

Synagogue Modeling Project Report: a Multi-faceted Approach to 3D, Academic Modeling

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With the click of a button, my body is transported through time and space. A flicker of light catches my eye. I look up. Flames dance upon the plaster walls, casting eerie shadows on the mosaic floor upon which I stand. I am in a synagogue. An ancient synagogue. Yet at the same moment, in the same space, I am also standing in my office. I feel like I could reach out and touch the mosaic floor. As I try to do so, I notice another hand stretching forth, a hand that is stylized in the mosaic below me. It is the hand of God, reaching from the heavens to stay Abraham's sacrifice of Isaac. I am standing in the ancient synagogue of Beth Alpha on a mosaic scene depicting the Aqedah of Genesis 22. I get on my hands and knees to examine the scene more closely. Each tessera of the mosaic stands out more clearly as my eyes draw nearer to the floor. I can almost count each individual piece of stone. I begin to count, but a sound from another world snaps me back to reality. My phone is ringing.

I remove the virtual reality (VR) headset as my office comes back into focus. The light from the flicker of ancient oil lamps is overtaken by the luminescence of a lightbulb. I have removed myself from Beth Alpha but Beth Alpha has not yet left my memory. The distance between objects, the number of steps I traveled, and how the moonlight poured through the windows – these are some of the experiences I remember from my time exploring one of the 3D environments created for study with virtual reality.

1 Introduction

The production of 3D visualizations has vastly expanded beyond its original use by Boeing for airplane cockpit design in the 1960's.¹ Animation, architectural design, and engineering are a few of the occupations that have since adopted 3D toolsets for professional use. A modeler can produce a 3D visualization

¹ Dreher, Thomas, *History of Computer Art*, 2011, IASLonline, trans. to English 2015, ch. 4: <http://iasl.uni-muenchen.de/links/GCA_Indexe.html>, accessed on 10.04.19.

using a variety of software packages that range in cost from free to tens of thousands of dollars. After producing a model, a user can experience the 3D visualization digitally on a computer or tactilely through fabrication with 3D printing, laser cutting, or CNC routing.

Biblical scholars and archaeologists, too, have embraced 3D modeling for its usefulness in providing visualizations of the past. In 2009, Robert Cargill published one of the first 3D-modeling based biblical studies projects in which he detailed a methodology “for using digital modeling to test various archaeological reconstructions” of Khirbet Qumran, the site of the discovery of the Dead Sea Scrolls.² In addition to Cargill’s project, several archaeological teams excavating ancient sites throughout the Middle East have also used 3D technologies to record data in detail greater than photography allows.³

This article explores how 3D modeling addresses difficulties intrinsic to fields dealing with material culture through a survey of a recently completed Byzantine synagogue modeling project that produced scaled, virtual reality environments of the 4th–6th century CE synagogues of Beth Alpha, Hammath Tiberias, and Sepphoris.⁴ For each synagogue in the project, a series of the following visualizations were produced: (1) an accurately scaled photogrammetric model of the synagogue’s remains, (2) a high-definition, colorized image of the synagogue’s mosaic floor, and (3) a suggested 3D reconstruction of how the synagogue may have looked in antiquity in which a user can explore via a first-person avatar using either an internet-connected computer or a VR device such as the HTC Vive. In what follows, I will identify a series of problems

2 Cargill, Robert, *Qumran through (Real) Time*, vol. 1, in: Cargill, Robert, *Bible in Technology*, Piscataway, NJ: Georgia Press, 2009, 4.

3 Two recent examples of archaeological excavations using 3D toolsets are the Jezreel Valley Regional Project in Israel (PRINS, Adam, “3D Modeling for Archaeological Documentation: Using the JVRP Method to Record Archaeological Excavations with Millimeter-accuracy”: <<http://www.jezreelvalleyregionalproject.com/3d-modeling.html>>), accessed 21 March 2018 and the 'Ayn Gharandal Archaeological Project in Jordan ('Ayn Gharandal Archaeological Project: <<https://religion.utk.edu/gharandal/>>), accessed on 10.04.19.

