

archAR - An Archaeological Augmented Reality Experience

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ABSTRACT

We present an application for Android phones or tablets called “archAR” that uses augmented reality as an alternative, portable way of viewing archaeological information from UCSD’s Levantine Archaeology Laboratory. archAR provides a unique experience of flying through an archaeological dig site in the Levantine area and exploring the artifacts uncovered there. Using a Google Nexus tablet and Qualcomm’s Vuforia API, we use an image target as a map and overlay a three-dimensional model of the dig site onto it, augmenting reality such that we are able to interact with the plotted artifacts. The user can physically move the Android device around the image target and see the dig site model from any perspective. The user can also move the device closer to the model in order to “zoom” into the view of a particular section of the model and its associated artifacts. This is especially useful, as the dig site model and the collection of artifacts are very detailed. The artifacts are plotted as points, colored by type. The user can touch the virtual points to trigger a popup information window that contains details of the artifact, such as photographs, material descriptions, and more.

Keywords: 3D Visualization, Data Exploration, Archaeology, Augmented Reality, Smart Phone, Vuforia.

INTRODUCTION

The Edom Lowlands Regional Archaeology Project (ELRAP) is part of UCSD professor Thomas Levy’s Levantine Archaeology Lab. This project focuses on the evolution of societies in the lowlands of the Kingdom of Edom, a southern Levant region, from the Neolithic to Islamic periods. The Levant today consists of Cyprus, Lebanon, Syria, Palestine, Jordan, Israel, southern Turkey, and the Aleppo Vilayet (Syria). archAR references data that ELRAP has been excavating from a dig site in Jordan’s Faynan district [4], which dates back to the Iron Age, a period where civilizations thrived on the use of iron and steel for tools, money, and weapons. Khirbat Faynan (Arabic for “the ruins of Faynan”) was one of the largest copper producing sites of the Iron Age and to this day still contains the largest concentration of copper deposits and its remnants. Copper was mined from the Neolithic Period throughout the Bronze Age (9000-1200 BC), allowing Faynan to flourish in the Iron Age, which followed from 1200-500 BC. Khirbat Faynan holds biblical importance as well. It is referenced as Punon, one of the places visited by the freed Israelites led by Moses during the 40 years of Exodus. There is scholarly debate as to whether Kings David and Solomon controlled Khirbat Faynan’s mines and the slaves who worked there. ELRAP seeks to use archaeological evidence to support who, if anyone at all - David, Solomon, other leaders of biblical times - controlled the Faynan area and what the environmental impacts were. Khirbat Faynan is unanimously considered one of the most important areas of ore mining and smelting, being the crossroads between Asia, the Mediterranean, and north Africa. ELRAP has helped excavate ancient artifacts that support the historical activity of the cultural and technological progression of an ancient people. The goal of this project is to provide the archaeologists in the field a means to view the

excavation history of the site three-dimensionally, without requiring a special display environment.

