3D visualization and reflexive archaeology:
A virtual reconstruction of Çatalhöyük history houses

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Abstract

More than twenty years of excavations at Çatalhöyük have generated data-driven interpretations on the repetition of Neolithic buildings over multiple levels of occupation. Current 3D technologies allow us to simulate Çatalhöyük's material culture and unique urban environment, but pose questions on the role of virtual simulation and 3D reconstruction in a reflexive and multivocal archaeological discourse. What is the significance of virtually rebuilding Çatalhöyük history houses? How can different viewpoints on history—in terms of class, race, ethnicity, and gender—be represented in a 3D reconstruction? This article aims to shed light on the role of 3D technologies for the dissemination of archaeological data in promoting reflexivity, multivocality, and heritage awareness in local communities and youth. This work discusses the preliminary phases of the Virtually Rebuilding Çatalhöyük Project with the goal of illustrating the theoretical underpinning and preliminary results of this initiative.

1. Introduction

1.1 Site background

Çatalhöyük is a nine thousand-year-old pre-historic city and a very rare example of a well-preserved Neolithic settlement. Çatalhöyük has been considered a key site for understanding human Prehistory (Cauvin, 1994; Hodder, 1997a). Çatalhöyük is located in the Konya plain in Central Anatolia near the town of Çumra, in Turkey (37° 40' 19.64'' N, 32° 49' 24.63'' E). The Neolithic East Mound is 13.5 hectares in area and 21m in height with 18 levels of occupation. The Neolithic occupation dating from 7100 to 6000 cal BC (Bayliss et al., 2015) held 3000-8000 people living in mud brick houses. The smaller Chalcolithic West Mound (8.5 hectares) lies on the west side of the ancient riverbed of the Çarşamba River, now canalized, and includes settlements from the 6th millennium BC (Biehl et al., 2012).

The site was discovered by James Mellaart in 1958 and initially excavated from 1961 to 1965 (Mellaart, 1967). Rapidly, Çatalhöyük obtained worldwide attention for its street-less settlement structure, evidence of early agricultural practices outside the Fertile Crescent, and for the evidence of the emergence of pottery and copious symbolic and ritual artifacts. In 1993 Ian Hodder started the Çatalhöyük Research Project with the goal to investigate Çatalhöyük East Mound and produce further interpretations of the repetition of architectural elements and buildings over time (Hodder and Cessford, 2004). In 2012 Çatalhöyük became inscribed on the UNESCO World Heritage list because of its universal value and exceptionality.

Ongoing excavation on the Çatalhöyük East Mound has documented the repetitive practices of rebuilding domestic features, or entire houses, in the same fashion over time, as a manifestation of physical constraints as well as social memory (Hodder and Cessford, 2004).

1.2 Project background

3D visualization and digital archaeological methods make it feasible to explore alternative means of meaning making in archaeology based on non-linear narratives, three-dimensional perspective, and virtual reconstruction. Hence, this article discusses the usage of 3D real-time technologies as a way to produce new knowledge on Çatalhöyük's archaeological heritage and the practice of history-making in early agricultural societies.

In 2015 the Virtually Rebuilding Çatalhöyük Project (VRCP) was initiated as a joint effort between the University of California Merced, Stanford University, and the e-learning firm Corinth. This project aims to virtually reconstruct and simulate a 3D sequence of Neolithic buildings in a data-driven, accurate and engaging way with the following goals; (i) to provide young students with a powerful digital learning tool that enables visual-interactive explorations of Çatalhöyük; (ii) to provide archaeologists with an analytical-interpretative tool to be used in the discussion and interpretation of Çatalhöyük's archaeological record.

As discussed in detail in section 3 of this paper, the VRCP has currently completed its start-up phase producing three virtual reconstructions of Çatalhöyük buildings that were published as free content for the mobile application Lifeliqe in 2016 ("Lifeliqe for iPad," n.d., "Lifeliqe for Windows 10," n.d.).

Although the virtual reconstructions produced by the project have been extensively discussed with the Çatalhöyük Research Project's Director Ian Hodder and presented to archaeologists during the Çatalhöyük field season 2015, thorough testing of the mobile app and its content have not been completed at this stage. Future work will address this issue by conducting a comprehensive user study involving members of the Çatalhöyük Research Project, other archaeologists interested in Anatolian Neolithic, and college students. The goal of said user study will be to quantify the differences between learning about Çatalhöyük in a traditional fashion versus using interactive 3D reconstructions. Such a comparison will also generate analyses on how our interactive simulations impact the discussion and interpretation of the practice of history-making at Çatalhöyük.

Thus, the main objective of this article is to illustrate the theoretical underpinning and preliminary results of the Virtually Rebuilding Çatalhöyük Project, and to discuss the role of 3D reconstruction in the reflexive archaeology methodology employed at Çatalhöyük.

The VRCP strives to define a new approach to digital archaeology that fosters an open and inclusive debate on the interpretation of the archaeological evidence. Our work also proposes a three-dimensional approach to reflexive archaeology that integrates a plurality of digital data and interpretations in a visual-analytical environment, where advanced interactive techniques simulate the cosmology, building practices, material culture, and history-making aspects of Çatalhöyük. In this regard, the start-up phase of our initiative devoted serious effort to represent in 3D the continuity of building practices in the stratigraphy of a number of Çatalhöyük Neolithic houses that were rebuilt multiple times in the same place (see Fig.1).