4 These three synagogues were chosen due to the level of preservation of their mosaic floors. The Beth Alpha synagogue dates to the 6th c. CE; The Hammath Tiberias synagogue dates to the 4th c. CE; and the Sepphoris synagogue dates to the 5th c. CE. Please note that multiple synagogues were constructed on top of one another at Hammath Tiberias, but the synagogue I have modeled for my project is the “Severos Synagogue” from Stratum 11a of Moshe Dothan’s excavation. For the dating methodology of each synagogue, please see the following excavation reports: Sukenik, Eleazar L., *The Ancient Synagogue of Beth Alpha: An Account of the Excavations Conducted on Behalf of the Hebrew University, Jerusalem: From the Hebrew*, New York: G. Olms, 1975, 44, 52; Dothan, Moshe, *Hammath Tiberias I*, Jerusalem: Israel Exploration Society, 2000, 67; and Weiss, Zeev, *The Sepphoris Synagogue: Deciphering an Ancient Message through Its Archaeological and Socio-Historical Contexts*, Jerusalem: Israel Exploration Society, 2005, 38-39.

that 3D modeling allows researchers working with material culture to overcome, provide a survey of the methods used to generate models in the synagogue modeling project, and conclude with a presentation of the final synagogue modeling data.

2 The Problem: Accessibility, Scale, and Dimensionality

Many items of scholarly interest sit on display in museums, reside in archival storage, or lie underground due to the need to backfill or build above former archaeological sites. If a scholar wishes to access a certain object, he or she must travel to its place of residence to do so. If a scholar cannot travel or access the needed objects, he or she must resign to view photographs of the objects.

Using photographs as a basis for interpretation presents a unique set of challenges, two of which are the problem of scale and static dimensionality. Once a photograph is taken, its sense of scale is largely lost. Though many pictures of artifacts and archaeological sites contain scale bars, such attempts to indicate scale within a photo requires viewers to visualize the re-scaled objects by imagining their correct size.

Photographs are two-dimensional representations of a three-dimensional environment. A viewer cannot step into the scene of a photograph and look behind any objects in the foreground that obscure the background. This problem of static dimensionality is similar to that of scale. A photograph requires a viewer to imagine how the two-dimensional image would have looked in three dimensions.

The problems of accessibility, scale, and dimensionality also affect the study of ancient synagogues. Concerning accessibility, the synagogues of Beth Alpha, Hammath Tiberias, and Sepphoris are all located in the Galilee region of Israel. For those living outside of Israel, visits to the synagogue sites prove expensive and time consuming. In lieu of a site visit, if a scholar wishes to view photographs of the site, he or she must rely on archaeological publications. The synagogues of Beth Alpha, Hammath Tiberias, and Sepphoris each contain mosaic floors upon which exist paneled images of the binding of Isaac from Genesis 22, the zodiac, and the Jerusalem temple. Scholars interested in studying the mosaic floors must rely on black-and-white or piecemealed photographs of individual panels and drawings of each mosaic since few aerial photographs of the entirety of any of the mosaic floors exist.⁵

⁵ For a drawing of the Beth Alpha mosaic, see Sukenik, Eleazar I., *Beth Alpha*, Plate XXVII; for a drawing of the Hammath Tiberias mosaic, see Dothan, Moshe, *Hammath Tiberias*, 34-35; for a drawing of the Sepphoris mosaic, see Weiss, Zeev, *Sepphoris*, 57.

The lack of holistic aerial images of these synagogue mosaic floors is due in part to conservation efforts and technological limitations. In 1929, Eleazar Sukenik excavated the synagogue of Beth Alpha and after the mosaic floor was brought to light, conservators built a protective structure over the remains.⁶ The excavators of Beth Alpha took pictures of portions of the mosaic, but they did not take a photograph of the mosaic floor in its entirety.⁷ The synagogue at Hammath Tiberias was excavated by Moshe Dothan from 1961-1965, and excavators took a holistic photo of the mosaic floor, which was printed in black-and-white.⁸ In a volume detailing the more recently excavated ancient synagogue at Sepphoris, the authors provide a side-angled (i.e. not from above), low-resolution, excavation shot of the synagogue mosaic floor.⁹ While helpful, the excavation shot does not provide enough detail for a close analysis of the mosaic floor or the narratives contained therein. Like Beth Alpha, the conservators of the synagogues at Hammath Tiberias and Sepphoris built protective, roofed structures above the sites' archaeological remains, rendering any high-definition, modern aerial shots of the synagogues impossible.

