Designing the Ideal Mixed Reality (MR) Headset for Archaeological Fieldwork

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Abstract. Mixed Reality (MR) headsets offer the promise of greatly enhancing the ways that archaeologists collect and interact with their data during fieldwork. Archaeology is inherently spatial, visual, and grounded in the 3D reality of the world, which makes immersive MR headsets a natural fit for our discipline. However, none of the existing MR headsets are suitable for continuous practical use during archaeological fieldwork. Therefore, we here undertake the important creative exercise of laying out a design for an ideal MR headset for archaeologists of the future. We base this design upon our own practical experiments with existing technology during our field excavation. First, we provide our motivation for pursuing this project, to enhance how archaeologists interact with their 3D data. We then present both a vision of how MR headsets could be used to support fieldwork, and we document the limitations of the current MR headsets that work against achieving this vision. Next, we present specific details for several different requirements for an ideal headset that could overcome these limitations. Our goal is to encourage other archaeologists to engage in experimentation with MR headsets during their own fieldwork in order to better understand the future possibilities. We also hope to encourage technologists and archaeologists to collaborate towards building new MR headsets that can achieve at least some aspects of our ideal design.

Keywords: Extended Reality · Archaeology · Fieldwork · Mixed Reality · Headsets

1 Introduction

1.1 Motivation

Archaeological fieldwork is a highly embodied mode of research. We travel to an ancient site, and we excavate that site using a variety of manual tools, from picks and trowels to brushes and sieves. Excavation is also, of course, an inherently 3D process in the real world (Roosevelt et al. 2015). We strongly believe, therefore, that archaeologists need to find ways to return our digital data collection procedures to this embodied 3D world. We should not simply replace paper and pencil with smartphone and finger as 2D collection medium (Morgan and Wright 2018). Instead, we should take advantage of the affordances of the new technology, the power of scientifically grounded, geometrically

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precise, digital 3D graphics that have been available to us for several decades. Indeed, many archaeologists collect 3D data during excavation, however, they are not using these data immediately and in-situ during that excavation to interpret data or guide further digging (Liang 2021; Petrosyan et al. 2021). We see immersive Mixed Reality (MR) headsets as the technology that will enable archaeologists to have immediate embodied interaction with their primary data during excavation. However, the ideal version of this MR technology does not yet exist. Therefore, we present here our vision for a headset that would actually be useful for practicing archaeologists in the field. Our purpose is to clearly articulate what is required and thus to set a research agenda and direction for the creation of new technology.

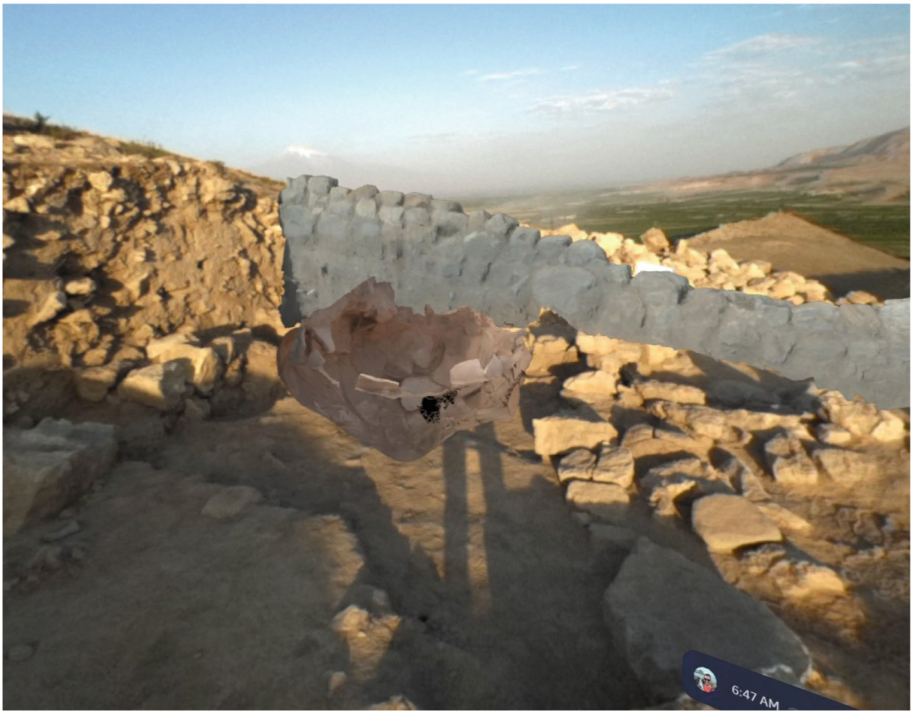

Fig. 1. Putting 3D models of pottery and stone walls back in place in their original positions in an archaeological trench. This is what a user sees through the Meta Quest Pro, with the digital virtual pottery (brown) and rocks (grey) that were previously excavated, seen back in-situ in the trench.

