MARTYRDOM, 3-D, BLACK EARTH, AND THE LIQUID BORDER

THE STONE AGE MEETS THE DIGITAL AGE

Exploring the Application of Digital, Three-Dimensional Technologies for the Study of Lithic Artifacts

SURF Conference Panel Session 6A

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I. Introduction

It broke! It was 19,000 years old and it broke (figure 1)! I will not name the undergraduate anthropology student at UC Berkeley who destroyed any possibility of studying an irreplaceable lithic artifact in its original form. Luckily, before it broke, I made a high-resolution, accurate, three-dimensional replica of the lithic that can be studied (figure 2). New media and digital tools offer us the ability to experience virtually reconstructed historic sites and cultural material.[1] It was only a matter of time before archaeologists saw the potential that 3D technologies offer for cultural heritage preservation and artifact analysis.

My research explores the ways in which digital, three-dimensional technologies can enhance the study of lithic material. Over the course of my work, I investigated the practicality of applying cost-effective 3D technology to the study of lithic material, particularly in the field, as well as the potential limitations and opportunities that this technology presents for the study of archaeology. My methodology includes an examination of how 3D techniques are currently being applied in archaeological research; experimentation with photogrammetry; an image-based approach for creating 3D models from 2D images; and self-training with free 3D modeling software.

1 Beng-Kiang Tan and Hafizur Rahaman, "Virtual Heritage: Reality and Criticism," *Proceedings of the 13th International Conference of CAAD Futures* 9 (2009): 144.

II. Background

3D technologies quickly became a medium that researchers utilize in many different academic and professional fields and in a number of exciting new ways. For example, 3D is being used by The Human Brain Project to develop a detailed 3D atlas of the human brain. This atlas is helping the fields of medicine and neuroscience to better understand the inner workings of the mind.[2] The National Aeronautics and Space Administration (NASA) routinely creates 3D models of hurricanes for tracking storm systems.[3]

The ongoing development of virtual reality technologies, interfaces, interaction techniques, and devices is greatly improving the efficacy and usability of virtual reality.[4] In fact, archaeologists started exploring basic 3D technologies for reconstructing whole archaeological sites well over 10 years ago.[5] Digital and 3D technologies allow archaeologists to create virtual exhibits, provide access to broad audiences, enhance education techniques, and collaborate with fellow researchers globally. Photogrammetry, the technique of using 2D photographs to determine the 3D properties of objects, in particular, offers the ability to create digital reconstructions from multiple scales. These include digital 3D reconstructions of landmasses from aerial photos and large environmental 3D reconstructions of archaeological excavations from ground photos. Of special importance to my work, a series of photos of an artifact, large or small, can be converted into 3D, rotatable models.

Archaeologists working on a collaborative research project at the Neolithic site of Catalhoyuk are creating a variety of multimedia platforms for wide audiences to interact with simulated reconstructions of what life at the 9000-year-old site may have been like.[6] Some institutions, such as the Smithsonian Institute and Arizona State University, are using laser-scanning based methods to create databases of 3D artifacts. However, the methods that these two institutions are using have limitations: they are restricted to a laboratory environment, and the laser scanners are costly and require a high level of training and specialization.

The study of lithic technology provides understanding of how humans lived and how humans have changed. In particular, it has the possibility to provide information about key social dimensions as technological acts are a fundamental medium through which social relationships, power structures, worldviews, and social production and reproduction are expressed and defined.[7] A 3D approach in archaeology offers a new conceptual research tool for exploring lithic technologies and the social dynamics that are expressed through lithic technologies. 3D analysis offers new ways of interacting with the material not possible with real-world objects, such as virtual refitting sequences (the process of fitting stone flakes back together to reproduce the sequence of events that created the stone tool) and examining multiple artifacts side by side,

2 “Big Brain,” Montreal Neurological Institute, accessed August 15, 2013, https://bigbrain.loris.ca/main.php?test_name=bigbrain&slice=1970

3 “Hurricane Season 2005,” National Aeronautics and Space Administration, accessed August 12, 2013, http://www.nasa.gov/vision/earth/lookingatearth/h2005_rita.html

4 *Ibid*., 145.

5 R. G. Laycock, D. Drinkwater, and A. M. Day, “Exploring Cultural Heritage Sites through Space and Time,” *ACM Journal on Computing and Cultural Heritage* 1, no. 2 (2008): 2.

6 Anja-C Wolle and Ruth Tringham, “Multiple Catalhoyuks on the World Wide Web”, in *Towards Reflexive Method in Archaeology: The Example at Catalhoyuk by Members of the Catalhoyuk Teams 2000*, ed. Ian Hodder (Cambridge: McDonald Institute), 2.

7 Marcia-Anne Dobres and Christopher R. Hoffman, “Social Agency and the Dynamics of Prehistoric Technology,” *Journal of Archaeological Method and Theory* 1, no. 3 (1994): 212.

digitally, for comparative purposes (figure 3). An online database of 3D artifacts could potentially be accessed anywhere, by anyone, at any time.

The best way to study lithic artifacts is through hands-on experience, however this is not always possible. Traditional methods to replace hands-on experience include analysis of 2D sketches (figure 4), but even the most detailed photographs and sketches can only provide a limited amount of information. A 3D rendering of a lithic provides tactile information, such as texture, color, and flake scarring, in a digital space. My goal with this project is to use only technical equipment that are already a part of the standard documentation procedure for archaeological excavations so that the process requires no additional technical training with the equipment and the technology can be applied in the field as well as in a laboratory.