RELATED WORK

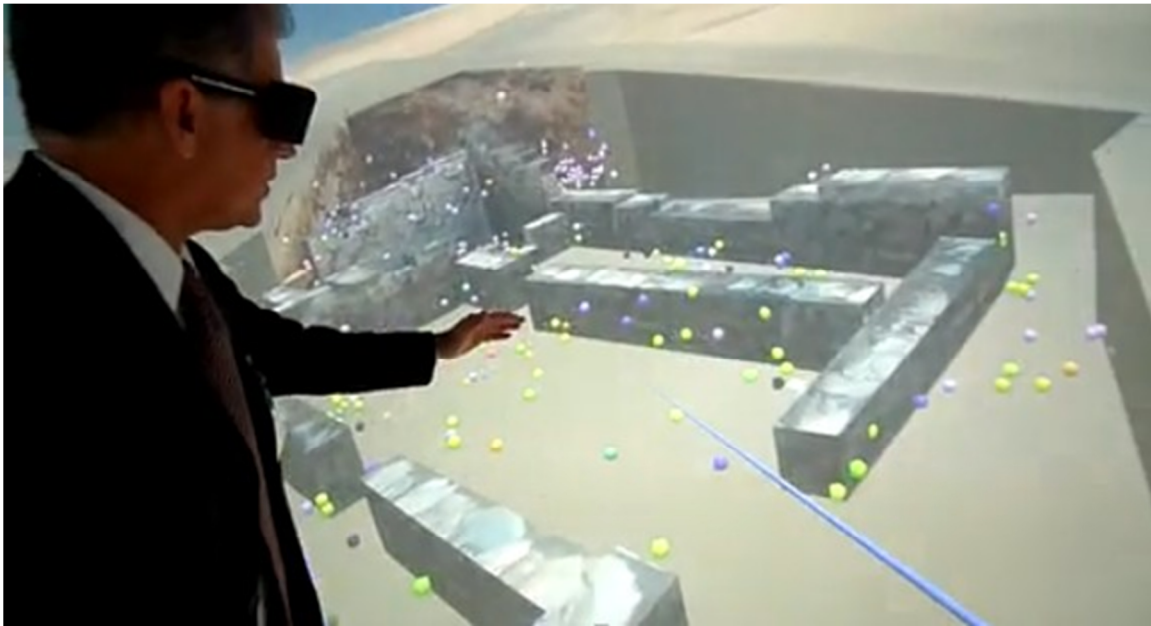


Figure 1: Professor Levy demonstrating ELRAP in CALIT2's StarCAVE.

ELRAP has been working on technological innovations with our research team at the California Institute for Telecommunications and Information Technology (Calit2) to visualize their laboratory research. As ELRAP excavates the historical copper mines in Jordan, they store a large collection of data and pictures that record the progress. One of Calit2's biggest contributions to ELRAP has been the ability to create a fully immersive virtual experience via the StarCAVE [6] as ELRAP seeks to digitally reconstruct the sites they excavate. Using the StarCAVE, we have been able to reconstruct an accurate digital representation of three main dig sites in Jordan, see Figure 1. Using a controller they can fly through the virtual model to explore the dimensions of the mines that they have uncovered. In addition, they have also uncovered artifacts in each of these dig sites, represented as colored spheres in Figure 1. The artifacts are plotted as points in the virtual world which can be clicked on.

We set out to recreate the StarCAVE experience in augmented reality (AR), using Android-based mobile devices. The goal was to allow archaeologists to take the visual data base to the field, which they cannot do with traditional virtual reality devices due to their large size. As Hürst and Helder [7] have shown, mobile devices are ready for virtual and augmented reality applications. However, they explored them for gaming applications, whereas we intended to explore their suitability for data visualization applications.

Using augmented reality technology for archaeology is not new and was already shown before the advent of smart phones by others such as Gleue and Dähne [8] in 2001. Our approach applied their idea to modern smart phone technology.

Unlike other applications of augmented reality to archaeology, such as Vlahakis et al. [9], who recreate the visual appearance of ancient sites, our approach aims at showing the dig site as it is today, with the added information of where artifacts were found and the ability of querying the existing meta-information about them (pictures, material, carbon dates, etc.). So in a way we set out to create a visual data base explorer for archaeological data.

OUR AR APPLICATION

archAR uses an image as a tracking target, upon which is overlaid a representation of one of the dig sites that ELRAP has been excavating. This representation includes a 3D model of the dig site that provides a reference for a collection of plotted points, each of which represent an artifact found in that dig site. The user can physically move the android device around the image target and see the dig site model from any perspective. The user can also move the device closer to the model in order to “zoom” into the view of a particular section of the model and its associated artifacts. This is especially useful, as the model (and collection of artifacts) is very detailed. The artifacts are plotted as points, colored by type. The user can touch the virtual points, which results in a popup information window that contains the details of the artifact. Figure 2 shows our app with the marker in the background (the picture with rocks in it).



Figure 2: Using archAR with a horizontal target.

