Luke Hollis and Jeffrey P. Emanuel
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MorgantinaVR: Cityscale Handheld AR and Cross–Platform VR for Visualizing Georeferenced Archaeological Datasets

Luke Hollis
luke@archimedes.digital

Jeffrey P. Emanuel
jemanuel@fas.harvard.edu

Abstract

The use of Augmented and Virtual Reality in cultural heritage has increased dramatically in recent years, with uses that go far beyond creating and displaying digital reconstructions for museum visitors and tourists. This paper describes the collaboration between Archimedes Digital and the Contrada Agnese Project (CAP) to develop a framework and suite of applications to support the examination display of archaeological data from the site of Morgantina, Sicily in VR and AR. Primary purposes of this digital approach include facilitating collaboration between CAP's specialists (archaeological, geospatial, and museum), and enabling the effective dissemination of data to researchers and to the general public.

Keywords: augmented reality, virtual reality, cultural heritage preservation, geospatial data visualization

Introduction

Though it may appear as though the emphasis on the digital is a sudden development in archaeological fieldwork, data analysis, and cultural heritage management, the phenomenon is not as new as it seems. As early as the 1980s (now nearly four decades in the past), the impact of digital methods on the collection, interrogation, and representation of archaeological data were being considered: virtual reconstructions (in C!) were being undertaken (Fletcher and Spicer 1988), while "computer database systems, high–level graphics systems, and artificial intelligence techniques are already beginning to allow archaeologists to ask new types of questions and to look at their data from positions which were previously impossible" (Reilly 1989: 579).

By the end of the millennium scarcely a decade later, augmented reality (AR) was being utilized at some historical sites (e.g. Vlahakis et al. 2002), and the applications of virtual reality (VR) to archaeology were becoming increasingly discussed at conferences and in publications (e.g., the papers in Barcelo, Forte & Sanders 2000). At that time – still a few years before Steve Jobs unveiled technology that would quickly place the computing equivalent of a Cray supercomputer in the palm of virtually an entire population's hands – attempts to provide a mobile AR experience were far more unwieldy. One example, which was first tested at Olympia, was called ARCHEOGUIDE (Augmented Reality–Based Cultural Heritage On–Site Guide). ARCHEOGUIDE utilized a PC, a differential GPS (DGPS), and portable units (laptop, pen–tablet, or palmtop) to provide a mobile experience. However, the user then had to carry a significant amount of gear with them to drive that mobile experience. For example, for the laptop-based version of the experience, "the user [wore] a bicycle helmet with a USB Web camera and a digital compass mounted on top, and a backpack containing the laptop, DGPS receiver, battery, power distribution module, and WLAN hardware" (Vlahakis et al. 2002: 57, especially Figure 7). For the pen–tablet, the user could forego the bike helmet and backpack, but still had to carry a hardware box under the tablet, as well as a battery in shoulder–slung case (Vlahakis et al. 2002: 58). In light of this, and in absence of the prescience necessary to see the smartphone revolution looming just around the temporal corner, it is perhaps unsurprising that one of the major needs identified by the ARCHEOGUIDE project team was "the development of custom–made mobile devices that are compact and lightweight enough to carry around outdoors" (Vlahakis et al. 2002: 59)!

That revolution, and the proliferation of mobile devices that it spawned – first smartphones, then tablets – spurred further advancement in the use of digital methods for archaeology, as well as more attempts to integrate digital methods and digital tools into data recording (e.g. Austin 2014; Ellis 2016; Uildriks 2016). The new world of mobile devices has provided archaeologists and users alike with the piece that the ARCHEOGUIDE team was missing two decades ago, while the increasing rapidity with which more and more complex computations can be carried out has allowed for nearly continuous improvement in the level of graphics and environmental interaction that can be provided to the user of an AR or VR experience.

At the same time, the sheer quantity of data being gathered during an archaeological excavation (and during post-excavation analysis) requires a computational approach that can render those data meaningful not just to a technical whiz working part-time on the project, but on an as-needed basis to any member of the broader team, whether their focus is on the archaeological, on the geospatial, or on museum-based cultural heritage. The collaboration between Archimedes Digital and the Contrada Agnese Project at Morgantina, Sicily, which is the focus of this paper, centers on that combination of services and features: the development of data workflows that allow for cross-team access, and the development of VR and handheld AR applications for rendering both excavation data and notional reconstructions of buildings on site.