III. Methodology

My method requires only a minimal amount of training with 3D software. While other methods use more sophisticated equipment and software (figure 5), my approach uses only a digital camera, a tripod, a homemade platform, and the free, online software program, 123D Catch (figure 6). 123D Catch generates a three dimensional mesh, known as a capture, using an ordered sequence of images taken with a standard digital camera. This sequence requires the camera to move in orbit around the lithic, implying that the first and last camera images share a majority of the same geometry, thus "closing the loop." To generate a successful capture, three sets of photographs need to be taken: one set around the center, one set around the top, and one set around the bottom of the lithic, with roughly 80% overlap so every angle of the artifact is represented in the capture. The best captures are produced from a matrix of 80–120 photographs (figure 7, 8, 9). I have created 3D captures with my iPhone using the 123D Catch mobile phone application (figure 10). However, the app is currently limited to 40 photographs per capture, and the capture required quite a bit more alteration with 3D modeling software (figure 11).

Evenly distributed light, consistency of camera placement in terms of distance from the object, and stillness of the artifact generate the most accurate 3D mesh. It is important to note that any part of the lithic that is in contact with a platform or prop will not be represented in the 3D capture. To mitigate this issue, I try to make the contact points as minimal as possible. Soft, evenly distributed light is essential for creating a successful capture because any change between the images, even lighting, can affect the outcome of the final 3D mesh. It is more effective to move around the lithic than to rotate the specimen on a turntable as this can change the lighting or placement of the lithic in relation to the camera.

After the photographs are taken, I upload the images first to a laptop or desktop computer and then into 123D Catch. The process of creating a 3D mesh through 123D Catch can take anywhere from 15 minutes to a couple of hours depending on the number and size of the images taken. The amount of modeling that will have to be performed is in direct proportion to the quality of the capture. If the 3D mesh contains few holes, has little background interruption, and closely resembles the original lithic, then the modeling process will require less alteration of the capture and less time (figure 12). However, if there is quite a bit of difference from the actual artifact, a decision must be made to either re-photograph it or to perform a considerable amount of modeling to the 3D mesh (figure 13). The latter is not ideal as the goal is to produce a 3D rendering suitable for analysis.

Putting a sizeable amount of modeling into the artifact may make it look good, but every alteration takes it further away from the accuracy of the final version of the model. I suggest that archaeologists perform the capture and modeling process rather than 3D artists. Archaeologists know what information on the lithic is important and what needs to be retained for research and analytical purposes. This is true for any model or reproduction of archaeological material. There is a level of specialization that is necessary for creating accurate representations of an artifact. While the method I am discussing is quite easy to learn, and there are no special skills required for creating a 3D model, certain background knowledge is required for creating models that will be suitable for analysis.

Once the final mesh is processed through 123D Catch, I import it into Autodesk Maya (figure 14). I use Maya because it meets my requirement that the method be cost effective. Maya is available to students free of charge, as long as the models produced from the software are not made for profit. In Maya, each mesh is composed of polygons, consisting of faces (figure 15), edges (figure 16), and vertices (figure 17). Each of the mesh components can be manipulated with only a few functions until the shape, size, and relief are an approximate facsimile to the original lithic. The main point I want to stress from this process is that the better the photographic capture, the less alteration is required in the 3D modeling software. Hence, a more accurate 3D lithic is produced for archaeological analysis.

IV. Limitations and Opportunities

I would like to turn to some of the limitations and opportunities of my research. I do not propose that 3D images replace actual lithic artifacts for analytical and educational purposes. There is nothing as valuable to the analysis process as working with an original lithic. However, when this is not possible, my method presents a viable option for disseminating a 3D model, which is suitable for analysis, to anywhere in the world with access to the Internet.

In the few short months of working on this project, what has struck me is how quickly technology advances and how techniques must constantly be refined. Staying on the ball, ahead of the curve, and developing new approaches for emerging technologies is vital. What is current and up-to-date today may be obsolete in six months. A key component of this research is a continuous exploration of emerging technologies so that this method remains relevant.

Another limitation I have faced is the dissemination of information. I have found a limited number of online platforms that accept 3D models up to a certain size to be uploaded for free. Because the files I am using have the potential to be larger than this limit, it could be costly to create a digital catalogue of artifacts. However, as previously stated, technology is constantly evolving, so this may not be an issue in the near future. These methods are still in their infancy, so the online infrastructure for this technology has yet to provide universal accessibility.

There are also limitations to the types of material that can be converted to a 3D mesh using an image-based method. Reflective material, such as obsidian, cannot be understood by 3D mesh software. Finally, as stated before, there are issues with how to position the material in order to photograph as much of the artifact as possible. I cannot make a lithic levitate, so there will always be some kind of alteration to the 3D mesh at contact points with the platform.