1.2 Vision

MR headsets create a visual integration between the real and virtual worlds for the user (Liang 2021). Visual archaeological information includes any material, features, and objects that have been excavated and thus removed from a trench on a site, as well as whatever has been uncovered but has yet to be removed (Dilena and Soressi 2020). Archaeologists may also create reconstructions to conceptualize and visualize how things looked in the past, both of objects and architecture. The most important characteristics of these data are spatial – the precise location of features or the scale and shape of objects (Klehm 2023). Archaeologists need to understand the spatial relationships among the material remains in a trench to trace the stratigraphy and unwind the depositional history (Fig. 1). This type of information can support decisions on where to dig next (Gaugne et al. 2019). With objects like artifacts and ecofacts, archaeologists need to examine their shapes to intuit how they were used and modified in the past. Broken artifacts can also be puzzled back together for a more complete understanding of their functions and styles. All these visual-spatial tasks can be simulated in 3D digital space, but archaeologists particularly need to do this work in-situ, at the location where the materials were originally excavated. They need to be able to mix, in their visual surrounding space, real objects and real material remains in the ground with removed objects and remains. MR provides the ability to support such precise, intuitive, and natural interactions for the user, in a way that leaves the user's hands free for physical work and the manipulation of the real world.

1.3 The Current State

We are able to suggest that no existing MR headset technology satisfies this vision for useful archaeological immersion due to our own extensive field testing of the current leading options at an active archaeological fieldwork project in Armenia (Cobb and Azizbekyan 2024; Cobb et al. 2025). All these options have limitations that prevent their continuous use in the hot, dusty, and sunny conditions of our archaeological site, which also lacks electricity (Table 1). Common problems include discomfort due to weight and the enclosing of the eyes, short battery life, constrained digital working area, low sunlight visibility, and restricted field of view. However, through these experiments and the recognition of these specific shortcomings, we can know what features an ideal MR headset would need.

Table 1. Summary of existing headset limitations.

Product	Description	Limitations
Microsoft HoloLens 2	MR with transparent screens	566 g, no sunlight visibility, 2-hour battery, small field of view
Meta Quest 3 (similar to Quest Pro)	Enclosed Virtual Reality (VR), with camera pass-through MR	515 g, small boundary area, 2-hour battery, no peripheral vision
Apple Vision Pro	Enclosed VR, with camera pass-through MR	unbalanced 600 g, motion blur, no peripheral vision
Vuzix Blade 2	Smart glasses with 2D screen in one eye	no 3D immersion, unreliable user interface, barely sunlight visible

2 Design

In this paper, we propose a design for an ideal MR headset that would one day change the way all archaeologists work in the field. This is an ideal – a yet unrealizable concept for an implementation to match our vision of how archaeological practice could be enhanced by immersive digital 3D in the future. We imagine that archaeologists would wear an MR headset all day in the field while digging, undertaking other physical tasks, and analyzing and interpreting data. Actually realizing this ideal would take a combination of the natural progression of technology based on the work of technology companies, together with close collaboration between research engineers and archaeologists in interdisciplinary projects (Anderson et al. 2021; Cobb et al. 2019). We undertake here the creative imaginative exercise of proposing an ideal design in order to spark interest and more detailed discussions among archaeologists and to provide a foundation for future work.

