Virtual Reconstruction of the 4th Century Ancient Synagogue of Susiya

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Abstract

Virtual reconstruction is a method of digitally reconstructing an object and then rendering the images as they are encountered in real time. In other words, in a virtually reconstructed New York City using real time technology, one can "fly" or navigate through the model anywhere and everywhere because the computer renders the images as one flies instead of having a set path.

The goal of this project is to virtually re-create the ancient synagogue of Susiya, located in the southern Hebron Hills of Israel. The synagogue dates from the 4th to the 7th Centuries CE and was used during the time the Romans ruled Israel. This site was selected because it is a magnificent synagogue in pristine condition with extensive excavation data.

1 Introduction

The ancient synagogue of Susiya, dating from the 4th to the 7th Centuries CE, is located in Khirbet Susiya, situated 750 meters (about 2,250 feet) above sea level in the Southern Hebron Mountains of Israel. The remains of the synagogue and the site were excavated between 1969 and 1972 by the late Shmaria Guttman. The archeologists who excavated the site assume that the synagogue was in use continuously by the Jewish residents of Susiya between the 4th Century CE to the 7th Century CE, when it was deserted and destroyed, and a mosque was built on the site.[1]

1.a Introduction- Technological

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[1] AmitDavidThe Synagogues of Hurbat MA'on and Hurbat 'Anim and the Jewish Settlement in Southern Hebron Hills. Jerusalem, Senta of the Hebrew University of Jerusalem, 2003, pp.68-83.

Virtual reality technology has been used for the entertainment of gamers for quite some time. Recently, this technology has been incorporated for the purpose of urban simulation. The application of virtual reality in urban simulation projects ranges from the planning and design of cities, to emergency action plans, and even to the reconstruction of ancient sites. The Urban Simulation Team at UCLA demonstrated a current use of this technology by virtually reconstructing the entire Los Angeles Basin area. These UCLA researchers believe that this technology provides a valuable option in viewing complex designs and plans.[2] For the past ten years, researchers at Aristotle University of Thessaloniki, Greece, have been converting archeological documentation from written data to three dimensional data reconstruction which allows the end user to navigate through the data, create connections between found objects and their contexts, and discover misinterpretations created either by years of aging or by field work.[3] Dr. Andrew Anderson of the Department of Archaeology and Anthropology of Cambridge University believes that virtual reconstruction aids understanding by providing education and scientific visualizations of ancient sites.[4]

Choosing a three dimensional virtual reality real time rendering engine to use in urban simulation is a very demanding and crucial decision for a researcher. The basic tool for any virtual reconstruction engine is Global Information System, or GIS. GIS creates an accurate

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[2] Urban Simulation TeamUrban Simulation Team at UCLA. *Urban Simulation Team*. [Online][Cited: 13 October 2008.]htttp://www.ust.ucla.edu/.

[3] *A 3D workflow for archaeological intra-site research using GIS*. KatsianisMarkoset al.2007, Journal of Archaeological Science, pp.665-667.

[4] *Comnputer Games and ARchaeological Reconstruction: The Low Cost VR*. AndersonMichaelAndrew2004, CAA, pp.521-524.

perception of landscape, without which the reconstruction cannot exist.[5] A fundamental question for computer rendering is how to create an inexpensive yet realistic reconstruction that can run on simple computers. According to the researchers from the Institute of Geodesy and Photogrammetry who excavated the geoglyphs of Nasca, Peru, it takes hours of testing and work with each of the many different forms of three dimensional modeling software to asses which modeling program is right for each specific project.[6]

Many different reconstruction engines were considered for this research project. Initially, the project was to be reconstructed using *Blender*, a Dutch open source three dimensional content creation software. After experimentation with *Blender*, many of the limitations of this software were experienced, forcing alternative reconstruction engines to be considered. 3D Studio Max, a three dimensional modeling, animation, and rendering software created by Autodesk Media and Entertainment, also the creators of the legendary AutoCAD, provided much more powerful modeling tools. 3D Studio Max has been used in the creation of movies such as *I Robot*, *X-Men*, and the *Hulk*, and is estimated to be used in the creation of 85-90 percent of recently created video games.[7] 3D Studio Max also provides the superior advantage of creating "ultimate high-resolution quality for high-speed compositing, advanced graphics, and interactive client-driven design".[8] Rendering gaming engines provide superior interface and graphic quality, with the added advantage of operating on every day computers, unlike some rendering programs which require super computers to operate. The final choice for a rendering engine for this project

[5] *A 3D workflow for archaeological intra-site research using GIS*. KatsianisMarkoset al.2007, Journal of Archaeological Science, pp.665-667.