3D modeling, however, allows for the generation of scaled and rectified aerial shots from within a 3D model, which can be generated and studied remotely once a model is produced. So even though the synagogue remains of Beth Alpha, Hammath Tiberias, and Sepphoris sit under protective structures, with 3D modeling, detailed aerial images of each site can be produced.

In addition to the production of ortho-rectified aerial images, the synagogue models grant scholars remote access to these sites. With the introduction of playable avatars in VR, users can embody and explore the site from a true first-person perspective. In the following section on methodology, the means of producing each model will be surveyed.

3 Method of Production

3.1 *Photogrammetry*

The first goal of the project was to create both photogrammetric models of each synagogue's material remains and a high-resolution, colorized image of each synagogue mosaic floor.

6 Sukenik, Eleazar I., *Beth Alpha*, 5 and 7.

7 The partial images of the mosaic floor can be seen dispersed throughout Sukenik's excavation report.

8 For excavation dates, see Dothan, Moshe, *Hammath Tiberias*, 6; for the aerial photograph of the mosaic floor, see Plate 10; for a colorized photo of the mosaic floor, see Hachlili, Rachel, *Ancient Synagogues*, 255.

9 Weiss, Zeev, *Sepphoris*, 27.

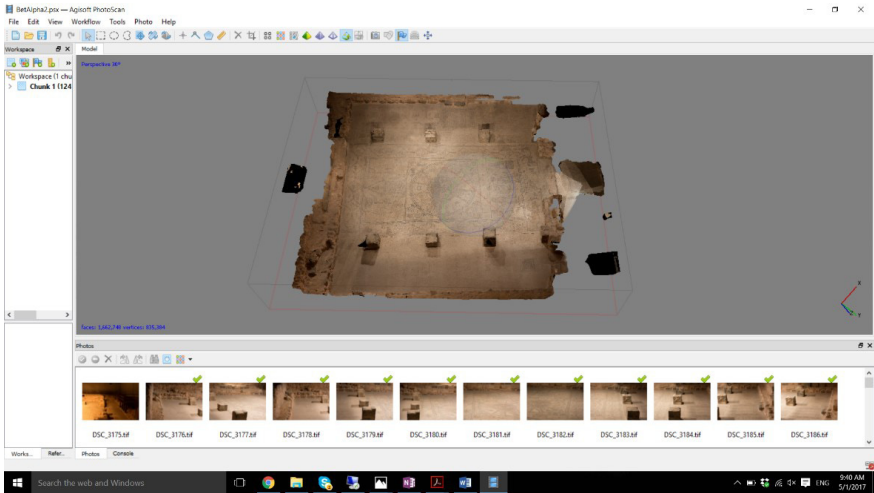


FIGURE 12.1 An in-progress shot of generating the photogrammetric model of Beth Alpha with Agisoft Photoscan; ©BRADERICKSON

Photogrammetric modeling is the process of photographing a site or object and from those photos generating a referenced, measurable 3D model of the subject. After making a photogrammetric model, a user can render a rectified image of the model from any angle, including an aerial shot otherwise known as an orthophoto.

To give an example of how a photogrammetric model and orthophoto are generated, I will use my work at Beth Alpha as an example. The photogrammetry project at Beth Alpha began with the taking of a series of 200 photographs of the synagogue's architectural remains and mosaic floor using a DSLR camera. Once all required photos were taken, each image was loaded into the photogrammetry program Agisoft PhotoScan.¹⁰ Once in Agisoft PhotoScan, all necessary parameters were set and the model was processed.

To create models, Agisoft PhotoScan uses a set of algorithms that examines and compares every portion of each picture to every other portion of every other picture. The program detects and traces identical features of an object from photo-to-photo, such as the corners of a door. After identifying and tracing points often numbering in the thousands between photos, the software begins to combine those points in three dimensions, creating a 3D modeled object or environment. At this point in the process, a user is able to add internal scale bars or known GIS points to ensure that the final model is scaled accurately.

¹⁰ See Figure 12.1 for a screenshot of the Beth Alpha model generated by Agisoft PhotoScan.



FIGURE 12.2 Orthophoto of the Beth Alpha Synagogue; ©BRADERICKSON

Once the model is complete, a user can export the model and utilize it in a number of ways, including loading the model online for internet viewing or further processing the model in a video-game engine so that a user can walk around the site using a digital avatar.