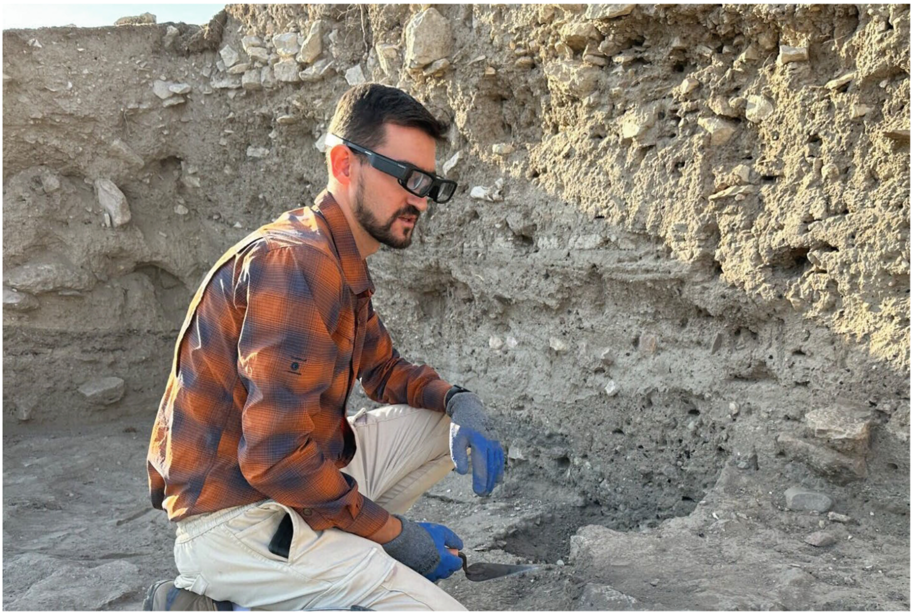

Fig. 2. The Vuzix Blade 2 smart glasses being used in the field, in an excavation trench.

2.1 Physical Comfort

The most important factor for whether an MR headset can be used for an extended period of time in the field will be its comfort to the human user. In order to continuously collect and interact with data while digging, the user should not want to remove the headset. We tested the Vuzix Blade 2 smart glasses at our excavation site (Fig. 2). This device contains a screen, camera, and microphone and has internet connectivity, in a package not much bulkier than normal glasses. Weighing 90 g, we felt that this was an acceptable form for the technology that we could use for an entire day of fieldwork, though it could still be more compact and lighter. In our ideal design, we recommend removing as many components as possible from the headset itself and placing them in a package that can be held in the user's pocket. The Apple Vision Pro, for example, has a separate battery connected with a wire. In addition to the battery, perhaps the processor could also be separated, leaving only the screen and sensors within the headset itself.

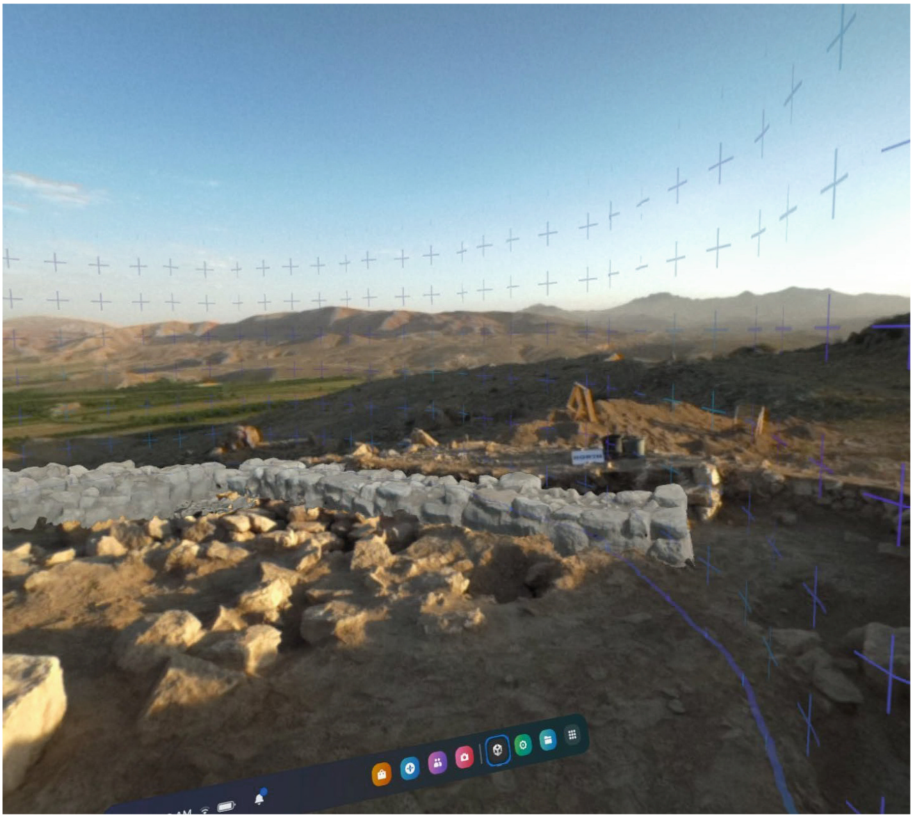

Fig. 3. User view through the Meta Quest Pro, showing the boundary limit for the virtual space as a curved plane of blue checks.