[6] *Visualisation and GIS-based Analysis of the Nasca Geoglyphs*. GrunArmin, SauerbierMartin, LambersKarsten2003, The Digital heritage of archaeology--proceedings of the 30th CAA Conference.

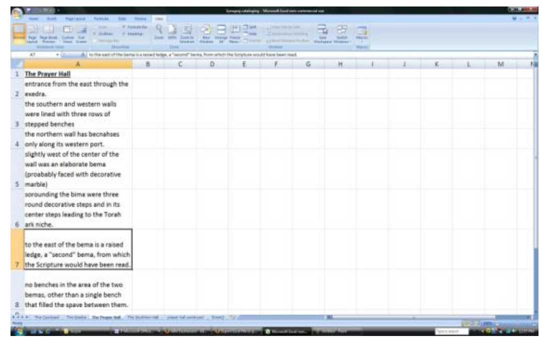
[7] http://usa.autodesk.com/industries/media-entertainment

[8] http://usa.autodesk.com/industries/media-entertainment

was between *CrytekEngine2* and _______. After testing both software systems, the choice eventually became clear: ____ was chosen due to its decidedly more realistic rendering capabilities.

1.b Introduction- Archeological

The scope of archeological information relating to the Susyia excavations includes excavation measurements, history, and digital aids. Archeologists produce specific measurements for every small detail of an archeological excavation. Charts from different publications were assembled to create the outlines and measurements of the various parts of the building for the reconstruction. For instance, measurements for the prayer hall, just a small part of the synagogue complex, are represented in Chart A which describes the object and its measurements.[9]



	A
1	The Prayer Hall
2	entrance from the east through the exedra.
3	the southern and western walls were lined with three rows of stepped benches
4	the northern wall has becnahses only along its western port.
5	slightly west of the center of the wall was an elaborate bema (proabably faced with decorative marble)
6	sorounding the bima were three round decorative steps and in its center steps leading to the Torah ark niche.
7	to the east of the bema is a raised ledge, a "second" bema, from which the Scripture would have been read.
8	no benches in the area of the two bemas, other than a single bench that filled the spave between them.

Chart A

Visual aids such as images A, B, and C below are being used for this project. These images are used as visual aids to help make the reconstruction as realistic as possible. The images were also utilized as layering surfaces in the actual reconstruction model. This ensures a guarantee of complete matching.

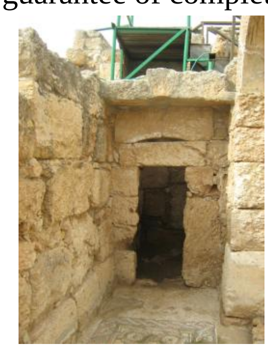


Image A

Image B

Image C

[9] NegevAvraham, YeivinZeev Susiya, Khirbet. SternEphraim book auth.. *THE NEW ENCYCLOPEDIA OF ARCHAEOLOGICAL EXCAVATIONS IN THE HOLY LAND*. Jerusalem, The Israel Exploration Society, Vol. 4, pp.1415-1421.

2 Research Question and Development

This research project's primary goal is to reconstruct the ancient synagogue of Susyia, Israel, using real time virtual reality technology. This reconstruction was completed using 3D StudioMax. The reconstruction was created on a user-friendly interface which can operate at personal leisure.

3 Topography/Terrain

The first step of the three dimensional virtual reconstruction of the ancient synagogue of Susiya, Israel was the construction of the terrain. For this task the researcher decided to use the same program that was used to reconstruct the synagogue complex itself. This was decided due to a concern with compatibility. Many different programs, specifically used for reconstruction of topography could have been used, but the researcher was concerned about the importation into 3D Studio Max, and then the importation to _____.

To reconstruct the topography, the researcher used Image D. A plane was created to the exact size of Image D (719X508). Image D was created as a Bitmap material, layered onto the plane, and then frozen at coordinates 0, 0, 0. Even with the plane being the exact size of the image, the researcher ran into problems with pixilation. Some parts of the contour lines were not perfectly visible, and many curves were squared off. Some of the smaller hills were represented as a small square rather than the circle that they truly are. To bypass this, the Driver in 3D Studio Max was changed from DirectX 9.0 to DirectX 10.0. The Driver was then configured so that under "Text Lookup", the selected field was changed from the pre-selected "Nearest" to "Anisotropic". Using Splines, Lines, the contour lines on Image A were traced. Once each line was created it was then