The opportunities that a 3D approach offers archaeology are far beyond the scope of my research. The following are just a few of the opportunities that my research provides the field of archaeology. First, I am an undergraduate student with a very limited budget, and second, I am neither a photographer nor a digital artist. I am a novice with both of these technologies, yet I have created a successful method for creating 3D models of lithic artifacts. My point is that my method is user-friendly, cost-effective, and convenient. This technique is a tool that can become as much of a part of an archaeologist's tool kit as the trowel and TotalStation. Creating a 3D replica of a lithic artifact in the field ensures that a digital facsimile of the lithic is preserved. In addition to the preservation opportunities, 3D models of artifacts offer an interactive way to catalogue and present archaeological information, not just for researchers or students but for the communities that are associated with the cultural material. In the classroom, an interactive method for teaching lithic analysis can allow students to be more engaged with the material as well as addressing a larger audience. Finally, with the advent of more sophisticated 3D technology, such as 3D printing, a detailed replica of a lithic could potentially be made and studied simultaneously in laboratories all over the world.

V. Conclusion

The most exciting part of my research is that this is only the beginning. The time that I have invested in experimenting with methods of creating 3D lithics will be parlayed into practical application throughout the next year and expanded upon for my senior honors thesis. I will create a digital, three-dimensional, catalogue of type specimens, using Jordanian artifacts from the Epipalaeolithic, as a case study for the effectiveness of using 3D models to enhance lithic analysis and the classroom experience. I will refine the practical application of this method in the field next summer. Digital modeling techniques can literally change the way we look at the past. Hopefully, in the not-so-distant future, this technology will be so common that when an undergraduate Anthropology student breaks a one-of-a-kind lithic, it will not just be luck that a 3D representation had already been made but standard procedure.

Appendix

Figure 1. Broken Jordanian Lithic Tool. Photograph by author.

Figure 2. Three Dimensional Model of the same lithic before broken, created by author.

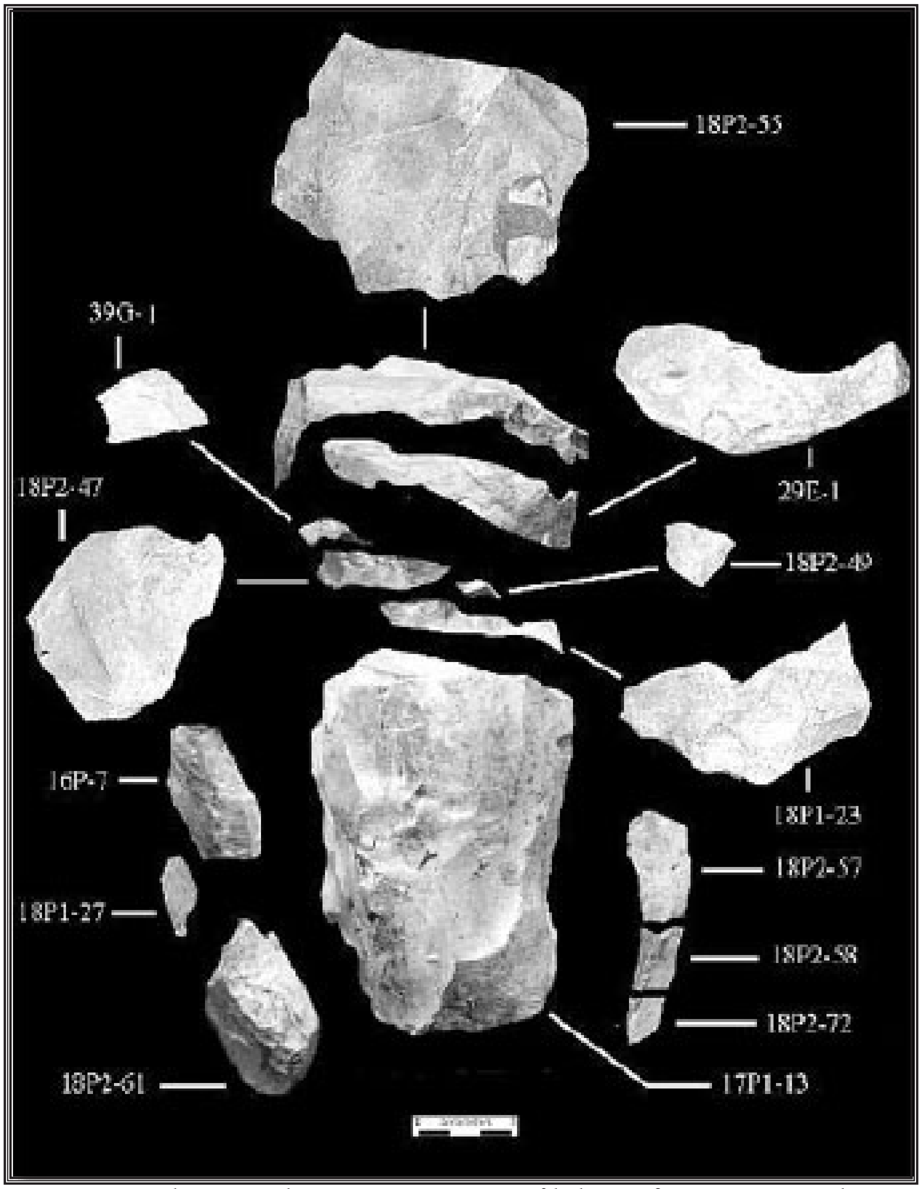


Figure 3. Photographic representation of lithic refitting. Source: http://www.texasbeyondhistory.net/pavoreal/paleoindian.html