2.2 Visibility

Archaeologists need to have as much visual information as possible and their natural view should not be distorted or obstructed in any way, since excavation is a precise and highly visual activity. Screens also need to be perfectly visible in bright sunlight, with the possibility for opaque graphics that can occlude the real world. The closed screens of VR headsets like the Quest 3 or Vision Pro currently provide the widest field of view, high resolution screens, and excellent sunlight visibility. However, it would be best to see the actual real world through transparent screens rather than via camera feeds, which always introduce some noise and distortion. The ideal, therefore, would be screens like the HoloLens 2, but with a significantly wider field of view that feels natural and the ability to see opaque graphics in the sunlight. Higher resolution screens will always be better, but we do feel that the current level achieved by the Vision Pro is sufficient. Finally, there should be no limit to the area where 3D graphics can be projected and where the user can move. The Quest devices have boundary boxes with areas no larger than about 6×6 m, which is not even sufficient to cover our excavation trenches (Fig. 3).

2.3 Durability and Electrical Power

Archaeological fieldwork presents uniquely challenging environmental conditions for electronic equipment. Our site is full of dust and dirt; sometimes it rains, though mostly the sun is baking us and our equipment in the heat; and the digging equipment and the movement of people and dirt can easily damage electronics (Fig. 4). Furthermore, our site does not have an electrical power supply, though we have recently begun carrying solar panels and a large battery to the field. Thus, an ideal MR headset must be able to survive in the outdoors while being used for many hours a day in the dust and sun, without overheating. For power, the example of the Vision Pro seems suitable, since the pocket battery can be swapped on a regular basis to enable continuous use of the device.

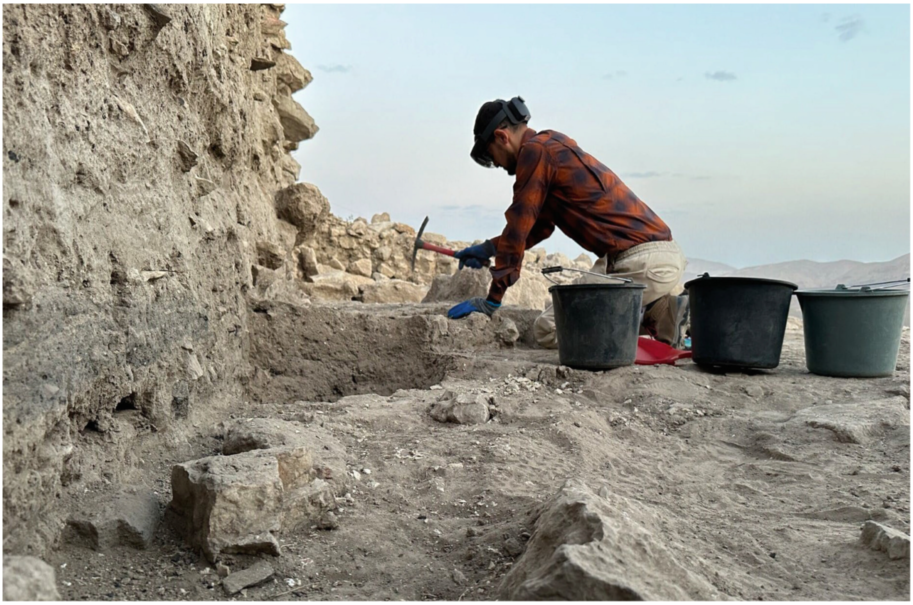

Fig. 4. Using the HoloLens 2 in the trench at the site, surrounded by dust and dirt under the hot sun. The user has hands free to utilize digging tools.

2.4 Interactivity

An MR headset opens the possibility for multiple types of interaction by the user with the digital information. We have experience with a touchpad on the Vuzix Blade 2, with hand gesture recognition in the HoloLens 2 and Quest devices, and with eye-tracking in the Vision Pro. We have also experimented with voice recognition in all these devices. None of these systems yet provide perfect seamless embodied interaction for the user, but they all have important affordances. The touchpad enables some precision as well as the familiarity of a touchscreen or mouse pointer, but we were challenged to use it with gloved, dirty hands. Hand gesture recognition is a good option, but can sometimes have a lag and the hands might be partially occluded from the headset's cameras (Fig. 5). This raises the possibility of voice recognition, especially when recording textual data, but also for controlling the device. A major advantage of voice interaction, of course, is that it leaves the user's hands free to dig and manipulate the real material world. However, our fieldwork environment can be noisy, and our team is mostly composed of users who speak English as a second language with an accent. We have had some success experimenting with Artificial Intelligence (AI) for voice recognition to overcome these challenges. In terms of a specific user interface such as with menus and windows, the goal should be to minimize disruption for the user. The user should be able to get and work with data as quickly as possible with the least distraction.