Archimedes Digital + the Contrada Agnese Project: Introduction

In the summer of 2014, a team of engineers and developers from Archimedes Digital (AD)[1] began working with the Contrada Agnese Project (CAP)[2] at Morgantina, Sicily to investigate the possibility of effectively visualizing and interpreting archaeological data in virtual and augmented reality. A major goal of the AD–CAP partnership was throughout this development has been to explore the optimal methods for integrating archaeological, geospatial, and museum data in the digital environment, both during initial field work and in the publication and dissemination phases of the Morgantina excavation (Figure 1). This project was the technical corollary to an effort on CAP's part to best support integration and collaboration, both in the field and during post–excavation artifact and data processing, by archaeologists, conservators, and other specialists (Smalling et al. 2016). Prior to AD's involvement, CAP had been developing a comprehensive collections database (the Morgantina Legacy Data Integration project; Lieberman et al. 2014), which CAP sought to make accessible to team members, researchers, and the general public.

CAP and AD built on the Morgantina Legacy Data Integration project by joining geospatial information systems data with museum records and 3D photogrammetry data. This was accomplished via a small network of connected data services which cleaned, processed, and transformed the data into a sharable standard that could be used across platforms, including web, mobile, and desktop applications. The 3D applications utilized the Unity game engine for visualizing data, because it was the easiest way to develop software that could grow and adapt to publish across VR, AR, and web-based solutions interchangeably.

As AD went about establishing these services, though, there emerged a persistent divide between the solutions being implemented (which were largely web–based at the time), the data that the CAP excavations team generated, and the landscape and context in the field, where the data were actually being discovered. This began to change in 2015, following the release of a new wave of consumer–grade hardware for mobile virtual and augmented reality devic-

1 The project team included Luke Hollis and Aden Brown (Archimedes Digital), Elliott Mitchell (Vermont Digital Arts), Jarien Sky–Stutts, and Jess Winter (Misc. Labs).

2 The CAP team was led by Alex Walthall, Assistant Professor of Classics at the University of Texas, with geospatial and data teams consisting of James Huemoeller, Adjunct Professor at the University of British Columbia and partner at JIM architecture, and Leigh Liebermann and Ben Gorham, PhD candidates at Princeton University and the University of Virginia, respectively.