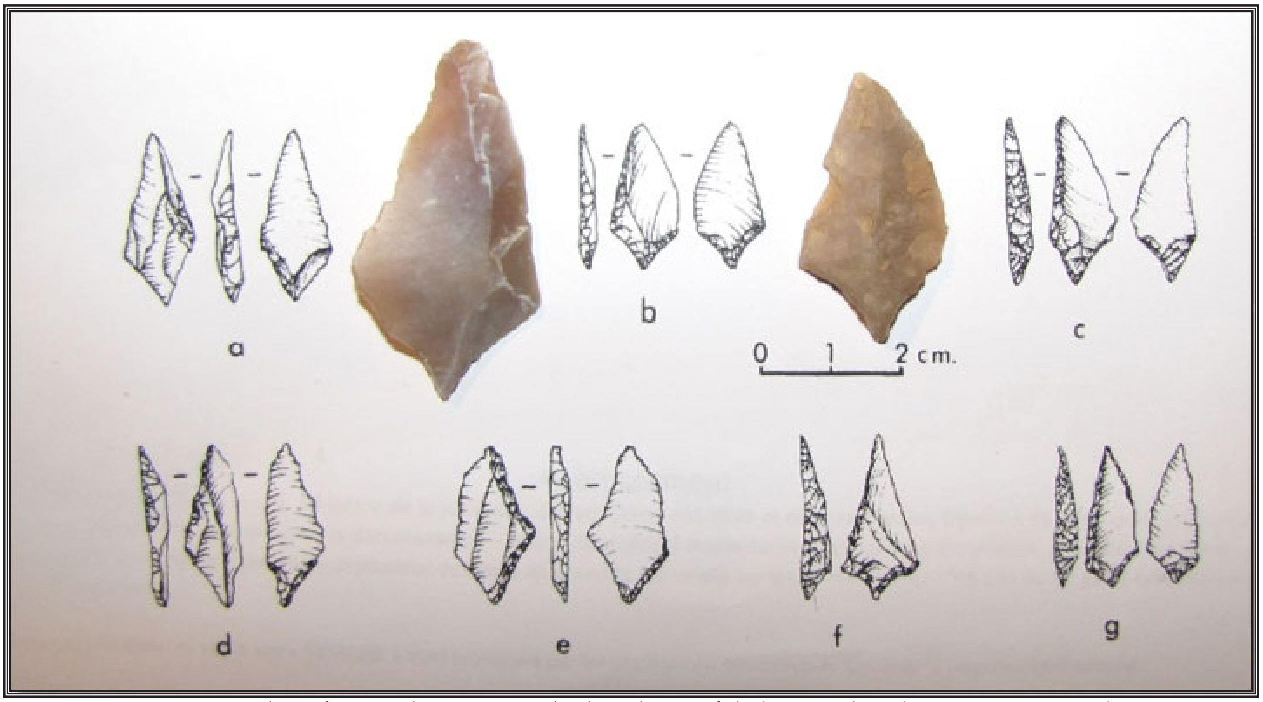


Figure 4. Example of two-dimensional sketches of lithic technologies. Source: http://www.aggsbach.de/page/9/

Figure 5. Demonstration of the Smithsonian Institute's equipment for creating 3D artifacts. Source: http://www.adafruit.com/blog/2013/05/16/the-smithsonian-is-3d-scanning-the-past-for-future-generations-3dthursday/