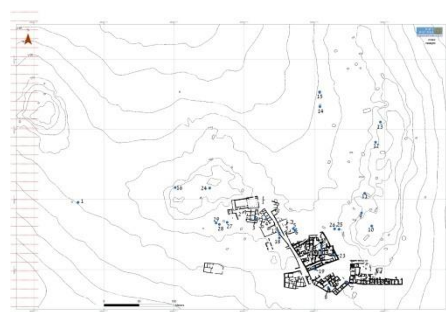


Image D

converted to an Editable Spline. This allowed the researcher to select an individual vertex, and

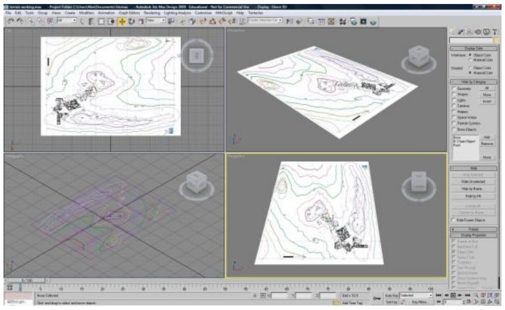


Image E

adjust any part of the line that did not match the contour line on Image A perfectly. Some parts of Image D that were not represented correctly in 3D Studio Max forced the researcher to freehand some curves using the original image (not imported in 3D Studio Max) as a reference. Once the created line matched the contour line perfectly, the line was named after the height it represented. For example, a line that represented 750 meters above sea level was named "750". After naming the line, the researcher would then "freeze" the line so that it could not move out of place. This process was used to create each line until all the contour lines were covered with editable splines. Once all lines were covered (shown in Image E), all lines were unfrozen and moved along the Z axis to their proper heights. Using Geometry and Compound Objects the researcher was able to create a terrain from the contour lines created. The created terrain is shown in Image F. The terrain was "separated" by color. Each 5 meters was represented by a different shade of green. The lowest level, 750, was a dark green, while the highest, 790, was white.

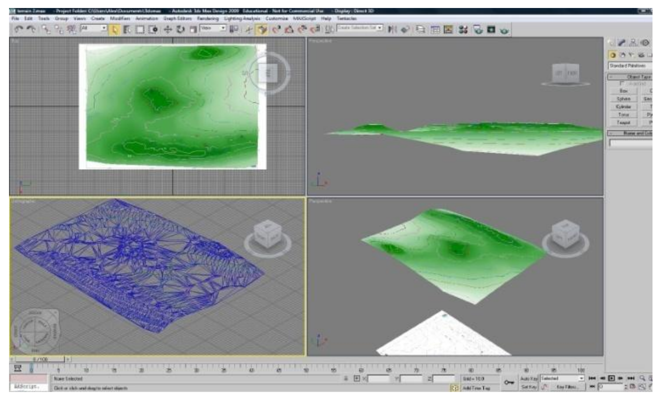


Image F

5 Modeling the Courtyard

Due to the fact that work was being done using editable meshes and splines, it was not easy to set the size of an object to its exact measurements. To overcome this, measuring boxes were used. One non-editable mesh box was created, meaning its size could easily be changed. For every object created in the reconstruction, a measuring box was created beside or on top of it, so that the object would be the correct size. Once the measuring box was the correct size and placed beside the object, its edges were extruded to match the correct size.

For all parts of the courtyard, a three dimensional form of blueprints was created. These blueprints represented the courtyard in its entirety, but were only extruded minimally in the Z direction. Once the courtyard was completed, the walls, columns, and arches were extruded to their correct height.

The first step in creating the courtyard was to create four very basic walls that would later be transformed into the walls of the courtyard. Each wall was only created to a height of .25 M so that the inside of each room could be easily worked on. Once the room was completed, the walls were extended to their correct height. The eastern and southern walls were both created to 20.8 M while the northern and southern walls were 22.0 M. The entire courtyard measured 20.8M X 22.0M. The next step was to create the foundations for the arches and columns that encompassed the interior of the courtyard. Both the eastern and western sides of the courtyard had matching arches, so only one set had to be created, cloned, and moved to the correct position on the other side. The researcher began working on the western arches. Due to much debate over which method would be best to create the arch, and the need to create the three dimensional blueprint before starting the aesthetics work, each column was represented by a small box. Once all “boxes” were set in their correct places, where an arch would be connected to the floor, the arch itself was then created. Each box was extended to a height of 2.739M. This was an arbitrary number that could easily be changed later. Between each set of two columns, three one dimensional arches were created out of lines. A box was created above the three columns on the north end of the courtyard. The three columns, northern wall, and the new box were all isolated and edited in isolation mode. This box was divided into 250 X 150 editable boxes. The box was