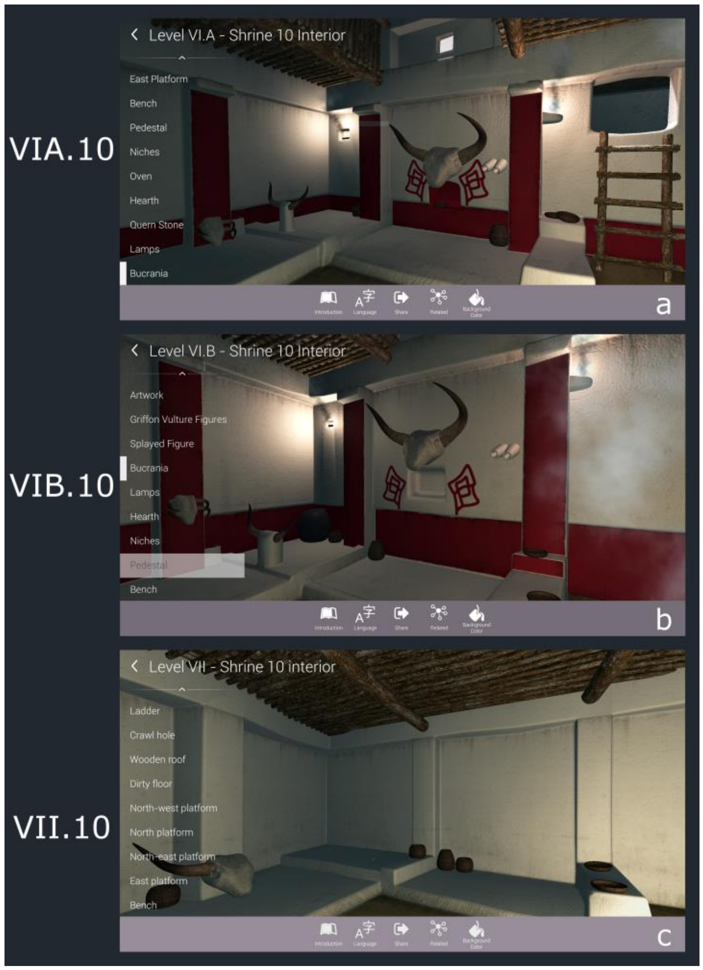

Figure 1. Overlaying view of 3D reconstructions of (a) 'Shrine' VIA.10, (a) 'Shrine' VIB.10, and (c) 'Shrine' VII.10 in Lifeliqe. Source: Nicola Lercari.

2. Virtual simulation as a reflexive method

Visualization, virtual space, interaction, presence, and immediacy are fundamental aspects of a virtual simulation of the past that may not seem related to the process of archaeological interpretation, at a first glance. As specified in Section 1.2, the goal of this paper is to verify whether the practice of simulating and virtually reconstructing Çatalhöyük history houses—or more elaborate buildings that were rebuilt multiple times in the same place (Hodder, 2016; Hodder and Pels, 2010)—can be integrated in the reflexive excavation methodology employed at Çatalhöyük.

Reflexivity in archaeology is defined as ‘the examination of the effects of archaeological assumptions and actions on the various communities involved in the archaeological process, including other archaeologists and non-archaeological communities’ (Hodder, 1997b).

Multivocality is one of the main reflexive strategies employed at Çatalhöyük. Multivocality is a mechanism that allows the archaeological discourse to represent dissonant voices and conflicting interests on the past as well as to engage local communities and multiple stakeholders in the interpretation process (Hodder, 1997b).

This article seeks to demonstrate that 3D reconstruction and virtual simulation, as non-linear and interactive data visualization systems, need to be considered as reflexive tools for the interpretation of the archaeological record (e.g. excavation diary, relational database, and Geographic Information System).

A long tradition of creative, analytical, and methodological techniques has characterized the fields of archaeological illustration and visualization for decades. However, recent work denounces that the practice of visualizing the past has been marginalized within the archaeological community as a discipline that is disconnected from the fieldwork that does not contribute to the actual production of knowledge (Perry et al., 2014). Nonetheless, more than twenty years of archaeological illustration and visual interpretation of Çatalhöyük’s built heritage and material culture have proven that the act of visualizing the past has an actual epistemic value, especially when this practice is embedded in a reflexive approach to archaeology (Hodder, 1997b; Swogger, 2000).

From the drawings and isometric visual restorations crafted by Grace Huxtable and N. Alcock in the 1960’s, to the interpretative illustrations created by James Swogger and Kathryn Killackey for the Çatalhöyük Research Project, to the 3D documentation methods utilized in a revised reflexive methodology (Berggren et al., 2015), visualization in archaeology has largely increased its scope and significance overtime. By enhancing the spatial-analytical capabilities of the visual tools that illustrators and archaeologists make available to other scholars and the general public, digital technologies and methods have certainly contributed to accelerate this process.

The limits and potential of using 3D data and visualization in archaeology in relation to GIS have been thoroughly discussed since the early 2000’s (Conolly and Lake, 2006; Lock, 2001, 2003). Despite their hermeneutical role, digital models and 3D visualization in archaeology have attracted the same criticism that targets analog illustration and visualization techniques (Perry et al., 2014).

A broader acceptance of 3D visualization had not pervaded the archaeological community until the late 2000’s, when the strength of a three-dimensional approach for intra-site research using GIS was finally proven (Katsianis et al., 2008). Recent work delivers additional evidence of the role of digital documentation, visualization, and 3D reconstruction in the generation of new spatial knowledge on ancient buildings within the context of a 3D GIS (Dell’Unto et al., 2016).