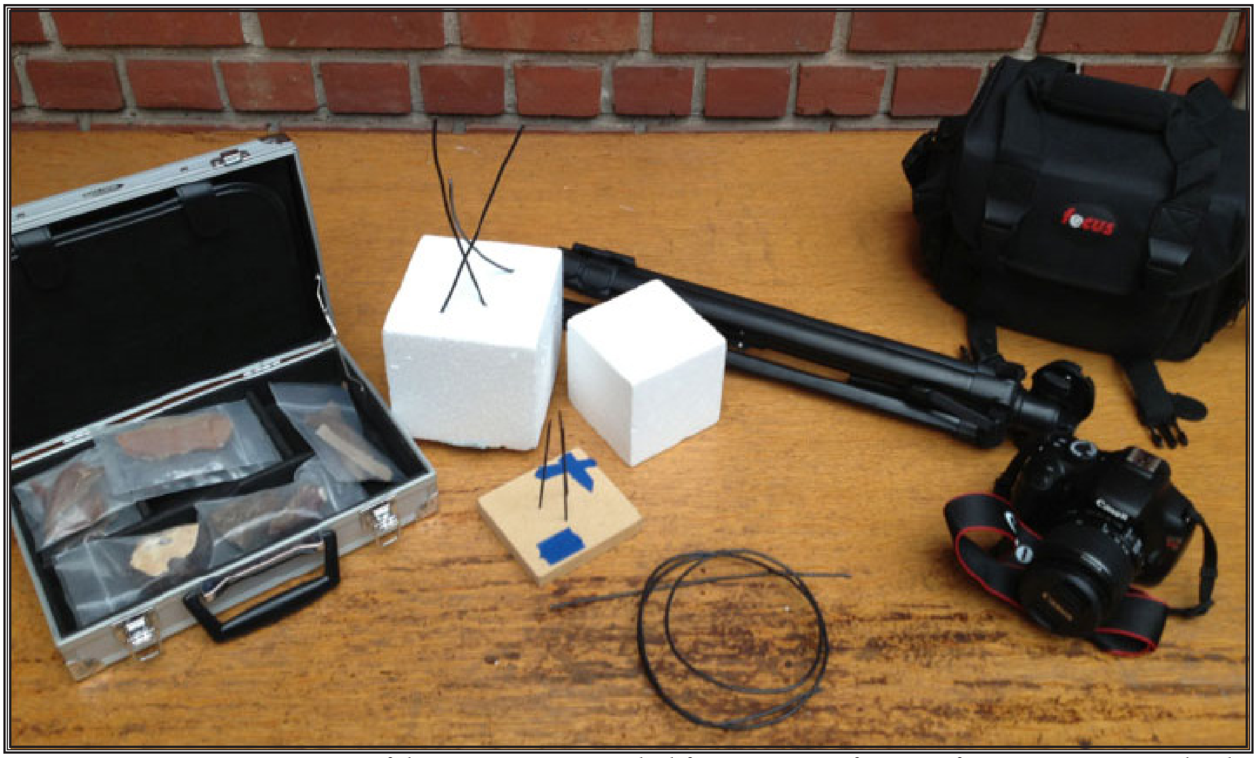
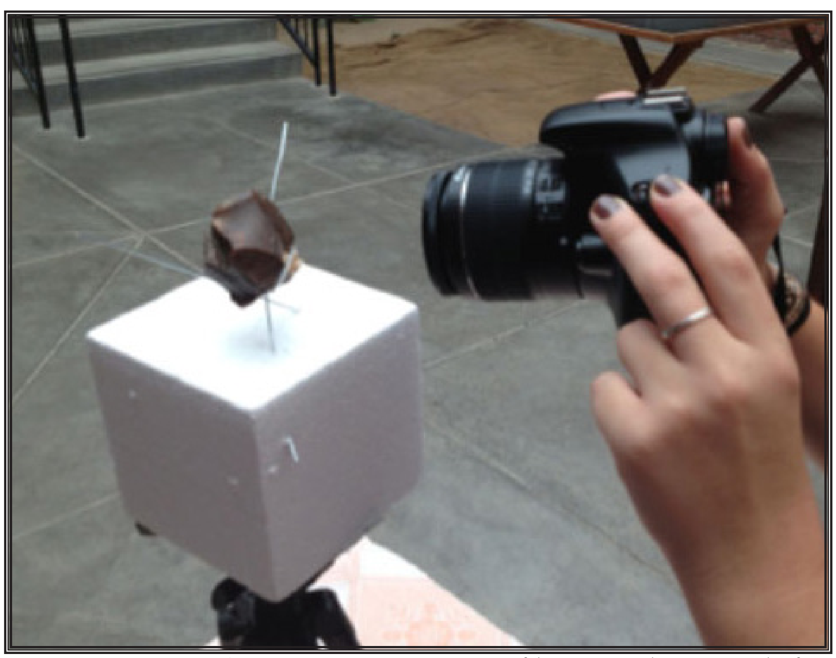


Figure 6. Demonstration of the equipment needed for creation of 3D artifacts using my method. Photograph by author.



Figures 7, 8, and 9. Demonstration of how to photograph for creating a 3D model. Photograph by author.

Figure 8.

Figure 9.

Figure 10. 123D Catch iPhone App. Captured by author.

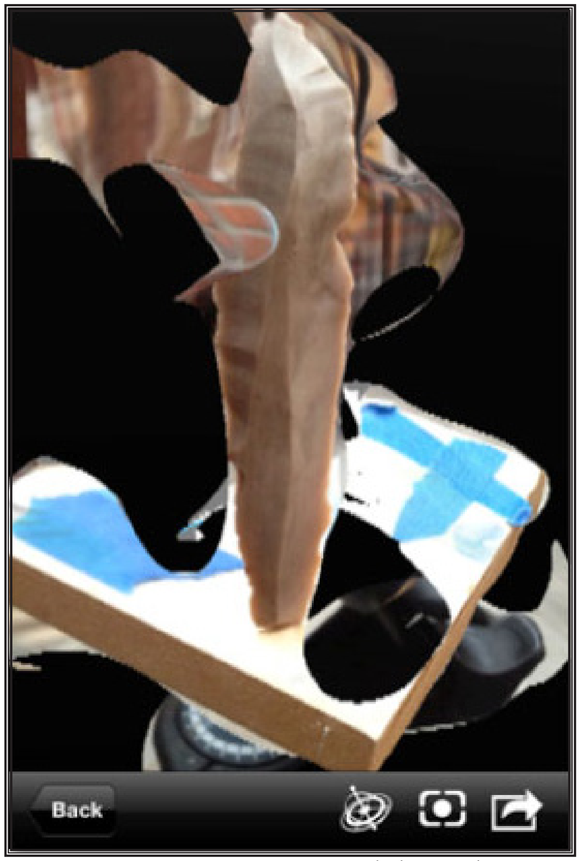


Figure 11. Capture created through 123D Catch iPhone App. Captured by author.