Once we were done implementing this more traditional approach with a horizontal marker, we found that it was quite hard to distinguish the artifacts along the vertical axis in this way, because the phone’s camera would lose the image when the phone was held at oblique angles to the marker.

Our solution was to install the marker vertically, on a wall, and add a switch to the application to level out the data set

in this mode (rotate it by 90 degrees). It turned out that the application made a lot more sense in this mode and allowed the display and selection of the artifacts in a more effective way, with much easier access to the subterranean data points without tracking interruptions. Figure 3 illustrates this mode.

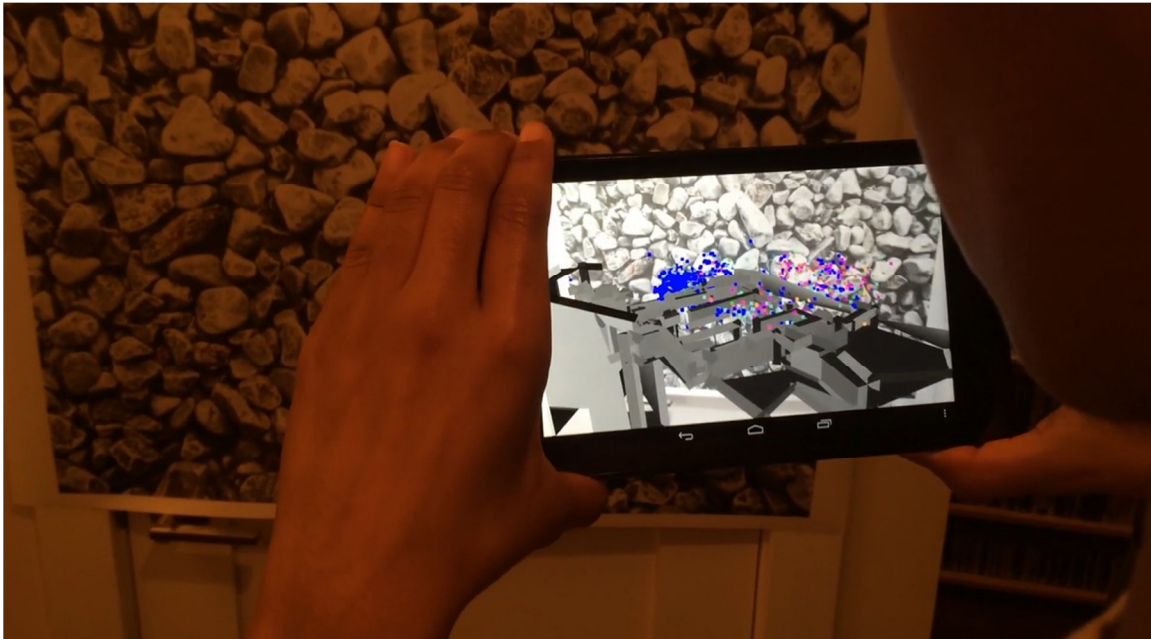


Figure 3: archAR with a wall-mounted marker.

APPLICATION WORKFLOW

When the app starts up it first shows a splash screen with our archAR logo. After a few seconds it will switch to a screen which summarizes the application and presents a Start button. Once the user presses the Start button, the screen switches over to camera mode and the user can see the live camera image. As soon as the device has identified the marker, it will render the dig site over it, and keep its orientation updated with changes of the Android device's orientation.

The user can move the device closer to the image target to perceive "zooming" into the dig site model. The artifacts become easier to distinguish and select, as shown in Figure 4.