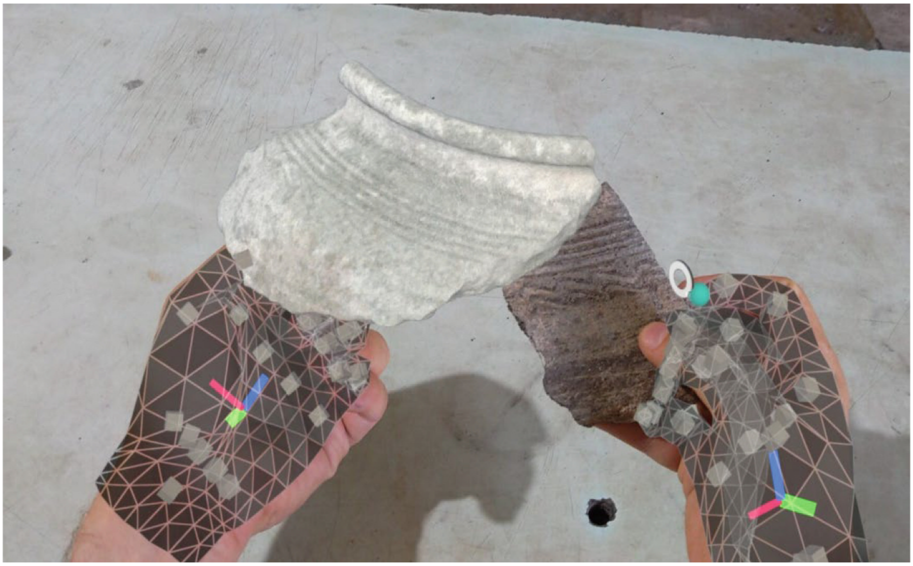

Fig. 5. The HoloLens 2 can track the actions of the hands and fingers of the user, enabling intuitive interaction with the real world. Here, the user is manipulating a digital 3D scan of a pottery sherd on the left and a real sherd on the right.

2.5 Information Display

The ability to interact with data is at the center of the usefulness of the MR headset during archaeological fieldwork. The archaeologist should be able to collect new data, including new textual information, visual images, or 3D models, in order to record the excavation process and results. The headset should be able to connect to a centralized shared data store on the Internet, a cloud database, so that multiple headsets can be used within the same fieldwork project. The user should be able to recall, interact with, and update any information from the central database. This process should be rapid, so it requires a reliable and fast Internet connection at the site. Based on our previously articulated vision, the user should be able to easily display any 3D model of the excavated remains or objects, and these should be placed in-situ in the trench. The models should be precisely positioned in the real world based on technology within the headset that is able to both find the absolute position on Earth of the surroundings and can constantly scan and measure the surroundings precisely in 3D. The user should be able to recall any textual, quantitative, or image data associated with each 3D model. Ideally, the headset would also enable quantitative analysis and complex visualizations of aggregated data.

3 Conclusion

Our goal here has been to lay out the specific characteristics and requirements for an MR headset that would be suitable to use all day during primary archaeological data collection. This presents a divergence from prior uses of MR headsets in archaeology, which have focused solely on applications in tourism and education (Cobb et al. 2024). We constructed this ideal MR headset design based on our extensive experimentation with existing devices during fieldwork. We hope that such an ideal will both make it more intuitive to work with 3D data during excavation and help to increase digital literacy among archaeologists (Kansa and Kansa 2021). We encourage archaeologists and technologists to work together to take the existing technology to the next level, to implement parts of our proposed design. As an example, we ourselves are now currently constructing custom smart glasses. Our goal is to make them light and comfortable and to match as many of the features listed above as possible. Our initial glasses, however, will not be fully MR, they will not enable immersive 3D interaction, as they only have 2D screens. Yet, we can all learn from every experiment in order to figure out the next step for the technology, towards our long-term goal of changing the way archaeologists use and interact with their data during fieldwork.

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