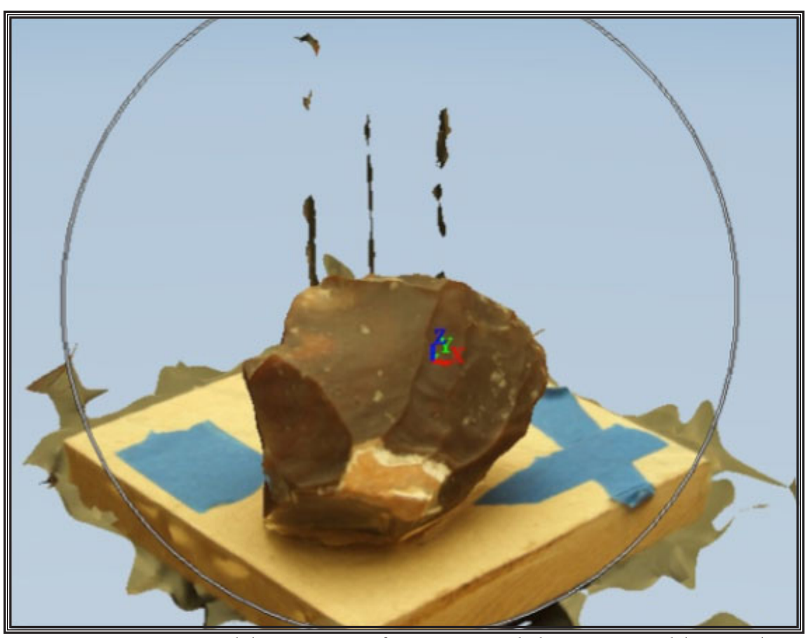


Figure 12. Suitable capture for 3D model. Captured by author.

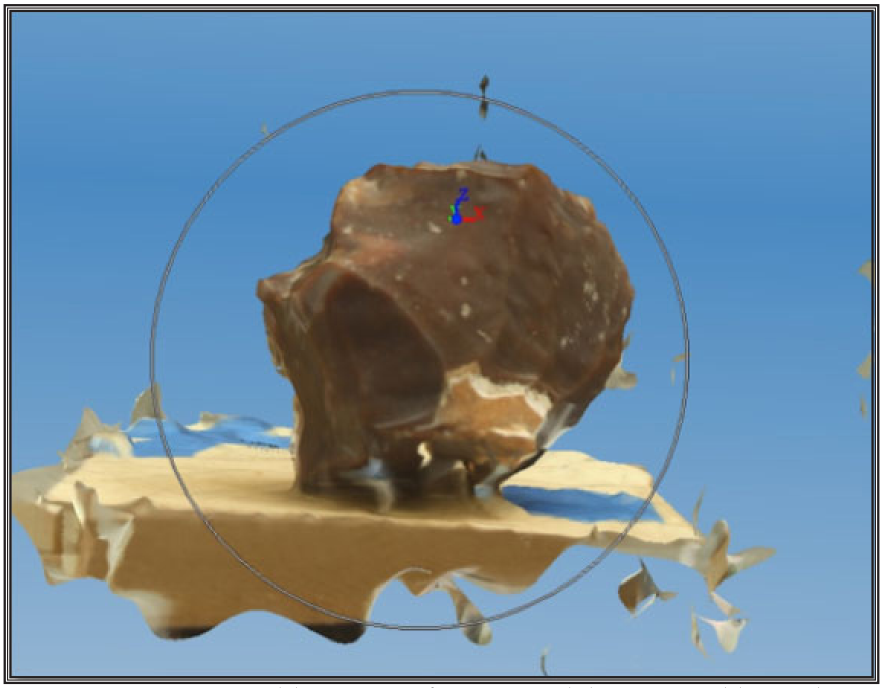


Figure 13. Unsuitable capture for 3D model. Captured by author.