To shed light on the role of visualization and virtual simulation in reflexive archaeology as well as to situate the work of the VRCP within the Çatalhöyük Research Project, this article needs to highlight the differences between our work and previous research conducted on-site by scholars and students from the University of California Berkeley, the University of California Merced, University of Southampton, Duke University, and other institutions in the last three decades.

Digital visualization at Çatalhöyük started in the 1990’s with the early 3D computer graphics imagery produced by the Karlsruhe team (Emele, 2000). Subsequently, the work of the Berkeley Archaeologists at Çatalhöyük (BACH) team on digital media and interactive data visualization contributed to further advance our understanding of the hermeneutical role of visualization in archaeology (Stevanovic and Tringham, 2012). Specifically, from 1997 to 2003 the BACH team led by Ruth Tringham produced seminal non-linear ways to disseminate the archaeological record and its interpretations, including open access metadata publications, remediation of different media content and platforms, interactive visualizations of archaeological data on the Web (Ashley et al., 2011), and collaborative virtual reconstructions in Second Life (Morgan, 2009).

More recently, the photorealistic approach used by Grant Cox and the Southampton team in rendering a highly-evocative reconstructions of Çatalhöyük history house F.VI.I, or the 'Shrine' of the Hunters, proved that a data-driven virtual simulation can be successfully merged with subjective interpretations to produce new knowledge (ArtasMedia, n.d., n.d.; Cox, 2011) (See Fig. 2).

Figure 2. 3D reconstruction of Çatalhöyük history house F.V.I, or the 'Shrine' of the Hunters. Source: ArtasMedia – Grant Cox.

In the 2010's, additional research on digital archaeological methods at Çatalhöyük contributed to emphasize the epistemic value of visualization in archaeology by integrating 3D modeling, digital documentation, and virtual simulation in the daily activities of the excavators (Forte et al., 2012). More precisely, between 2010 and 2015, a multidisciplinary team of archaeologists and heritage specialists from the University of California Merced, Duke University, and Lund University digitally recorded the 3D topology of each stratigraphic layers of Building 89 in the framework of the 3D Digging at Çatalhöyük Project (3D Digging) led by Maurizio Forte (Lercari, 2016a). The goal of this initiative was to define novel methods for the interpretation of the archaeological record using interactive visual-analytical tools, such as the ones available in the 3D Geographic Information System (GIS) platform ESRI ArcScene, or the in the custom virtual reality software for archaeology Dig@IT developed at Duke University (Forte et al., 2015).

The main differences between the VRCP and other 3D visualization initiatives mentioned above lies in the approach that we employed to simulate the archaeological record. While the BACH team's and the

3D Digging team's work focused on the digital documentation of ongoing excavation, the digitization of stratigraphic layers or artifacts, or the online publication of 3D models and metadata, the VRCP used a different approach to digital archaeology more geared towards education and public outreach using mobile devices (Lercari, 2017). Thus, our 3D reconstructions of Çatalhöyük buildings were designed and built for interactive exploration on tablets. In this regards, they differ from the hyper-realistic animations created by the Southampton team as they are real-time and interactive. In addition, our virtual simulations not only render in 3D the archaeological record of 'Shrine' 10, but they also attempt to visualize the spatial and temporal relationships that connect overlaying buildings, architectural elements, and ritual objects over time with the goal to interpret and represent the ritual and history-making practices that make Çatalhöyük history houses so unique.

To continue the discussion on the role of 3D visualization and virtual simulation in the reflexive methodology, one needs to underline that a new development of the reflexive archaeological practice shows that a broad spectrum of visual-analytical 3D technologies can be successfully integrated with the interpretation 'at the trowel's edge' (Berggren et al., 2015). Hence, one can verify that in the 2010s virtual simulation at Çatalhöyük has gained legitimacy by implementing interactive analytical and visualization tools able to convey spatial and temporal information on layers, features, and entire buildings in 3D real-time virtual simulation platforms (Lercari et al., 2014, 2013).

Broadly speaking, virtual simulation can be defined as a visual-analytical method able to render, reconstruct, and interpret the past using non-linear digital technologies. This article considers virtual simulation as an essential component of the reflexive methodology employed at Çatalhöyük. The significance of this practice builds upon the relevance of other reflexive information systems widely used in the current project, such as the Çatalhöyük Database ("Çatalhöyük Database," n.d.), the Çatalhöyük Image Collection Database ("Çatalhöyük Image Collection Database," n.d.), and the GIS (Berggren et al., 2015). Similarly to other reflexive tools, such as the excavation diary (Mickel, 2015), a virtual simulation contributes to produce redundant information on the archaeological process itself by creating networks of meanings and interpretations generated by archaeologists and non-archaeologists who interact with the simulated data.

In addition, consumer technology such as tablet PCs or iPads, currently enables archaeologists to interact with 3D models and virtual simulations directly in the trench. Pondering the 'mobile nature' of a tablet-based 3D reconstruction, one can further align the process of virtual simulation of the past with the reflexive practice of interpretation 'at the trowel's edge' employed in the excavation of Çatalhöyük. As discussed in Section 3, all the 3D reconstructions that we created in the Virtually Rebuilding Çatalhöyük Project are available on tablet PCs featuring Windows 10 or on iPads.