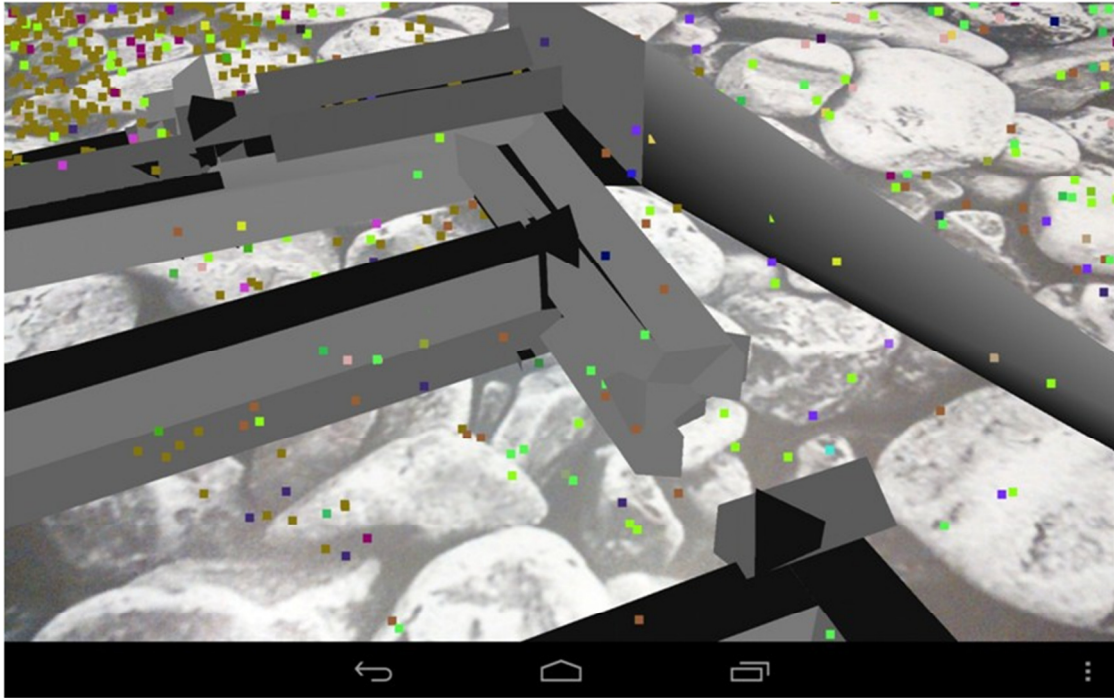


Figure 4: Zoomed in.

Selecting (by touching it on the screen) an artifact brings up a dialog window with metadata about the selected artifact (see Figure 5). Since the artifacts are displayed as small points which often have a size of only a pixel, we select the nearest artifact to the finger position in projected space.

