Professor of History and Social Science Education. Following the virtual reality experience, the panel members provided feedback on the positive and negative aspects of the project. The members generally agreed on feeling a sense of PI, or Place Illusion, and sensations of immersion. However, the fact the laptop was tethered to the HMD was a main factor in breaking the participant’s sense of PI. The scale of the church was slightly decreased to fit within the dimensions of the Cube, having an additional impact on sense of immersion. As Dr. Paterson stated, “What was dislocating was how fast you could move through the space.” This sense of scale, the presence of the Cube model in the scene, and the tethering of the laptop were the primary factors limiting PI. Professor Hicks brought to light the importance of various “typologies of people” in virtual space. While he explored the environment quickly, individuals with other personality types may interact more slowly and with more hesitance. Professor Tucker discussed the potential of incorporating augmented reality in the scene as a means for displaying additional information or maps to guide the user. When questioned about the use of coins as information points, Professor Webster noted the change of transparency to highlight architecture. He stated, “That’s what is really effective about seeing things in a way that we previously could not”. On the subject of VR as an educational tool within a classroom setting, Professor Ogle noted “We are now starting to look at sites as artifacts”. These digital representations, or artifacts of historical environments are now capable of being experienced immersively.

Figure 10.1: Members of the expert review panel experience the virtual reality environment.