The orthophoto of the Beth Alpha mosaic, along with the orthophotos of the mosaics of Hammath Tiberias and Sepphoris, can be viewed in the list of figures to this article and are labeled Figure 12.2, Figure 12.3, and Figure 12.4, respectively. Following the completion of the photogrammetric portion of the modeling project, it was time to move to the next stage: creating suggested reconstructions of each synagogue.

3.2 *3D Modeling*

As in the previous section on photogrammetry, the ancient synagogue of Beth Alpha will be used as an example to describe the methodology for 3D modeling ancient environments. The modeling of Beth Alpha began with a close reading of Sukenik's excavation report with an eye to details that relayed the dimensions and styles of recovered architectural features. Architectural top plans of



FIGURE 12.3
Orthophoto of the Hammath Tiberias
Synagogue; ©BRADERICKSON



FIGURE 12.4
Orthophoto of the Sepphoris Synagogue.
Please note that the lights appearing on the synagogue
floor are from modern light fixtures hanging above the
synagogue remains and that the shadows appearing on
the lower right of the image are due to modern railing;
©BRADERICKSON

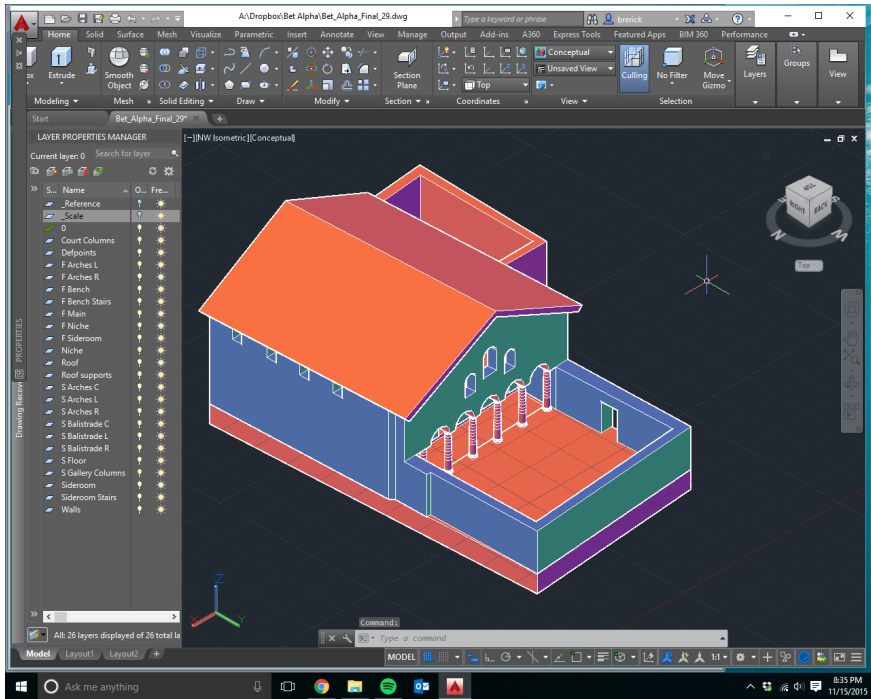


FIGURE 12.5 An in-progress screenshot of applying textures to the model of Beth Alpha in Blender; ©BRADERICKSON

Beth Alpha were scanned and loaded into AutoCAD, a drafting software application.¹¹ With the architectural top-plans loaded, a correct scale for the model was set and each feature of the structure (e.g. walls, benches, columns, etc.) was traced and extruded in three dimensions.

The next step in the modeling process was to export the scaled base model from the drafting software into a 3D modeling program. The drafting software is perfect for producing generic details, but a 3D modeling program is required to fine-tune the model and add unique aspects, such as fine details, animations, and textures. The open-source 3D modeling platform Blender was used.¹²

11 For architectural top plans, see Sukenik, Eleazar L., *Beth Alpha*, Plate XXVII; DOTHAN, Moshe, *Hammath Tiberias* 28-29; Weiss, Zeev, *Sepphoris*, 9 and 40. For a working screenshot of the Beth Alpha model production in AutoCAD, see Figure 12.5.

12 For a working screenshot of model production in Blender, please see Figure 12.6. For early renders of the outer and inner portions of the Sepphoris synagogue visualization, please see Figures 12.7 and 12.8. For a pre-textured render of the Beth Alpha synagogue, see Figure 12.9.