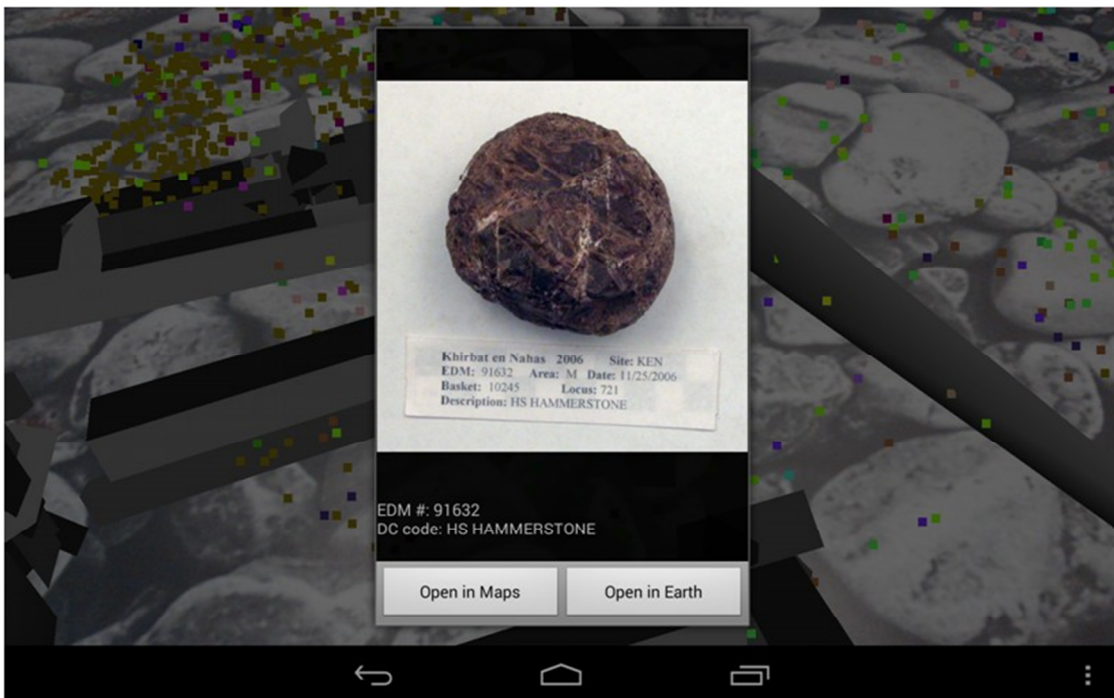


Figure 5: Meta-data screen for an artifact, displayed when an artifact is selected.

Clicking on the “Open in Maps” button in the meta-data window uses the coordinates of the artifact to plot it in Google Maps, see Figure 6.

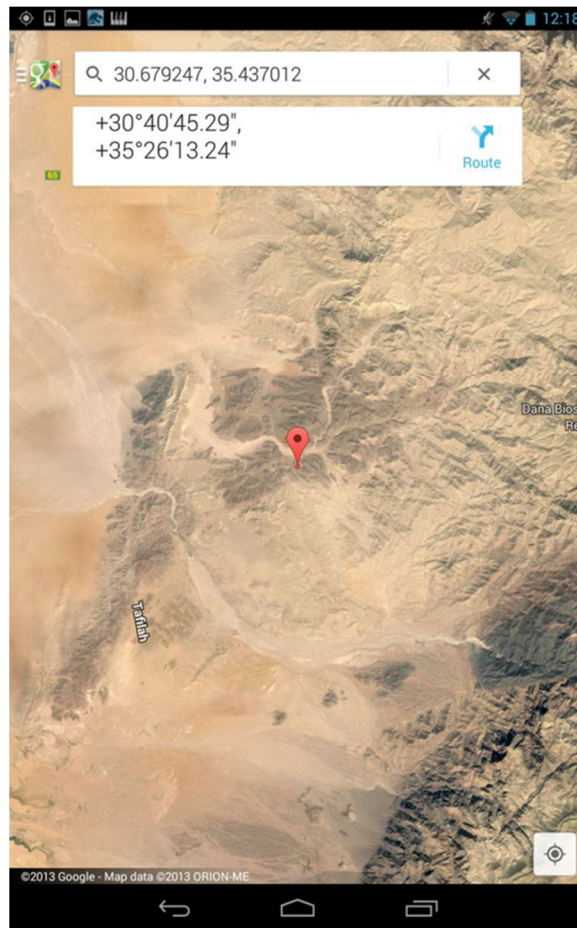


Figure 6: Google Maps view of artifact location.

Clicking on the “Open in Earth” button in the meta-data window uses the coordinates of the artifact to plot it in Google Earth. Unfortunately, due to limitations in the API Google Earth doesn’t fly the user to the exact coordinates. Instead, the user is taken to the nearest town.



Figure 7: Google Earth view of artifact location.

IMPLEMENTATION

archAR is an Android application, which we wrote for Android version 4.3 (Jelly Bean). It was developed using the ADT plugin for Eclipse and tested on a Google Nexus 7 tablet, as well as a Samsung Galaxy S4 smart phone. Development was done in C++ and Java, using the Java Native Interface (JNI) as a bridge between the two languages. archAR uses the augmented reality library Vuforia [1], which is developed by Qualcomm and is written in C++. Vuforia improves over earlier marker based AR tracking solutions, such as ARToolKit [5] with a tracking algorithm optimized for mobile devices, and the option of using any photograph as a marker (ARToolKit requires the use of black and white images of square markers).