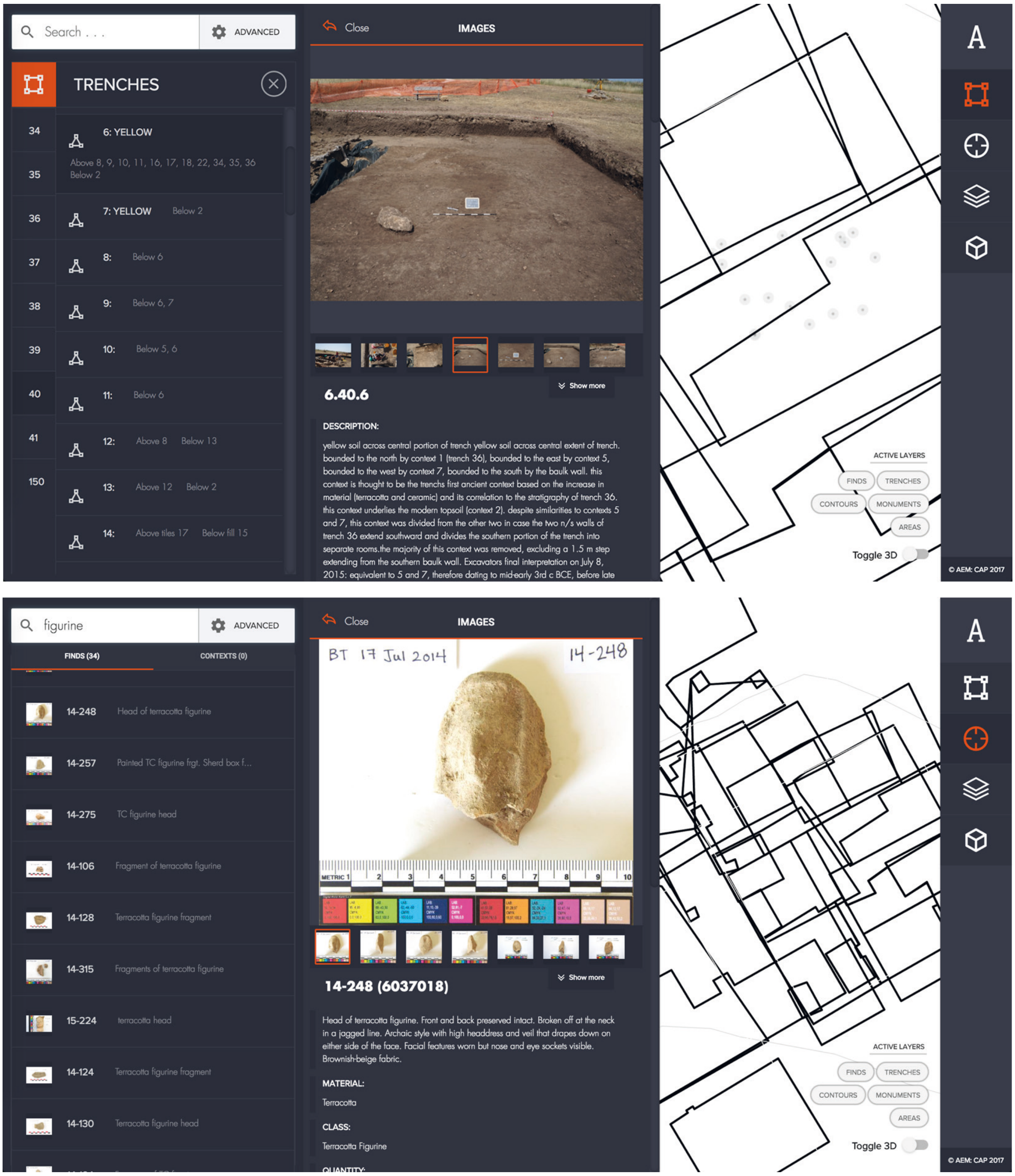

Figure 1. Data from the GIS and museum collections, Filemaker databases, and other services displayed on the CAP data integration and presentation website.

es, such as the Project Tango augmented reality hardware, as well as widespread adoption of the GearVR and Google Cardboard headsets for mobile virtual reality.[3] The team was interested in exploring the optimal platform(s) for three uses in particular: in active field excavations, at museums that dealt with the content, and in classroom–based educational experiences. The project was initially drawn to Project Tango for querying and interpreting archaeological data in the field in AR. However, because the Project Tango software development kit (SDK) required specialized hardware in the smartphone or tablet that it was to be run on, we eventually expanded the mobile

3 Project Tango was released in June 2014 by the Google Advanced Technology and Projects group. The platform was retired in March 2018 in favor of ARCore, Google's new platform for building augmented reality experiences (https://developers.google.com/ar/discover/).

Figure 2. Google Project Tango screenshot showing the integration of 3D GIS and the Morgantina collections database.

Figure 3. Example usage of the augmented reality application on site at Morgantina to explore architectural reconstructions of the agora in 211 BCE.

applications to include, as of this writing, most mainstream AR and VR platforms.

The value of the project on any platform was continually judged by its ability to leverage multiple data sources and types in a 3D environment using the Unity game engine. These data sources and types included the GIS database (PostGIS, a spatial database extender for PostgreSQL), photogrammetry, and museum collections data. In other words, work was evaluated first and foremost based on how well it communicated the CAP geospatial, museum, and photogrammetry data at varying layers of interpretation. In the initial stages, we focused on visualizing all of the “finds” data (the location data on objects themselves) from the GIS database. This was joined with the museum collections records for those finds, and with an image or images of the find (these were hosted on Google Cloud Platform Online Data Storage) (Figure 2).