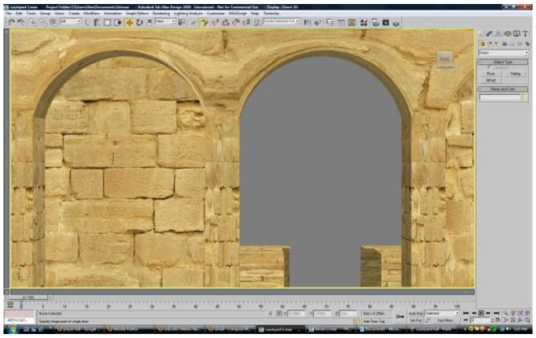


Image G

attached to the northern wall (Images G and H). Each box was then extruded to perfectly match the arch that was created by the previous line. Image F represents the north end of the building with three completed arches.

Once the columns were completed, the stairs leading to the prayer hall were created. There are four stairs, each .25 meters tall ascending to a height of 1 meter. At this stage, the courtyard was roughly done. All that remained to be completed was the extension of the walls and columns. Once this was accomplished, the courtyard was finished except for the textures.

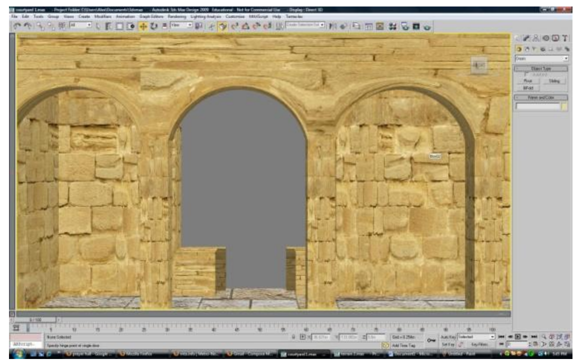


Image H

6 Modeling the Eastern Wing

The modeler then moved to the western end of the building, creating the three dimensional blueprints for the prayer hall and tangent hallways. To effectively make use of time, the model was not created in multiple files, but rather in isolation mode. This made it difficult to operate around some of the objects, but overall was beneficial for the model. The floor for the western wing was created out of a simple 1 meter wide by1 meter long by 1 meter high box. This was an easy way to establish the elevation of the western wing at a height of 1 meter. The prayer hall wall facing Jerusalem was double the thickness of the other walls. The Torah cabinet was then "carved" out of the wall by moving the 100 by 100 by 100 boxes that created the editable poly wall.

So that modeling would be easier because of more entry points, all doors into the prayer hall and the adjacent halls were created. This included the three doors leading into the prayer hall from the east, the door leading into the southern hall from the east, the door leading to the prayer hall from the southern hall, and the door separating the two southern halls in the western wing. The prayer hall was isolated, and work began on the benches. Three sets of benches were created, one measuring 8M X 1M X 1M, another measuring 16M X 1M X 1M, and the third measuring 5M X 1M X 1M.

After building the benches, the doors and roof were created. The roof was created out of an editable cube split into 100 X 100 X 100 cubes. Cubes were deleted and then vertexes were moved. Image G shows the roof completed in isolation mode, and Image H shows the roof attached to the building. The doors were created the same way. Cubes were deleted from the wall to make room for a door. Once the door frame was created, doors were inserted.

7 Creating the Second Floor

Details about the second floor are very scarce. All that is known for sure is that above the western hall there was a second floor. Speculations were made that the second floor extended over the main prayer hall, but nothing is known for sure. For this reason, the model does not include the second story over the prayer hall. The stairs were created in the same exact manner as the other stairs in the model. Thirteen individual stairs were created that extend to the top of the western hall.

8 Texturing

Texturing is a crucial part to any virtual reconstruction. If not done correctly, no matter how precise and detailed the model may be, the final outcome can look sloppy and unprofessional. Much time was spent on texturing the model. The model’s texturing was completed using a process known as UV Texturing, also known as UV Mapping.

UV Mapping is a way of changing a 2D image into a 3D image. Image I shows a perfect example of UV Mapping. A 3 dimensional image (shown at the far left) is digitally "folded" to cover a 3D image. This allows a model to look as realistic as possible without having to make the modeler digitally cut and paste each separate side on to the 3D image. 3D Studio Max uses the following two formulas to obtain the (u,v) coordinates, similar to (x,y), and map the 2D image on a 3D object.

$$u = \sin\theta\cos\phi = \frac{x}{\sqrt{x^2 + y^2 + z^2}} \qquad v = \sin\theta\sin\phi = \frac{y}{\sqrt{x^2 + y^2 + z^2}}$$

In this model, JPEG images were used as UV Textures. To save memory space and processing time, a directory was created at //text/UV/ which helps all the UV Textures used in the model. The better the organization of files and directory, the quicker and better the model will render, due to a lack of need to search entire drives.