The dig site model was created by Dr. Levy's student Kyle Knabb with ArcGIS [2] and Trimble Sketchup [3], based on the archaeologists' original 2D maps which were created in the field. We exported it to an Alias Wavefront OBJ file and read it into the application session via a custom-written parser, written in C++.

OpenGL ES is a standard for rendering 2D and 3D content on embedded systems, and version 2.0 is what is used in archAR. OpenGL ES is responsible for rendering the dig site model overlaid onto the image target. We have written

custom GLSL shaders to support basic lighting of the dig site model and coloring of the artifact points.

The picking algorithm for selecting an artifact was initially implemented as a ray-intersection equation. A ray would be drawn from the pixel touched on the device screen out into the virtual world. Each object is then represented by a sphere with an appropriate radius that allows it to be easily selected. From all of the artifacts that are intersected by the ray, we choose the closest one to the viewer. Upon further research, we discovered that the Vuforia API had a function that helped solve the picking problem in a different way. The current implementation projects the 3D coordinates of the artifact in virtual space onto the 2D screen of the Android device. Using the artifact's projected point, we find the closest artifact. The artifact with the shortest distance to the screen point that the user touched becomes the selected artifact.

CHALLENGES

Initially, we had problems loading the dig site model file, which traced back to a problem with the memory space on the device and the size of OpenGL buffer objects required to represent our large model. We decided to extracting a single site from the larger initial dig site model with five separate sites all in one 3D model file reduced it to a manageable size.

Another issue we ran into was that we discovered that there are focusing problems with the Android device's camera when the user gets close to the image target, or when the image target is glossy and it confuses the focus sensor. Often, the camera loses track of the image target and the user has to "reset" the view by backing further away and providing a view of the entire image target. We improved this by printing the image target onto a large poster (approximately 36" x 24"), allowing the user to move more freely around the image. The bigger poster size helps the user experience by allowing finer granularity of relative movement while exploring the dig site, but starts to encroach on the portability of the application if the size of the target gets too big. We hope that future revisions of the camera hardware will have increased image precision and focusing ability, which will likely alleviate this issue.

RESULTS

archAR is a successful example of how augmented reality can be used to explore archaeological dig sites. archAR provides a viable way of exploring a dig site with a portable interface that can be used almost anywhere. We think that we were successful in porting major parts of the StarCAVE experience to a mobile device.

A major difference between the two is immersion: in the StarCAVE the user feels like they are at the site, looking around, and the user gets an accurate idea of scale, of the size of the dig site as well as density of artifacts. Because we had to scale down the dig site to allow working in the confined space around the marker, the user does not get the same sense of scale – now the scale of the site is shrunk to the size of a map. Naturally, the feeling of immersion is also very different, as the user only perceives the virtual world through a small screen in front of them, which at best makes it feel like the tiny dig site is located right in front of the user.

CONCLUSIONS AND FUTURE WORK

Overall, we had a rather positive experience with Vuforia and Android development. Android development is well-documented on the internet and the Vuforia API is also very complete. Augmented Reality has plenty of

applications to many different fields of study - it only needs a capable device to fluidly run the software to support it, which will only improve over time. There is a lot more research to be done to continue to find the best way to visualize information in an intuitive and comfortable way with mobile devices.

Changing the image target to be a more useful image, such as a Google Earth satellite image would be more interesting and provide a better platform for the virtual dig site to rest upon. With a satellite image or a map, more context would be provided for the location of the dig site. In order for Vuforia to accurately track any part of the image, it is important that the image be rich in detail, have good contrasting regions, and have no repetitive patterns. It would be interesting to explore under what circumstances these requirements could all be met.

Since memory availability on mobile devices is an unfortunate drawback, one way to address our issue of having had to downsize the data set would be to store the information in a database and use a server to intelligently display the closest artifacts within a certain depth range in the current field of view. That way the full resolution of the model and all artifacts (plus their textures and metadata) would not need to be resident on the device at once.

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