THE USE OF COMPUTER GRAPHICS TECHNOLOGIES IN ARCHAEOLOGICAL RESEARCH ON THE EXAMPLE OF ÇATALHÖYÜK

Tinatin Mshvidobadze
Doctor of Technical Sciences
Associate Professor, Gori State University
+995 555 11 83 79. tinikomshvidobadze@gmail.com
https://orcid.org/0000-0003-3721-9252

Abstract

Archaeological research conducted over the years at Çatalhöyük has produced data-based interpretations of Neolithic buildings. Modern 3D technologies allow us to create a multifaceted archaeological discourse about the material culture and unique urban environment of Çatalhöyük. The article aims to highlight the role of 3D technologies in the dissemination of archaeological data. It discusses the virtual restoration projects of Çatalhöyük, showing the theoretical foundations and results of these initiatives. The application of the cyberarchaeology approach is presented, whose main research goals are the creation of real-time data simulations and the interaction between users and the virtual environment. These initiatives focused on the 3D virtualization of excavations and the virtual reality software of the data. Including the Dig@IT software, which was developed specifically for Çatalhöyük. In short, the paper discusses in detail the research questions and results obtained within the framework of the projects implemented in Çatalhöyük and how these results led to the adoption of diverse digital products in the form of 3D data collections and advanced visualization systems.

Keywords: Çatalhöyük historical houses, digital archaeology, 3D reconstruction, virtual simulation, digital photogrammetry, cyberarchaeology.

Introduction

The development of computer technology at the modern stage allows us to understand the history lost in the past without conducting fieldwork. In this regard, we will consider the analysis of the simulation of the works carried out in the city of Çatalhöyük (Turkey) using 3D computer graphics.

Excavations carried out in Çatalhöyük in recent years have produced data-based interpretations of the multi-level repetition of Neolithic buildings. Modern 3D technologies allow us to present the material culture and unique urban environment of Çatalhöyük.

Çatalhöyük is a nine-thousand-year-old prehistoric city, which contains rare examples of well-preserved Neolithic settlements.

Çatalhöyük is located on the Konya Plain in Central Anatolia, near the city of Çumra, Turkey. The Neolithic sites of the East Hill are 13.5 hectares in area and 21 m high, on 18 levels of settlement. The Neolithic settlement, which dates from 7100 to 6000 BC, housed 3,000–8,000 people in mud-brick houses.

This place was discovered by James Mellaart in 1958 and initially excavated from 1961 to 1965 (Mellaart, 1967:136). In 1993, Jan Hodder initiated the Çatalhöyük Research Project, which aimed to study the eastern mound of Çatalhöyük and to develop further interpretations of the repetition of architectural elements and buildings over time. (Hodder, 2016:78-80).

In 2012, Çatalhöyük was inscribed on the UNESCO World Heritage List for its universal value and uniqueness.

The ongoing excavations on the eastern mound of Çatalhöyük have documented the repeated practice of rebuilding residential buildings, i.e. entire houses, in the same way over time.

3D visualization, laser scanning and digital archaeological methods offer the opportunity for archaeology to explore important alternative means, based on non-linear narratives, three-dimensional perspective and virtual reconstruction. (Mills % Andrews, 2011:57-60).

The article discusses the use of real-time 3D technologies, which has allowed us to gain new knowledge about the archaeological heritage.

Methods

This article uses descriptive, analytical and explanatory methods, based on which important issues of the study are highlighted. To formulate the concept, we examined the views of various researchers, based on which we presented our reasoning and conclusions.

The paper provides an overview of computer graphics methods in the study of archaeological materials, demonstrating their effectiveness.

Results

Based on the data obtained from field research conducted in previous years, the paper presents an analysis of the virtual restoration projects of Çatalhöyük, showing its theoretical foundations and results. In addition, it shows how virtual reality-based data visualization systems are changing the ways of recording, discussing and interpreting archaeological information. These approaches still allow for new interpretations through virtual simulations.

Discussion

Analysis of Virtual Restoration Projects. The Çatalhöyük Virtual Restoration Project (VRCP) was launched in 2015 as a joint effort between the University of California, Merced, Stanford University, and the e-learning platform Corinth. The project aimed to virtually reconstruct a 3D sequence of Neolithic buildings and present them in a data-driven manner. The project aims to define a new approach to digital archaeology that will foster open debates on the interpretation of archaeological evidence.

The project resulted in the creation of three virtual reconstructions of the Çatalhöyük buildings, which were released as free content for the mobile app Lifeliqe in 2016 (Lifeliqe for iPad, untitled; Lifeliqe for Windows 10, untitled).

In 2015–2016, the initial phase of the project was completed with the virtual reconstruction of three roofed buildings (Buildings VIA.10, VIB.10, and VII.10), excavated by James Mellaart in 1962 and 1963.