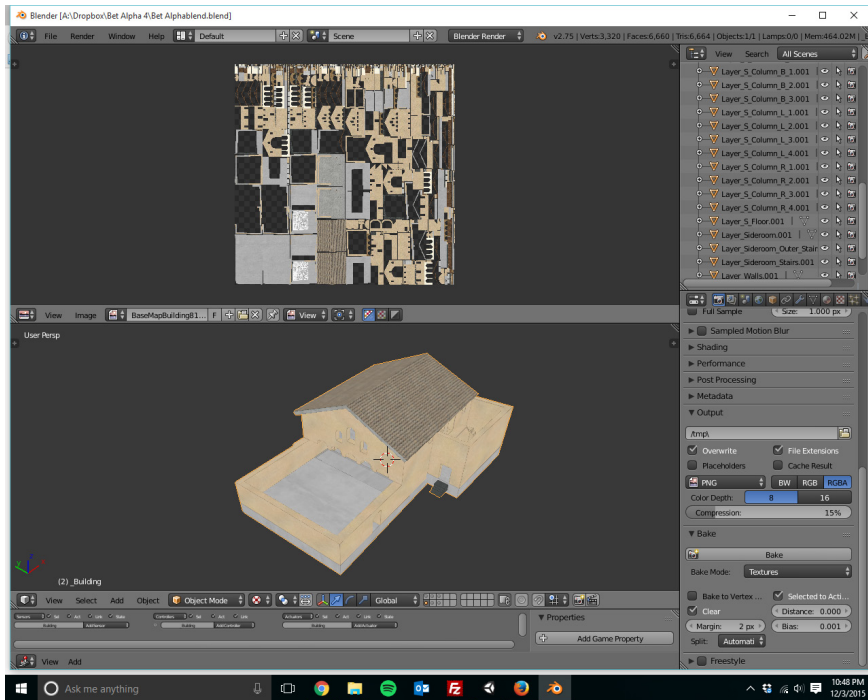


FIGURE 12.6 An in-progress screenshot of constructing the architectural model of Beth Alpha in AutoCAD; © BRADERICKSON

Once each synagogue was modeled, interactive elements needed to be added to the model, including a playable character that a user could control and use to explore the synagogue from a first-person perspective. For this final interactive portion of the project, video-game engine software was used.

3.3 Game Engine

Video game engines are programs that aid game developers by taking care of large portions of needed computer code to create video games. So instead of having to program the effects of gravity or how light will reflect off objects in each model, Unity3D comes with a full suite of physics and environments pre-programmed into its system that saves developers time and effort. For this portion of the project, the photogrammetric model and suggested reconstruction of each synagogue was imported into Unity3D.¹³

13 For a working screenshot of model production in Unity3D, see Figure 12.10.



FIGURE 12.7 Early render of Sepphoris synagogue visualization, outside; ©BRADERICKSON



FIGURE 12.8 Early render of Sepphoris synagogue visualization, inside without Torah shrine; ©BRADERICKSON

Once loaded into Unity3D, a series of features were added to the model of each synagogue, including (1) a menu screen that allowed users to choose features for the character that they would embody in the virtual environment (e.g. height and walking speed); (2) a programmed sun to rotate around the model so that users could experience different lighting conditions within the synagogue through the model's day-night cycle; and (3) an option to toggle a collection of non-playable characters to fill the synagogue so that users could gain a sense of comparative scale.

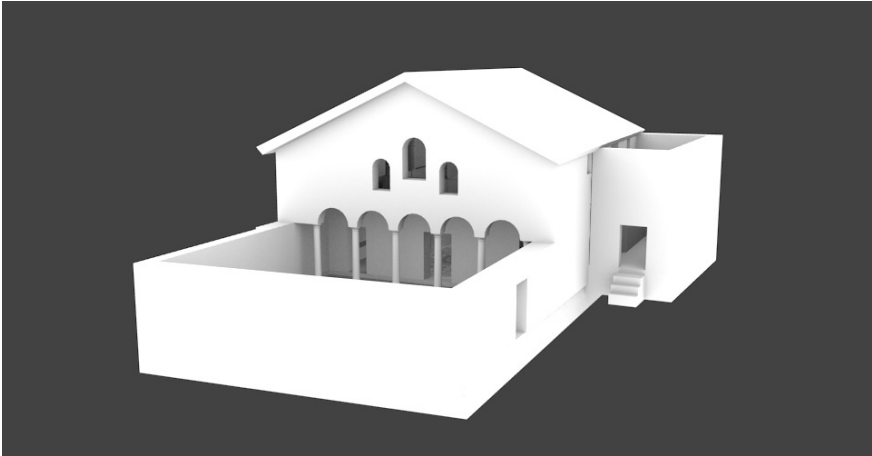


FIGURE 12.9 A render of the Beth Alpha synagogue visualization, Pre-Texture;
©BRADERICKSON