In a later phase, the team began to focus on 3D reconstructions of monumental architecture in the agora at Morgantina, so that they could be used as educational or interpretative tools in AR for visitors to Morgantina and in VR by users located elsewhere (Figure 3). For these conjectural 3D reconstruction models, we hoped to be simultaneously experimental and pragmatic in refining our method for future work that will be used during future excavation seasons and in the classroom.

Archimedes Digital + the Contrada Agnese Project: Technical Background

During initial stages of development, a primary goal was creating an interoperable service for exposing geospatial data from the geographic information systems (GIS) database maintained by CAP via the open–source QGIS software (Figure 4). To this end, the team created a small service that monitored shapefiles on a local server on site at the CAP. Whenever a shapefile was updated, the service ex-

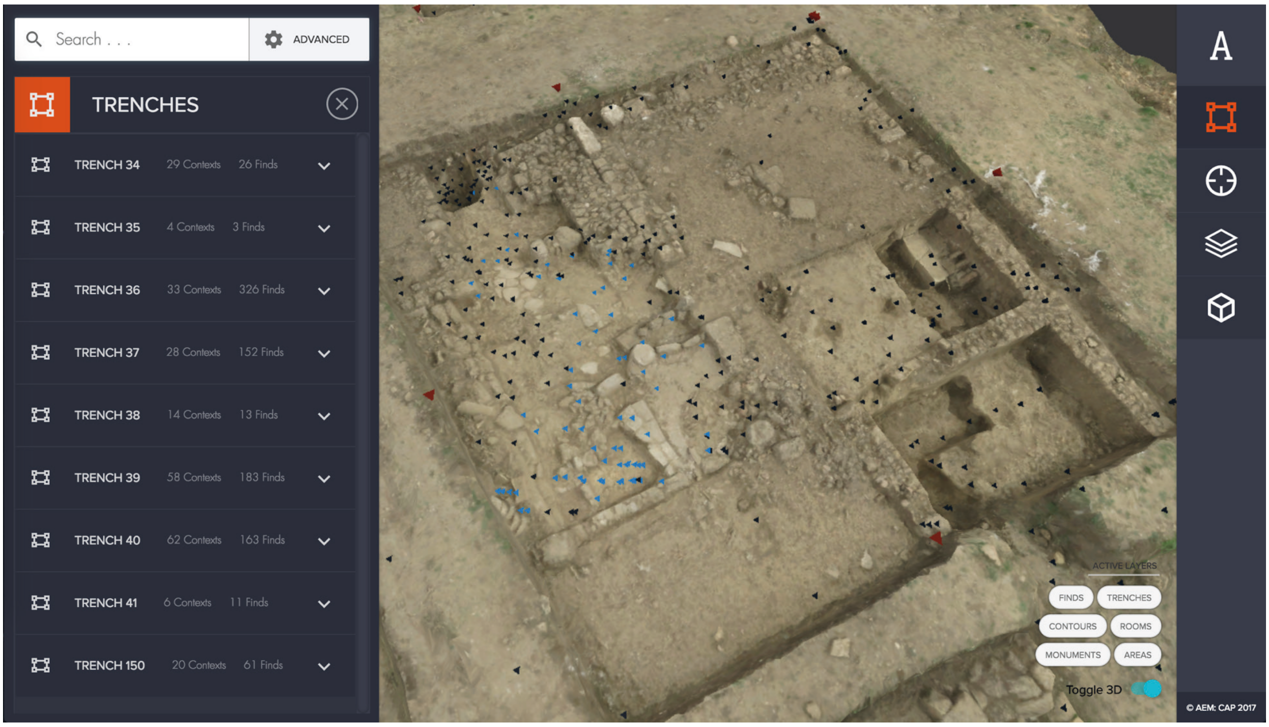

Figure 4. An example of the 3D geodatabase visualized with Unity on the CAP data website, alongside a georeferenced photogrammetric model of the excavations.

tracted its contents to GeoJSON. These were stored in a PostgreSQL database with PostGIS and served via the GraphQL Application Programming Interface (API) query language, which we adopted as a simple standard for sharing data between applications. This API was paired with an API from the project's collections database to create a minimal data presentation layer that our Unity applications could use to visualize object records from the collections and geospatial databases in a 3D environment that we adapted to VR and AR platforms as well as a traditional interpretative website and mobile application.