The project aims to demonstrate that contemporary discourse on virtual representations of the past should adopt a reflective perspective and consideration of technological advances, which is often characteristic of digital archaeological literature. (Lercari, 2019: 152–65).

A similar project using 3D technology was launched at Çatalhöyük in 2012, involving the use of image-based modeling to represent burial scenes.

Using appropriate photographic recording techniques and software, team members independently began to create 3D models of simulated burials. (Fig. 1.). Initially, the technique was used only to document fully exposed skeletons, but by creating geographically referenced models at each stage of the excavation process, the team was able to virtually reconstruct the often-complex sequence of burials beneath the floors of houses. (EARL, 2013: 226-244).

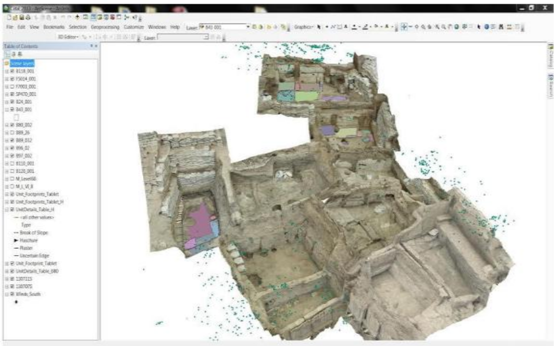

Fig. 1. Software: Creating 3D models of burial simulations.

In the Neolithic period, successive burials under the floor of Çatalhöyük often took place on the same house platform. Consequently, early burials are often disturbed by cuts made for later burials, which leads to a reduction in the size of the data. In such situations, 3D modelling has significantly improved the ability to visualize, interpret and reconstruct burial practices.

Cyberarchaeological approach applied at Çatalhöyük. This project, conducted between 2010 and 2015, investigated the use of three-dimensional spatial data recording, simulation, and visualization at the Neolithic site of Çatalhöyük, a collaboration between Duke University, the University of California, Merced, and Lund University. The theoretical and methodological approach adopted is based on the principles of cyberarchaeology (Forte 2010a), whose main research questions are the creation of real-time data simulations and the interaction between users and virtual environments.

It focused on the virtualization of the contextual method of excavation (layer-by-layer), 3D geographic information system data, the implementation of digital collaborative systems (teleimmersion), and virtual reality software for data curation. (Forte & Kurillo, 2010).

The first phase focused on data collection, analysis, and modeling technologies, while the second half focused on visualization and data curation technologies, including the Dig@IT software developed specifically for Çatalhöyük.

Cyberarchaeology is a field of archaeological research dedicated to the digital simulation of multimodal and three-dimensional archaeological data (Forte et al, 2015).

This approach requires the study of multimodal simulation models based on archaeological datasets drawn from different fields of knowledge. The "cybernetic" factor can be measured by recording interaction and feedback data, where the "trigger" of data collection is the gateway through which we enter the cyberworld.

The main objectives of the Cyberarchaeology project are 1) to apply new digital data recording techniques to archaeological excavations and artifacts, to study methods for processing 3D big data; 2) to create interactive analytical tools for the appropriate data mining of 3D big data and the creation of realistic 3D models; 3) to study cases of virtual excavations based on data collected from archaeological sites; and 4) to explore these virtual sites together in a fully interactive environment.

The digital work carried out in the Çatalhöyük laboratories and field conditions included several experiments: data recording, collaborative visualization (teleimmersive archaeology), and simulation of digital data in virtual reality environments (e.g., Dig@IT and Duke Immersive Virtual Environment).

The main goal of this work was to experiment with new ways of interacting and interpreting data. In particular, attention was paid to the systematic 3D digital recording of all stratigraphic units of Building 89 and the interactive visualization of the corresponding data set [38].

Building 89 (East Hill, South Area; Fig. 2) was the main research site for the 2011-2015 excavation work and 3D digital recording. It is located in the eastern corner of the South Area, under Sequence B.76. It is a large square building, 5.80 m north-south and 5.20 m east-west.

Digital documentation and soil sampling revealed a stratigraphic sequence of approximately 60 plastered floors, likely representing the entire use of the house. These floors were sealed on the eastern side with a 5 mm thick compound layer of light gray, silt, and white clay plaster, which extended over the eastern central platform of the space.

One of the most interesting discoveries in this building was the bucranium, which was built into the western boundary of the main floor sequence of the central space of the building (Fig. 2).