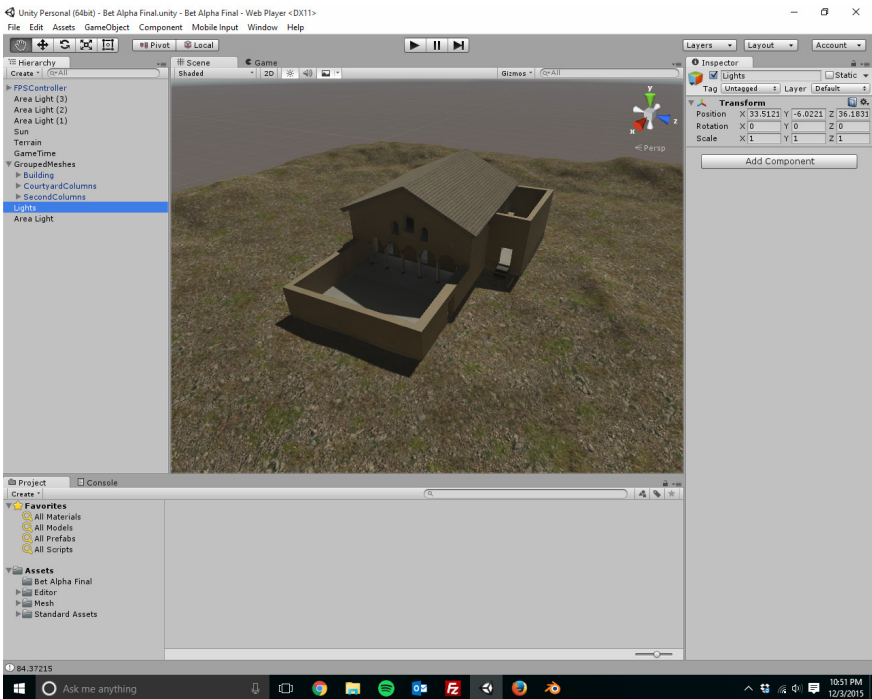


FIGURE 12.10 An in-progress screenshot of adding interactive elements to the model in Unity3D. Please note that the actual synagogue would have been surrounded by buildings and not an open field; ©BRADERICKSON

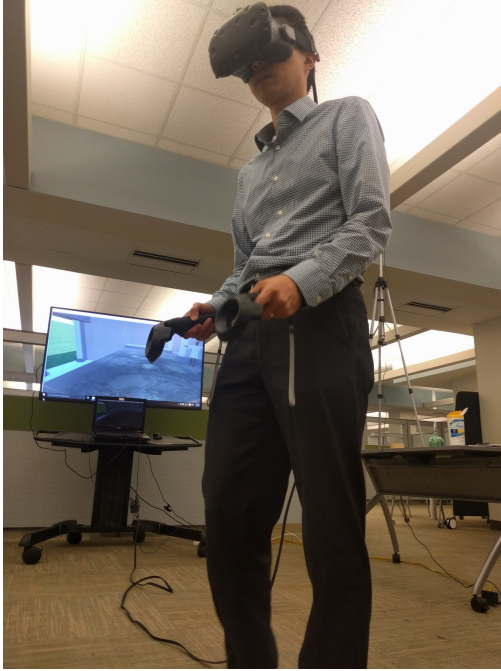


FIGURE 12.11

A user exploring the ancient synagogue of Sepphoris in VR with the HTC Vive. The user wears a headset through which he receives a first-person view of the synagogue. The hand-held controllers allow the user to interact with objects in the building. The television screen in the background projects what the user sees through the headset;

©BRADERICKSON

3D visualizations can often give the false impression of free, uninhibited experience. It is important to remember that designers are required to make decisions at every juncture of a modeling project. These decisions often establish boundaries to a player's experience. For example, concerning the playable character, a designer must input a number of pre-set features for the character, such as the character's height. In the synagogue models, I chose to make the basic, pre-altered avatar 1.6 m tall, which equates to roughly 5 ft. 7 in. This height setting might limit users wanting to experience the synagogue as someone taller or shorter. In order to combat my decision of a user's height as having an effect on his or her experience, I included a short computer script to allow the user to alter his or her avatar's height.