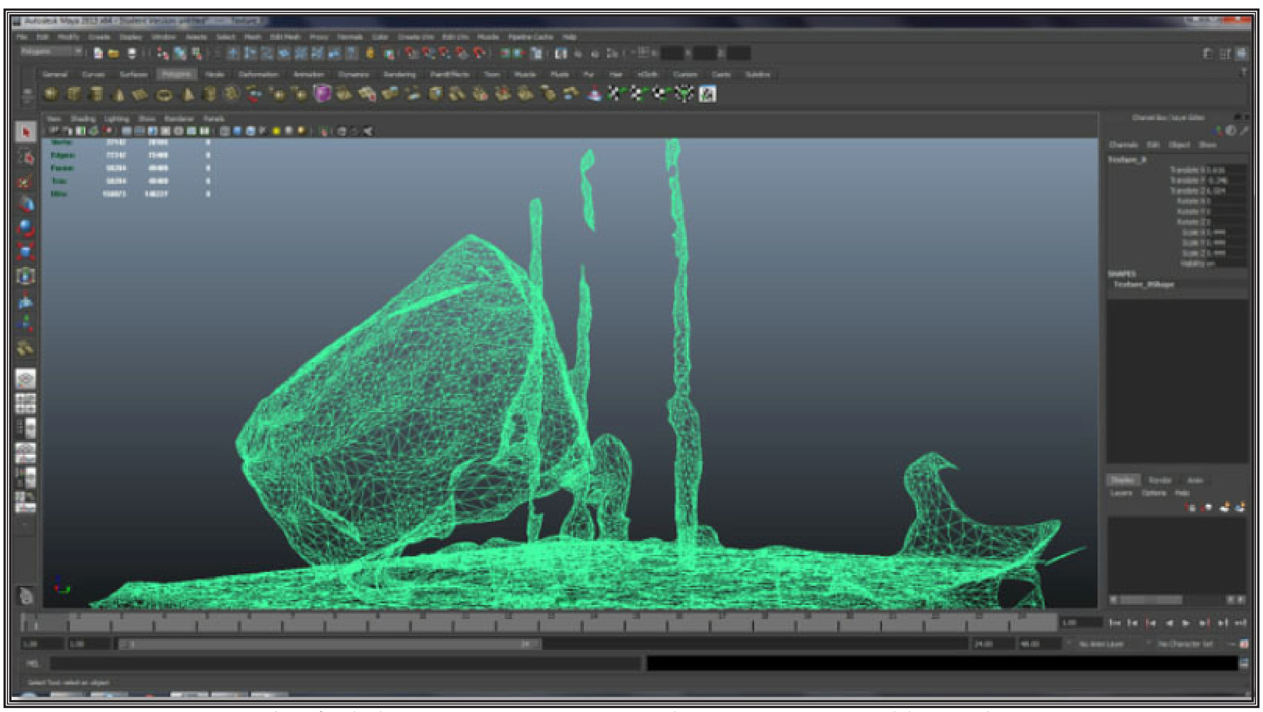


Figure 14. 3D mesh of a lithic capture in AutoDesk Maya. Captured by author.

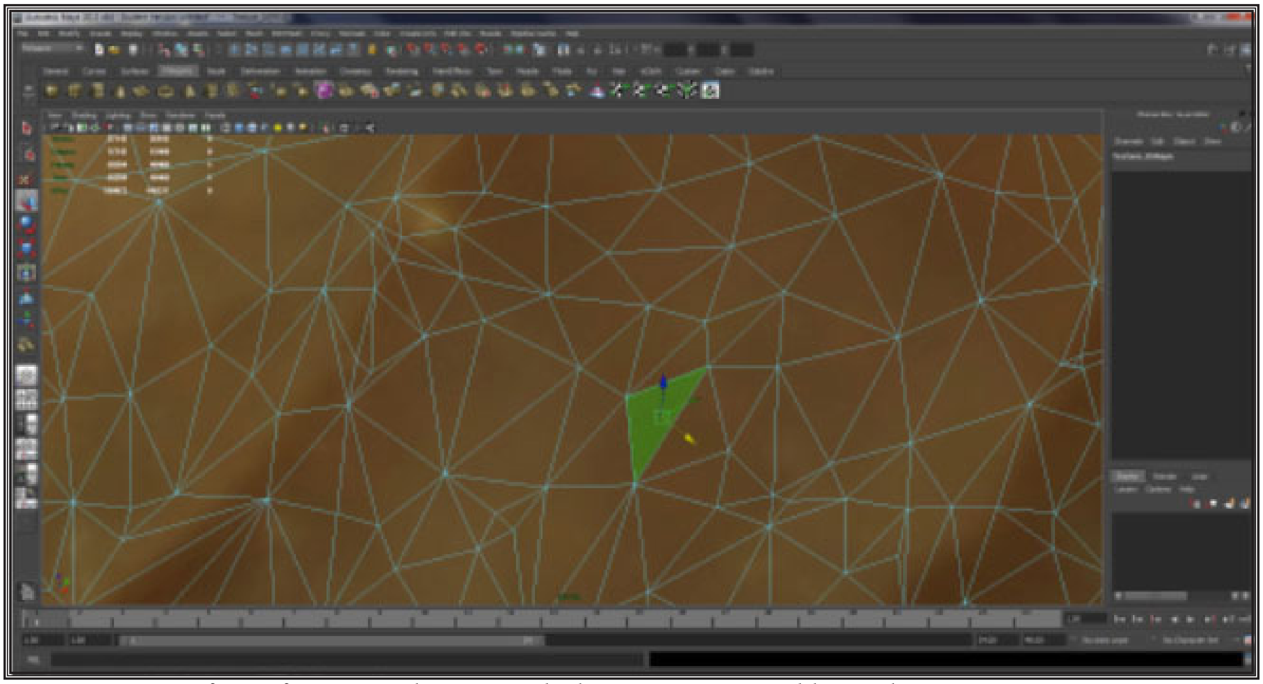


Figure 15. A face of a 3D mesh in Autodesk Maya. Captured by author.