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[38] Digital Çatalhöyük: A Cyberarchaeological Approach. Edited by Hoder I. and Tsoraki S., Societies in the Making: The Making of Çatalhöyük (pp. 89-102). London: British Institute at Ankara, Monograph 55, Çatalhöyük Research Projects Series No. 15. ISBN 9781912 090211

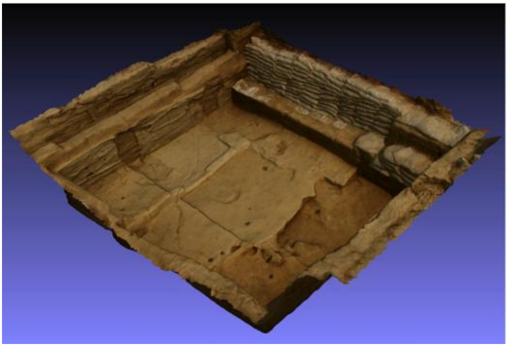

Fig. 2. 3D visualization of building B.89 using digital photogrammetry.

The first experiments in virtual simulation using data from B.89 also demonstrated the potential of this interpretive approach. For example, in MeshLab, using the computer graphics visual effect, X-Ray, the visualization of 19,807 units (cast architectural elements) shows the room filling, the relationship between walls and other architectural decorations.

In the first experiment in 2010 (Forte, 2010a: 155–62), a Minolta 910 was used to record all excavation layers of the intermediate zone.

Accordingly, in 2011, two systems were introduced simultaneously for data recording: a new phase-shift scanner (Trimble FX) and a suite of camera-based digital photogrammetry and image modeling software (PhotoScan, Stereoscan, and Meshlab).

In 2012, it became possible to record and reconstruct 21 tombs in 3D, according to skeletons and other features. In this case, the digital workflow included digital photogrammetry to generate 3D models, 2D and 3D georectification, 2D drawings of the tombs in CAD, and finally their implementation in ArcGIS as digital maps (raster-vector) and 3D models.

An interpretive challenge in this process is the comparison between the graphic realism of 3D data (stratigraphy, monumental structures, finds) and the schematic layout of vector and spatial georeferenced data.

Digital Photogrammetry and 3D Geographic Information Systems

Photogrammetric technology (digital photogrammetry) is now recognized as a tool in the field of 3D documentation in archaeology. The introduction of this recording method to support archaeological practice has made it possible to study and analyze aspects of the collected information that were previously impossible to consider (Callieri et al. 2011: 33–40).

Significant results were finally achieved during the 2013 field campaign, when the 3D textured models produced by SfM were imported and visualized in the geographic information system used on site.

In addition, during the 2010, 2011 and 2012 field seasons, optical laser scanners were also used to digitally store the artifacts of Çatalhöyük. Data such as figurines, ceramics, stone and bone tools and, in general, small finds were digitized using the Next Engine HD scanner.

Teleimmersive archaeology. A teleimmersive system is a visualization system that uses stereo cameras and Kinect haptic systems for visualization.

The Çatalhöyük teleimmersion experiments used data from buildings and focused mainly on spatial and editing tools: measurements, lighting, shading, virtual excavation and data mining. The two buildings were selected due to their architectural features and the accuracy of the available digital documentation. The 3D visualization included both 3D models and spatial databases of geographic information systems, and it was possible to simulate stratigraphic layers and metadata in virtual space. (Dell'Unto, 2020:453-59).

To achieve these goals, the following application was created to visualize the metadata available through a "virtual tablet" (Fig. 3).

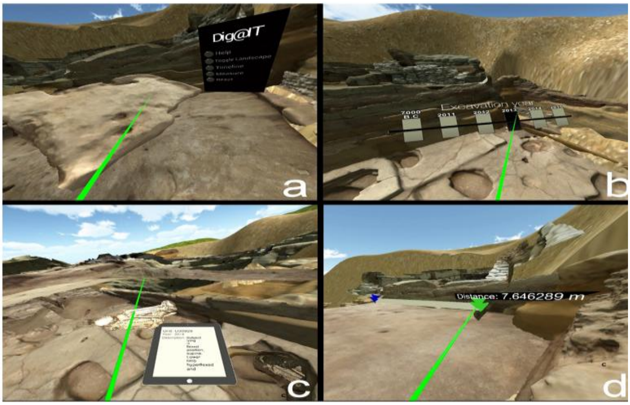

Fig. 3. Dig@IT. (a) Context menu; (b) Timeline; (c) Virtual tablet; (d) Tape measure tool view.

The archaeological documentation and 3D data represented in Dig@IT includes hundreds of 3D stratigraphic layers and features recorded from 2011 to 2014 using the digital photogrammetry workflow discussed above. Accordingly, Dig@IT allows users to visualize and exploit the stratigraphy of this building from its subsequent depositional phases.

To ensure the sustainability and preservation of digital documentation and 3D data, all 3D models of B.89, source images, digital photogrammetry project files, processing reports, and associated metadata were also published on the UCSD Library Digital Collections Portal (Lercari et al. 2017).

These experiments included simulating the building data and archaeological context and the ability for users to virtually excavate all layers recorded with digital photogrammetry at the DiVE research center.