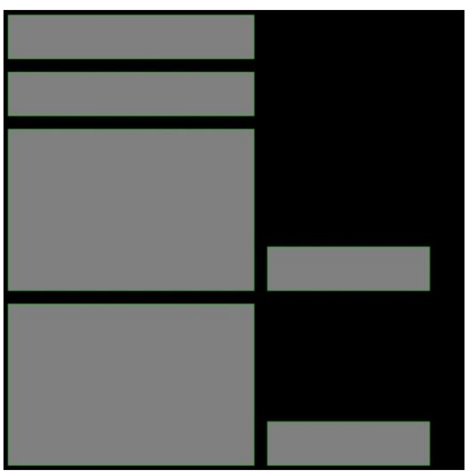


Image I

To save time, the model was manually devised into different models, so that the texturing process would be easier to complete rather than trying to change all the textures on one huge map. Once the UVW map was created, it was flattened and saved as a JPEG. The JPEG was then imported into Adobe Photoshop where the texture was applied. As demonstrated in image I, each gray box represents a side of the object that is being UVW Mapped. All sides were selected and deleted. This allowed for a transparent box for each side. A layer was created in Photoshop for each individual side of

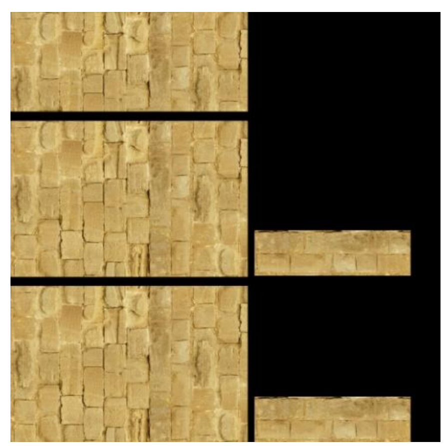


Image J

the object. The final Photoshop image is demonstrated in Image J.

In 3D Studio Max, the Unwrap UVW map was opened with object face selected. A bitmap background was selected, that being the Photoshoped .psd file. Almost all files matched perfectly, but one or two had to be edited slightly. Once the background was installed, the material editor was opened: color was set to 100%. The layering was then complete. Some walls were later taken into Photoshop to edit, so that the texturing did not look too similar to other walls (since the same original image was used).

9 Mosaics

At its height, the synagogue included a number of different mosaics:

> “Rembered be for good and for
> Bles[ing]
> The second of the week
> [year]
> Four thousa[nd]
> When the world was creat[ed]
> In it.
> Let there be pea[ce]”

In the southern end of the courtyard:

> “Remembered be for good the sanctity
> of my master and rabbi
> Isai the priest, the honorable, the
> "venerable", who made
> this mosaic and plastered
> its walls with lime,
> which he donated at a feast
> Rabbi Yohanan the priest, the
> venerable scribe
> his son. Peace on Israel!
> Amen!”

Even though the mosaics were not incorporated into the model, they are a very important part of the synagogue. It was debated whether to use the modern day image files of the existing mosaics as textures, however, this was not done because the images do not represent the mosaics as they were during the 4th and 5th Centuries. The mosaics were not initially included due to a concern to save processing time, but would be a decorative addition at a later date.

Conclusion

The final model represents the synagogue of Susiya, Israel as it was in use during the 4th and 5th Centuries CE. The model is the most accurate representation that was able to be created with the information available today. 3D Studio Max worked perfectly for all the necessary tasks. One benefit of 3D Studio Max is that all parts of the model could be created in this software. Nothing had to be completed using a different software. Since 3D Studio Max is a standard in this field, the rendering software worked perfectly and no adjustments had to be made with the importation into the rendering software. The texturing process could have been significantly simplified. Since it was the first reconstruction created by this modeler, a very long and tedious texturing method was used. This was to ensure detail and understanding of the process. For future models, UVW mapping will be used, but without the unwrapped modifier.

To save processing time, fewer vertexes should have been used. Each vertex being loaded takes more time for the software to render. The excessive number of vertexes was not necessary. The researcher was uncertain regarding the amount of detail that would be able to be created with fewer vertexes. Because of this, many extra vertexes were created that were subsequently not used.

The model's processing time is relatively fast, its accuracy is precise, and its aesthetics are appealing. Future work on this model could be done, including adding mosaics and text screens to guide users through the synagogue.

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