In order to display geospatial data in the Unity game engine, the AD team created a content management system for curating AR experiences while in the field. This allowed a reference point to be added to the Project Tango Area Description Files (or the GPS and compass readings in smartphones) to position a mobile device appropriately when starting the app onsite at Morgantina. Specifically, the content management system back-end includes a map–based interface and similar GraphQL API to the geospatial service to inform the Unity application of its real-world position in the context of the project's services-data presentation layer. On a conventional modern smartphone, the device requests information at runtime from its geolocation sensor data. After the GPS sensor reaches an accuracy threshold of 10 meters, the camera in the Unity scene is moved into the proper position relative to the internal coordinate system.

Orienting the device to its position in relation to the globe has always been a difficult issue, and that continues to be the case. We have found that the accuracy level of GPS sensor data in conventional smartphones continues to be one of the major blockers of any mobile AR application (at least, any that is more sophisticated than 'Pokemon Go'). At Morgantina, fortunately, the mobile AR application was primarily used to visualize architectural reconstructions of large buildings in the agora. As these buildings tended toward hundreds of meters in length, smartphones' 10-meter accuracy offset did not present as much of an issue. Ultimately, the team decided that whatever the application lacked in to–the–meter accuracy (in terms of placing the building reconstructions directly on those buildings' extant foundations) was more than made up for by the visualization itself, which allows site visitors to view the architectural remains that are present in the agora as they may have looked at the time of their use.

Conclusion and Future Prospects

Following the 2016 field season, Archimedes Digital's work has focused on adapting existing 3D assets for two uses: continued virtual reconstruction of the agora and stratigraphic presentation of the excavation trenches. This is being optimized for VR experiences to create an enhanced reconstruction that features props and educational interactive materials, with the HTC Vive and Oculus Rift being targeted as primary platforms for use. On higher–end desktop VR platforms, we have been able to factor in higher–quality photogrammetry of finds from the Contrada Agnese Project's collections database, such as terracotta figurines, ceramics, architectural fragments, altars, grain mills, and other objects. Development of the Morgantina VR and AR applications will continue, following the guidelines developed from our previous exploratory prototyping, as will continued support for CAP's data services and forthcoming website. In early 2018, we hope to launch production AR applications that will be available for Android and Apple smartphones on the Google Play and App Stores, respectively, while CAP and AD will collaborate closely in the summer of 2018 to integrate AR into the workflow for active excavations.

The Vive and Oculus Rift versions of the Morgantina reconstructions in particular have been geared toward the classroom educational experience, with a first integrated use planned for an archaeological survey class in Spring 2018. To support this educational use, AD will focus on developing the Vive application in particular to include further interactive assets, including variations in architectural reconstruction. An essential element of planned classroom use is a quest–based exploratory learning experience that allows students to view between five and ten different alternatives for the reconstruction of a given building. This tool will allow students to evaluate each alternative reconstruction, based on its merit and relative to a few salient features, such as the archaeological record, the architectural style in use at that time in Sicily, and general knowledge of building materials available at the time of construction. We intend to set up a HTC Vive running the application in a lab that will be accessible to students so that they may complete a session with the application on their own time and terms.

As noted above, more institutions, organizations, and researchers exploring the AR, VR, and 3D space may mean more fragmentation in terms of methods and approaches, but it also means that all can benefit from the constantly–ongoing development of workflows and testing of technologies. Archimedes Digital, and the AD–CAP team, continue to benefit from researchers and technologists working on similar software applications for archaeological data presentation across web, mobile, and AR/VR platforms. While the use of AR as a tool for tourism also continues to grow (e.g. Vhlahakis et al. 2002; Fritz et al. 2005; Kounavis et al. 2012; Yovcheva et al. 2012; Linaza et al. 2014), the immediate future of Archimedes Digital's work in archaeology and at archaeological sites is expected to continue prioritizing education, research, and other scholarly use cases first, and tourism for the general public second.

Through all of this, we plan to continue contributing both to archaeological practice and dissemination, and to the wider web of developers and practitioners who will continue to benefit from open-source development and applications like those in use at Morgantina.

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