Once all scripted interactions and settings were programmed into the models in Unity3D, the final step of the production side of the project was to export the model as a single, useable package. Using Unity3D, the final versions of each models was exported so that the models could be accessed in two ways: online via a web portal and on a desktop personal computer via a VR headset – the HTC Vive.¹⁴

¹⁴ For a demonstration of someone navigating a synagogue model in virtual reality, please see Figure 12.11.

4 Results of Modeling and Final Products

I created my synagogue models with several goals in mind. First, I simply wanted a means through which I and others could embody ancient space. Through the embodiment of a virtual avatar questions such as how long would it take someone to walk from the entrance of the synagogue to the Torah shrine, how might different lighting conditions affect someone's experience of observing the synagogue's mosaic floor, and how many people could comfortably fit in the synagogue became questions answerable through observation within VR versions of the models. Second, through photogrammetry, I could generate the first high-resolution, holistic images of the synagogues' mosaic floors, which allowed for remote and detailed inspection of the mosaic remains.

In addition to my stated goals, other avenues of inquiry arose during the modeling process. It is important for the designer of an academic model to remain open to serendipitous discovery. For example, when adding windows to several of the synagogue models, I questioned how archaeological illustrators decided to place windows at certain heights in their architectural drawings of synagogue buildings. This led me to generate a set of models that allowed users to alter the height, size, position, and number of windows throughout the synagogue models so that users could observe how differently positioned and scaled windows affected natural light entering the building.

My synagogue models will be used in additional capacities to help visualize other theories in synagogue research. In Chad Spigel's recent volume on synagogue seating capacities, Spigel estimates a seating capacity of approximately 161 people for the Beth Alpha synagogue.¹⁵ To test this theory, a user can populate a model with 161 non-playable characters, disperse them throughout the building, and explore the remaining space via the first-person playable character.

Photogrammetric models, orthophotos, and the navigable 3D visualizations of each synagogue can be accessed on my website at <<http://bcerickson.com/synagogue-modeling-project/>>. The photogrammetric models are hosted on Sketchfab and can directly be accessed at <<https://skfb.ly/WBHQ>>. The high-resolution versions of the orthophotos are hosted on Flickr and can be accessed at <<https://flic.kr/s/aHskTQnvab>>. All 3D models and images produced for this project have also been uploaded to the University of North Carolina at Chapel Hill Digital Repository to ensure that all models are preserved in case any website hosting a portion of the project goes down

¹⁵ Spigel, Chad, *Ancient Synagogue Seating Capacities: Methodology, Analysis, and Limits*, Tübingen: Mohr Siebeck, 2012, 158.

5 Conclusion

3D modeling in academia offers many unique avenues for research. Through digital avatars, scholars, students, and the public can embody and explore visualized ancient space, and explore the past from a first-person perspective.

While the ancient synagogue modeling project is in a technical state of completion, no digital project is ever truly finished. I am currently working on recording sounds that will play within each model when users approach certain areas of the models. I hope to add this sound feature both to provide audible guidance within the models and also to imagine what the background noise of ancient synagogues may have been. The project as it currently stands has allowed me to produce interactive models through which I can test hypotheses, teach others about ancient synagogues, and generate detailed photos of the mosaic floors.

To conclude this article, I want to share a story that conveys a powerful narrative of experience. At a recent research showcase, I setup my VR equipment and allowed university students to explore the model of the ancient synagogue of Sepphoris. A line quickly formed, and the first student stepped forward to try it out. After I instructed the student on how to navigate the model and explained the history of the synagogue and the project, the student put on the VR headset and hesitantly began to walk around the room.

After the student had walked for a few seconds, he looked down and noticed the mosaic floor for the first time. He gasped and apologized, asking if it was okay to walk on the mosaic floor – a floor that only existed in the digital environment rendered in the VR headset.

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