Another aspect of a virtual simulation, which is relevant to the methodologies discussed in this section, is the possibility for a 3D reconstruction to render multiple hypothesis and interpretations of the past. This capability allows a virtual simulation to foster discussion, multivocality, and inclusive interpretations. Due to the high cost, time, and amount of resources needed to create multiple visualizations of the same case study, many 3D reconstructions often do not to exploit this potential. As a consequence, reflecting on the 3D model and its relationship with the archaeological record becomes a fundamental component of reconstructing archaeological heritage in 3D. Thus, one can infer that being involved in the creation of a 3D model or in the design of a virtual simulation is a hermeneutical process itself. Since reconstructing the past in 3D entails re-interpreting the archaeological record, one can assume that scholars, students and the general public that get involved in the reconstruction process participate in a discussion that is often more informative than exploring the models themselves.

To solve this issue, this paper proposes an approach to the virtual simulation of the past that enables a direct and active connection between the visualized data, its creators, and users. Dismantling the boundaries between cultural production and reception, the participatory 3D reconstruction of the past empowers its users, making them protagonists in the co-creation of cultural meanings and different interpretations within the simulated environment itself. As of 2017, implementing this open and multivocal approach in a real-time simulation platform still represents a technological challenge. The Virtually Reconstructing Çatalhöyük project aims to address this issue in future implementations of our 3D reconstruction by developing a custom interactive visualization application.

Potential criticism to a participatory and multivocal approach to the simulation of the past may come from those who believe that presenting multiple view-points on history could undermine the authoritative role of international standards and principles on virtual reconstruction (Beacham et al., 2006; Denard, 2012; Lopez-Menchero and Grande, 2011). Nonetheless, this article argues that involving multiple individuals—defined by different classes, races, ethnicities, and gender—in the co-creation of meaning within a virtual simulation may contribute to expanding our viewpoint on the archaeological evidence and, thus, enhance the analytical value of the 3D reconstruction. From a technical standpoint, said multi-vocal approach to the simulation of the past is quite difficult to implement in a 3D reconstruction that is pre-determined by domain specialists and rendered by a computer. The VRCP aims to solve this technical challenge allowing its users to take part in an interactive discussion on the simulated material by leaving comments and proposing alternative reconstructions. For instance, one could hypothesize that in the near future, the general public of the Internet will be able to experience the simulation of the 'Shrine' 10 sequence through the Çatalhöyük Living Archive's website ("Çatalhöyük Living Archive," n.d.; Grossner et al., 2012); such a digital access will be enabled by linking the online 3D interactive visualization to the archive itself. In this supposed scenario, different users, with alternative viewpoints on Çatalhöyük's art and religious rituals, could participate in the negotiation of cultural meanings on the simulated history houses, expressing critiques on the hypothesis proposed in the virtual environment and proposing their own interpretations. To close the reflexive loop, such alternative interpretations will need to be recorded by the system and then included in the virtual simulation of 'Shrine' 10 in a way that allows transparency and keeps the reconstruction process open to further feedback.

3. A 3D reconstruction of Çatalhöyük history houses

As anticipated in Sections 1 and 2, the case study of the VRCP is the visualization of the practice of history-making in early agricultural societies with a specific focus on the 3D reconstruction of a number of Çatalhöyük history houses.

From 2015-2016 we completed the start-up phase of the project by virtually reconstructing three highly decorated overlaying buildings (Building VIA.10, VIB.10, and VII.10) excavated by James Mellaart in 1962 and 1963 in the so-called 'Shrine' 10 sequence. Mellaart's and Hodder's work have testified that 'Shrine' 10 is one of the longest and most elaborate repetitions of buildings ever documented at Çatalhöyük (see Fig. 3a); thus, the 'Shrine' 10 sequence is an optimal case study for virtually simulating building variation and history-making practices in this Neolithic city.

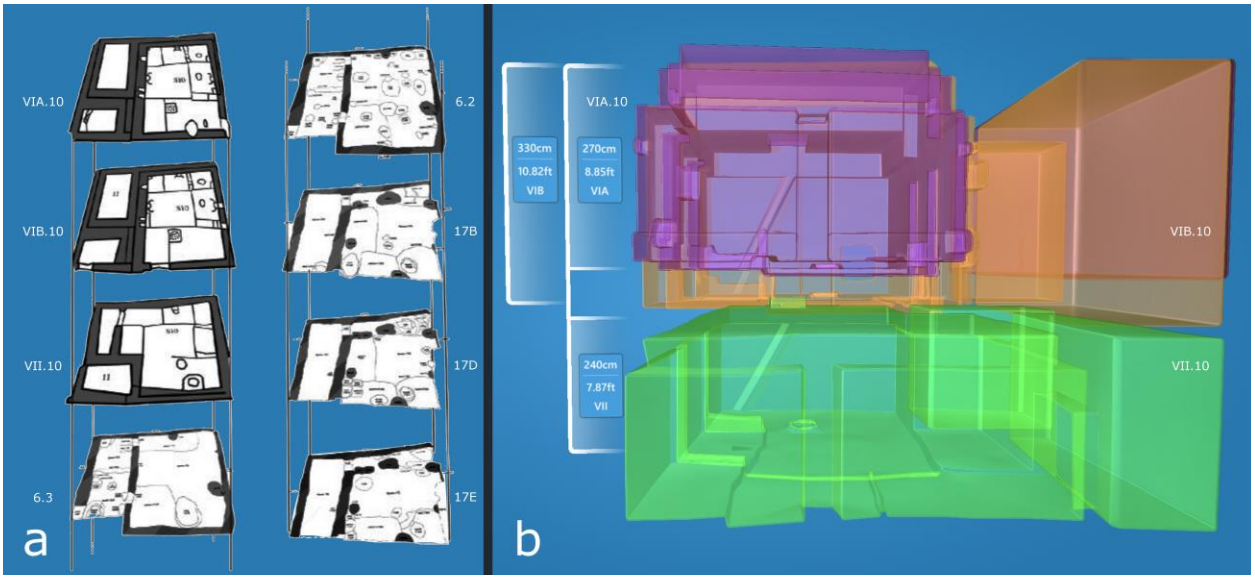

Figure 3. (a) Drawings of the complete 'Shrine' 10 sequence and (b) View of Mellaart's 'Shrine' 10 in level VIA, VIB, and VII rendered as transparent overlaying layers in Corinth Classroom. Source (a): Çatalhöyük Project - Tim King. Source (b): Nicola Lercari.