Conclusion

The paper summarizes the main digital applications and experiments developed in the context of 3D data recording within the framework of the Çatalhöyük archaeological excavations in 2010–2015.

Photogrammetry, laser scanning, virtual reality, computer graphics, geographic information systems and teleimmersion systems represent a particularly complex combination of different technologies, methods and tools.

The findings show how digital documentation and analysis methods, 3D GIS and virtual reality-based data visualization systems, are changing the ways in which archaeological information is recorded, discussed and interpreted (Forte el al, 2015:34-35).

The right approach to data collection and spatial archiving also enabled the long-term use of these datasets in various forms, such as geographic information systems, 3D modeling, virtual reality, and collaborative systems.

The cyberarchaeological workflow and 3D documentation system developed at Çatalhöyük proved to be very effective, producing high-resolution models that were perfectly georeferenced to the excavation grid and compatible with the geographic information system on the day the data was recorded.

Therefore, digital preservation is the best and most sustainable approach available today. All 3D data obtained from the investigated buildings were linked and georeferenced to previously recorded layers and datasets, and finally a complete 3D map of the site and the entire stratigraphic context was reconstructed.

A new open-source platform called Morphosource was developed at Duke University, where the extracted 3D models and metadata can be archived.

The project also released and developed special software for collaborative research (teleimmersive archaeology) and for virtual simulation of archaeological excavations. Both platforms are designed for real-time interaction and interactive environments.

Thus, it is quite interesting to note that even after so many years since their inception, these approaches still allow for new interpretations through virtual representations.

References:

EARL, G. (2013). *Modeling in archaeology: Computer graphic and other digital pasts.* Perspectives on Science 21(2):226-244;

Callieri, M., Dell'Unto, N., Dellepiane, M., Scopigno, R., Soderberg, B., Larsson, L. (2011). *Documentation and interpretation of an archeological excavation: an experience with dense stereo reconstruction tools'* in F. Nicolucci, M. Dellepiane, S. Pena Serna, H. Rushmeier, L. Van Gool (eds.), VAST 2011: The 12th International Symposium on Workshop on Graphics and Cultural Heritage: Prato, Italy, October 18–21, 2011. Goslar, Eurographics Association: 33–40;

Dell'Unto, N. (2020). '*The analytical role of 3D realistic computer graphics' in M. Gillings, P. Hacıgüzeller,* G. Lock (eds.), Archaeological Spatial Analysis: A Methodological Guide. Routledge: 444-459;

Forte, M. (2010a). '*3D Digging Project' in Çatalhöyük* 2010 Archive Report, 128–32. http://www.catalhoyuk.com/sites/default/files/media/pdf/Archive_Report 2010.pdf ;

Forte, M., Kurillo, G. (2010). '*Cyberarchaeology: experimenting with teleimmersive archaeology'* in 2010 16th International Conference on

Virtual Systems and Multimedia: VSMM 2010: October 20–23, 2010, Seoul, Korea. Piscataway, Institute of Electrical and Electronics Engineers: 155–62. https://doi.org/10.1109/VSMM.2010.5665989;

Forte, M., Gallese V. (2015). '*Embodiment and 3D archaeology: a Neolithic house at Çatalhöyük'* in R. Crook, K. Edwards, C. Hughes (eds.), Breaking Barriers: Proceedings of the 47th, Annual Chacmool Archaeological Conference, November 7–9, 2014, Calgary, Alberta, Canada. Chacmool, Chacmool Archaeological Association of the University of Calgary: 35–55;

Lercari, N., Matthiesen S., Zielinski D., and Kopper R.. (2014). 'Towards an Immersive Interpretation of Çatalhöyük at DiVE.' In ASOR Annual Meeting - San Diego. American School of Oriental Research;

Lercari, N., Shiferaw, E., Forte, M., Kopper, R. (2017). *Data from 'Immersive visualization and curation of archaeological heritage data: Çatalhöyük and the Dig@IT app'.*

Lercari, N, (2019). '*Monitoring earthen archaeological heritage using multi-temporal terrestrial laser scanning and surface change detection'* Journal of Cultural Heritage 39: 152–65. https://doi.org/10.1016/j.culher.2019.04.005;

Mellaart J. (1967). ÇatalHüyük: *A Neolithic Town in Anatolia. London: Thames and Hudson*, 1967. pp., 136 pls. (15 in colour), 56 figs. 84s;

Mills, J., Andrews, D. (2011). *3D Laser Scanning for Heritage: Advice and Guidance to Users on Laser Scanning in Archaeology and Architecture (Second Edition*). Swindon, English Heritage. P. 57-60.

Hodder, I. (2016). More on history houses at Çatalhöyük: A response to Carleton. Journal of Archaeological Science, Volume 67, p.78-80