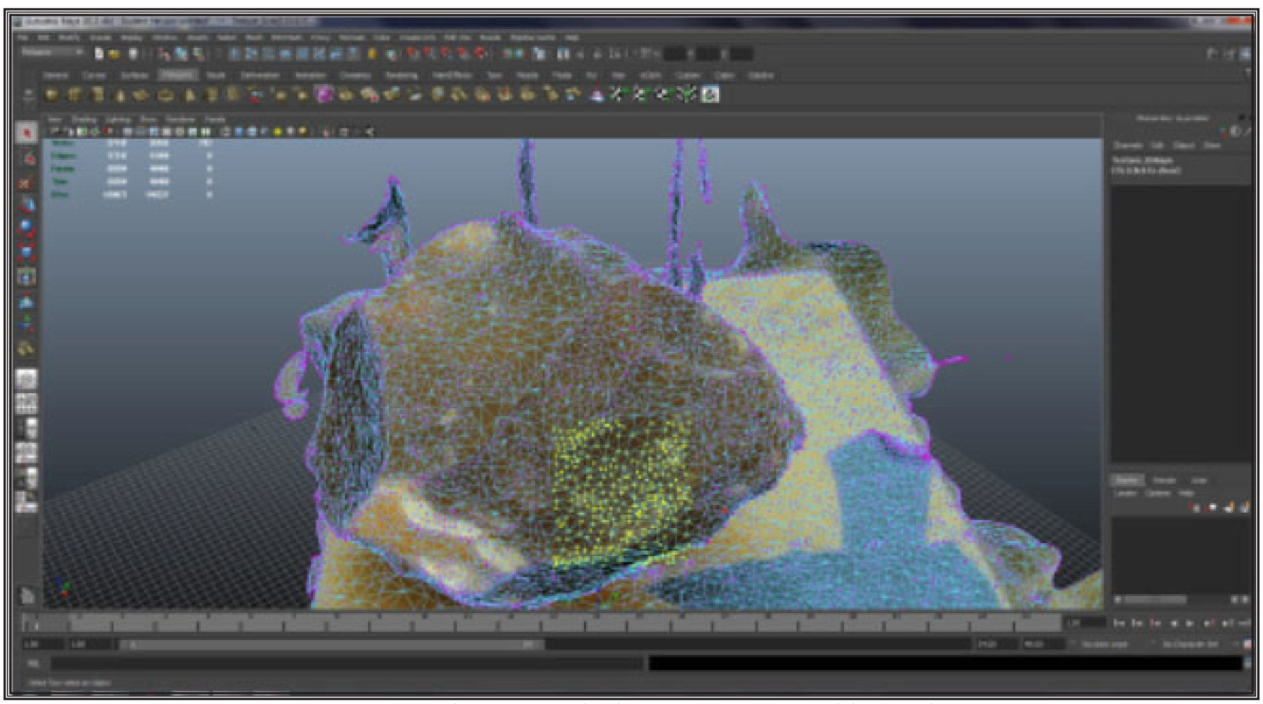


Figure 16. Vertices on a 3D mesh in Autodesk Maya. Captured by author.

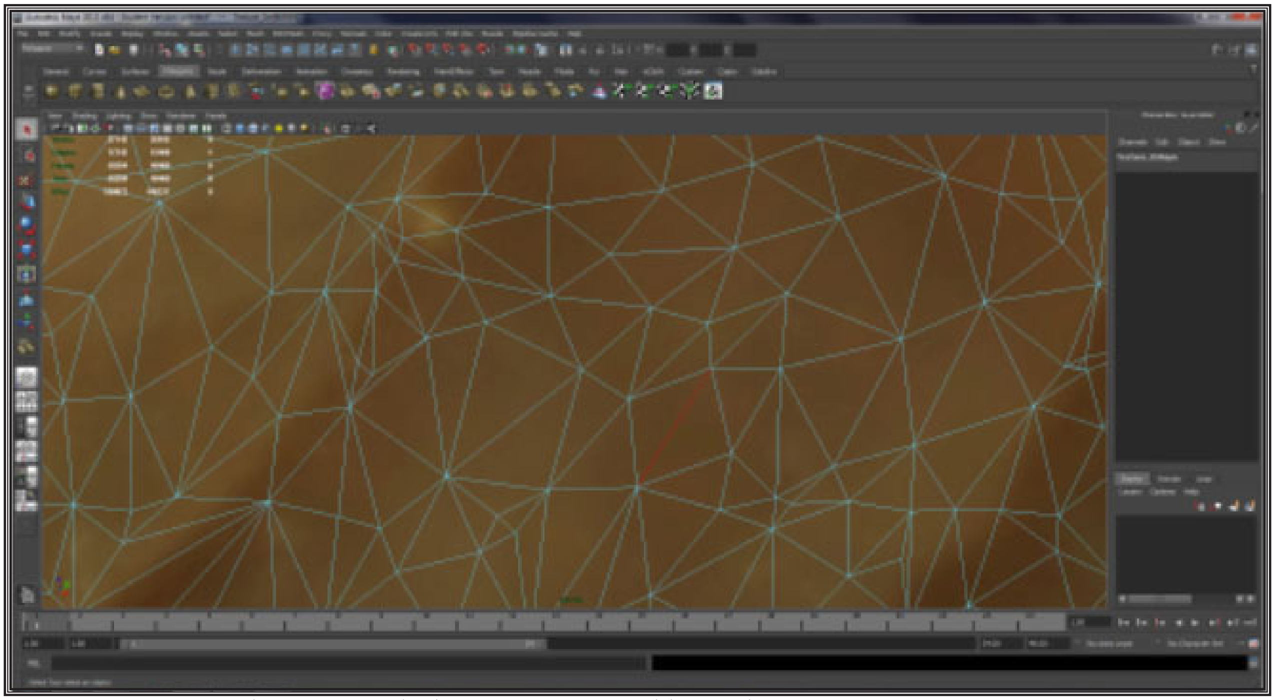


Figure 17. An edge in Autodesk Maya. Captured by author.

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