Drawing on seminal work on building variation at Çatalhöyük (Hodder, 2010, 2006), our project sought to explore the practice of history-making by producing interactive 3D reconstructions that could be freely disseminated online or as an app for mobile devices. To achieve this goal, we leveraged the capabilities of Corinth Classroom, a digital learning software that allows users to: (i) browse collections of 3D content and metadata, (ii) make annotations on the 3D models, (iii) take quizzes, (iv) capture snapshots and drawings, and (v) participate in interactive discussions on the simulated material ("Corinth Classroom," n.d.). This application is capable of displaying textual and visual information such as 2D images and graphics, and 3D interactive content with incredible realism and advanced shading and lighting effects.

In 2016, our preliminary results were also published in the Apple Store and Window Store as free content for the mobile application Lifeliqe ("Lifeliqe for iPad," n.d., "Lifeliqe for Windows 10," n.d.). By accessing Lifeliqe as 'guests', users can freely explore the 3D reconstructions of the three history houses reconstructed by our team.

The most noteworthy features of Lifeliqe are: (a) ability to display high quality 3D interactive real-time visualizations; (b) ability to support visual learning with bilingual view (English and Spanish); (c) ability to display background information and metadata side-by-side with the 3D reconstruction; (d) possibility to interactively annotate the 3D models with comments and custom descriptions; (e) ability to share snapshots and views of the 3D reconstructions displayed in Lifeliqe directly in a PowerPoint; (f) augmented reality capabilities that merge the 3D reconstructions with the real world in front of the user; (g) ability to zoom on the 3D data from a wide angle view to a very close range view.

The initial phase of our project builds on Mellaart's reports on the excavation season 1962 and 1963 (Mellaart, 1964, 1963). Using CAD-based documentation produced by the Çatalhöyük Research Project

(See Fig. 4a), we reconstructed in 3D a large ‘Shrine’ 10 in level VIA measuring approximately 5.75x4.35 meters (Lercari, 2015a)(See Video 1).

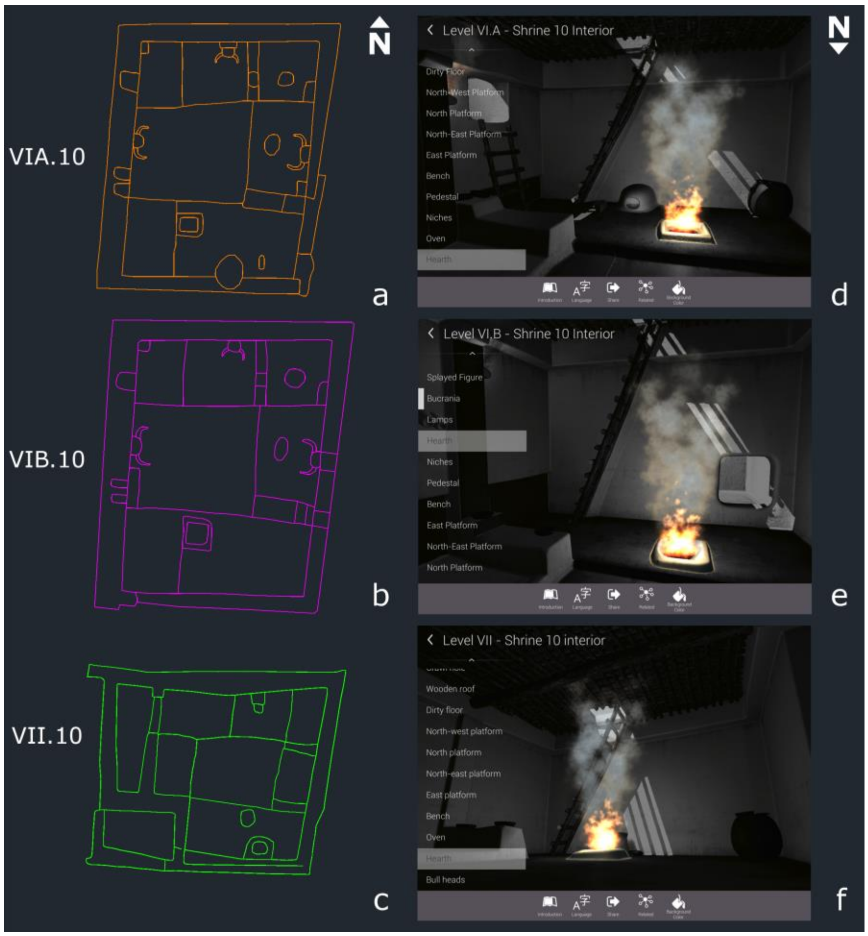

Figure 4. Overlaying view of CAD drawings of (a) VIA.10, (b) VIB.10, and (c) VII.10 and overlaying view of house-based history-making in the ‘Shrine’ 10 sequence, displaying the repetition of the hearth in level VIA (d), VIB (e), and VII (f) rendered in Lifeliqe. Source (a), (b), (c): Çatalhöyük Project. Source (d), (e), (f): Nicola Lercari.

Video 1. Demo showing a 3D reconstruction of ‘Shrine’ 10 in level VIA in Corinth Classroom. https://www.youtube.com/watch?v=6ggPhwbNRAM

The virtual simulation of this history house presents details of the Northern platforms with painted panels, a bull-pillar, and of the northern wall with a double-horn ram head in the middle and a plaster box for offerings. Our 3D reconstruction also illustrates the elaborated composition of a painted bull head, its surrounding wall painting, and a niche located in the East wall. Most remarkably, the visualization of this building includes “three superimposed bull heads” attached to the West wall and the approximately 1 m tall splayed figure of a goddess giving birth to a ram that was discovered partially preserved at the bottom of the west wall (See Fig. 5). The size of this monumental splayed figure brought Mellaart to hypothesize the presence of a 3-meter-tall clerestory in the central part of the building.

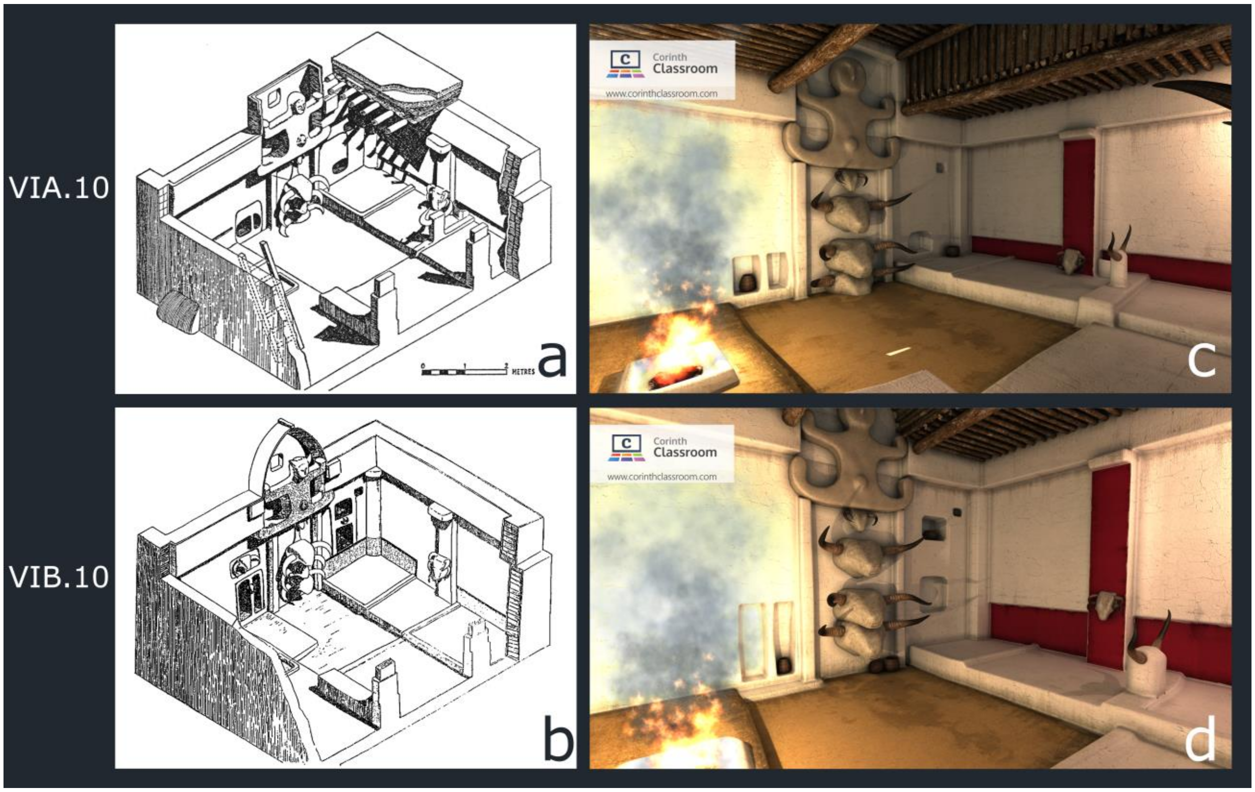

Figure 5. Overlaying and comparative views of (a) Mellaart's visual restoration of 'Shrine' 10.VIA, (b) Mellaart's visual restoration of 'Shrine' 10.VIB, (c) 3D reconstruction of 'Shrine' 10.VIA in Lifeliqe and (d) 3D reconstruction of 'Shrine' 10.VIA in Lifeliqe. Source (a) N. Alcock and Grace Huxtable in Mellaart 1962. Source (b) Grace Huxtable in Mellaart 1963. Source (c) (d): Nicola Lercari.

The 3D reconstruction of 'shrine' 10.VIB presented in this article displays that burials in this earlier phase were also located in the same location as in 10.VIA, specifically the Central East and North East platforms (see Fig.6).

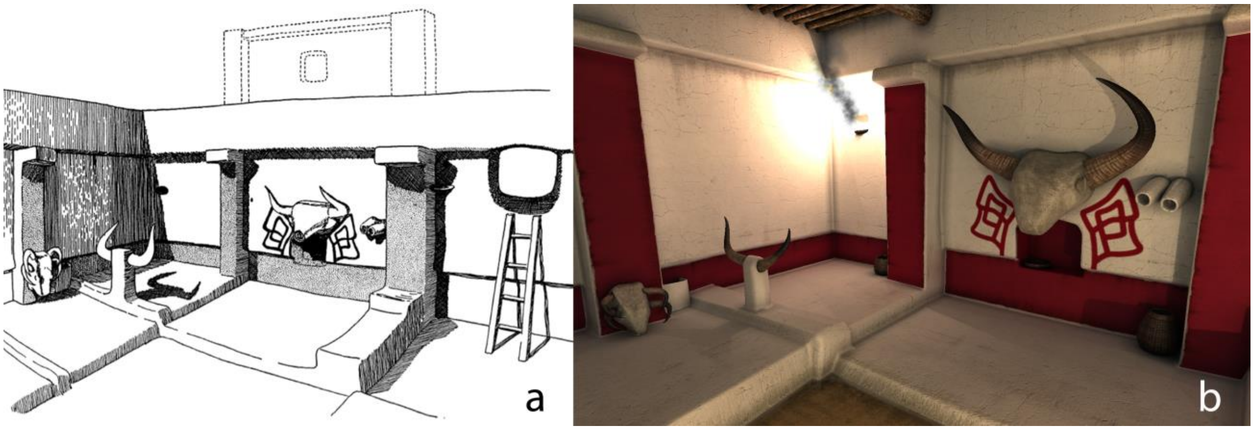

Figure 6. Comparative view of (a) Mellaart's visual restoration of the Eastern part of 'Shrine' 10.VIB and (b) a 3D reconstruction of the Eastern part of 'Shrine' 10.VIB in Corinth Classroom. Source (a): Grace Huxtable in Mellaart 1963; Source (b): Nicola Lercari.

The elaborated bucrania and wall-painting that adorned the West, North, and East walls of VIB.10 were maintained in situ and renewed in VIA.10, even though the Southern part of the house was modified. This evidence suggests a clear and intentional display of a common history between the people who occupied 'Shrine' 10 in subsequent periods. Our simulations of buildings in levels VIA and VIB also include the splayed figure discussed above and two different reconstructions of the clerestory as proposed by Grace Huxtable, the illustrator working with Mellaart in the 1960s.

The virtual simulation of 'shrines' 10.VIA and 10.VIB (Lercari, 2015b) (See Video 2), aims to emphasize the continuity existing in these two phases (see Fig. 5) as an evidence of history-making. It is particularly interesting to see how few details changed in the two phases of this building. Major discontinuities between the two phases substantiate in the following variances: difference in the location of the crawl holes, located in the Southern part of the East wall in 'Shrine' 10.VIA and in the Western part of the Southern wall in 10.VIB, in the absence of an oven in 10.VIB, and in the reduced size and number of the niches in the West wall of 10.VIA.

Video 2. Demo showing a 3D reconstruction of 'Shrine' 10 in level VIB in Corinth Classroom.
https://www.youtube.com/watch?v=mEKGHKwW0nw

The virtual simulation of 'Shrine' 10 in level VII shows that this earlier building was less ornate if compared to its later remakes in level VIA and VIB. Even if its plan strictly resembles the one of 10.VIB, 'Shrine' 10.VII only has a plaster relief in the North wall and do not present evidence of wall painting. Mellaart's reconstruction of 10.VII shows another plastered artwork in the North East corner of the building, specifically "a stag on a rock". This feature was consciously omitted from our 3D reconstructions because Mellaart's interpretation was not adequately supported by the photographic documentation provided in his 1967 publication (see Fig. 7).

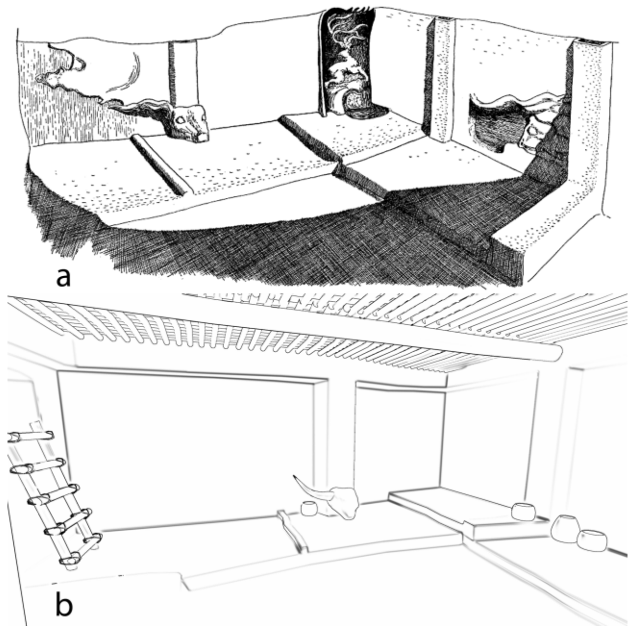

Figure 7. Comparative view of (a) Mellaart's visual restoration of 'Shrine' 10.VII and (b) isometric drawing of 'Shrine' 10.VII automatically generated by Corinth Classroom. Source (a): Grace Huxtable in Mellaart 1963; Source (b): Nicola Lercari.

Besides the educational value of the proposed virtual simulations of three 'shrines' in level VIA, VIB, and VII, the significance of our preliminary results derives from the possibility to visualize in 3D the spatial relationship of features and parts of these buildings in a comparative view of their levels (see Fig. 3b). This type of 3D visualization also informs the user of the estimated height of each building and correlates the available data with a three-dimensional representation of the stratigraphy of the 'Shrine' 10 sequence (Lercari, 2017).

Finally, the comparison of the 3D reconstructions in three overlaying levels allows users to actively learn about the repetition of patterns and spatial relationship of features among buildings as well as to propose their own interpretations. For instance, users can verify the vertical alignment of the hearth features in all of the three buildings we reconstructed in 3D (See Fig. 4b) (See Video 3) (Lercari, 2015c) and discuss their role in the history-making practices that characterize this sequence of history houses.

Video 3. Demo showing Corinth Classroom app menu and comparative view of Mellaart's 'Shrine' 10 in level VIA, VIB, and VII rendered as transparent overlaying layers.
https://www.youtube.com/watch?v=sVIgJjz2DZg

Future work will complete the simulation of the stratigraphic sequence of 'Shrine' 10, adding 3D reconstructions of Building 24 in level VII, Building 6 in level VIII, and Building 17 in level XI as they were excavated and documented by the current project (Hodder and Pels, 2010).

We plan to replicate the methods and reconstructions discussed in this Section using 3D game-engines like Unity 3D ("Unity 3D," n.d.) or Unreal Engine ("Unreal Engine," n.d.). These 3D visualization platforms can be customized to include analytical tools and real-world coordinates to produce new paradigms for the virtual simulation of the past. Such technologies present a great potential because they are able to reduce the gap that still exists between the processes of data collection and interpretation on the one hand and the dissemination of archaeological data on the other.

For instance, the users of a future 3D reconstruction of Çatalhöyük buildings—created in Unreal Engine for the VR headset Oculus Rift ("Oculus Rift," n.d.)—will take part in simulated religious rituals or social activities embodying themselves as digital avatars that represent the people who lived in this Neolithic city.

4. Conclusions

This article strived to demonstrate that a contemporary discourse on the virtual simulation of the past needs to utilize a reflexive perspective and go beyond the discussion of technological advances that often characterizes digital archaeology literature.

History-making in 3D, virtual place-making (Champion and Dave, 2007), the role of spatiality and temporality in a historical virtual environment (Lercari, 2011), the representation of multiple viewpoints on history (Lercari, 2016b), are almost unchartered territories in a virtual simulation and 3D reconstruction of the past that future research in this field should address.

The significance of virtually rebuilding Çatalhöyük history houses derives from the fact that a 3D reconstruction 'attracts' people inside the archaeological context and involves them in a synesthetic process of meaning making in which both tangible and intangible elements of the past can be discussed, shared, and understood (Lercari, 2010; Lercari et al., 2011).

While GIS and other visual-analytical tools have contributed to expand the boundaries of archaeological interpretation, our reflexive and three-dimensional approach to the study of Çatalhöyük history houses proposes to expand the interpretation of the archaeological record beyond the fieldwork and data processing phases, by including the new knowledge produced by the multivocal feedback provided by its users.

In our approach, the power of a 3D reconstruction of the past is consolidated by new peculiar typologies of spatiality and temporality, typical of a virtual environment. Such formal structures allow users to identify, analyze, discuss, and interpret the spatial and temporal dimensions of Çatalhöyük 'history houses with a greater ease, when compared to a traditional form of data curation such as a textbook or a photo collection.

This article strived to situate the practices of 3D visualization and virtual simulation within the revised reflexive methodology utilized at Çatalhöyük. This work also expressed the importance of creating virtual simulations that promote multiple viewpoints on the past, presenting a more inclusive, and multivocal approach to the interpretation of Çatalhöyük history houses. Beyond the pedagogical value of the virtual reconstruction proposed in this article, the significance of our preliminary results derives from the possibility to provide scholars, students, and the general public with a three-dimensional perspective on the stratigraphy of these buildings across multiple levels as rendered in Corinth Classroom or Lifeliqe (see Fig.3).

This paper argued that a virtual simulation allows users to better visualize and read the conscious, or unconscious, repetition of building patterns and rebuilding or destruction of features in overlaying buildings. For instance, the users of our 3D reconstructions can verify the repetition of the hearth in three history houses belonging to the 'Shine' 10 sequence that were simulated in Lifeliqe (see Fig.4d, Fig.4e, and Fig.4f). This type of comparative 3D visualization also informs its users of the estimated height of each building and correlates this information with a three-dimensional perception of the stratigraphy of the visualized buildings.

To conclude this paper, one needs to highlight that our aim is to conduct additional research on 3D reconstruction and virtual simulation as reflexive methods in archaeology as well as to develop a custom 3D visualization and interactive data exploration platform that will build on the theories and methods presented in this article. Our ultimate objective is to expand the Virtually Rebuilding Çatalhöyük Project and to design and develop a custom 3D data curation system that leverages virtual reality and real-time computer graphics; using the powerful Unreal Engine, the new system will be open to feedback by enabling a more immersive and multivocal visualization of Çatalhöyük's past. Future work will focus on designing strategies and methods that will allow our simulation platform to be engage its users in the interactive exploration of different types of archaeological data and propose alternative interpretations.

As mentioned in section 1.2, additional research needs to be performed to test our 3D models and virtual simulations in a comprehensive user study involving the archaeological community and college students. The goal of such a user study will be to produce new quantitative data on the pedagogical role of 3D reconstructions, virtual simulation, and to assess the impact of simulation technologies on the interpretation of archaeological data.

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