Virtual Museum 'Takeouts' and DIY Exhibitions – Augmented Reality Apps for Scholarship, Citizen Science and Public Engagement

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Abstract. This paper presents an Augmented Reality (AR) project for the curation of virtual museum 'takeouts' and DIY exhibitions. The project's outputs include novel AR app technology demonstrators to support co-design with museum users and stakeholders - the goal being to create useful and easy-to-use AR apps for scholars, citizen scientists and the interested public.

The apps were designed for users to create, display, animate and interact with exhibitions of selected 3D artefacts that could, for example, reflect academic specialisms for sharing with fellow researchers, support curators in exhibition planning or enable friends and students to share eclectic favourites from museum visits. The overarching project ambition was to create AR apps to support research, engagement and education, and to enable interactive and personalized visualizations of individual artefacts as well as reconstructed forms. As presented in the paper, these forms are exemplified in the AR apps with 3D models of a cuneiform envelope and its tablet contents, viewable either as i) separate artefacts or ii) in their reconstructed enveloped form, with the AR apps enabling animated opening and 'X-ray views' of the contents within. In this way, the apps can enable users to visualize individual objects and reconstructions that could, for example, incorporate artefacts held in different museums.

Keywords: Augmented reality, Digital heritage, Virtual reconstruction.

1 Introduction

Augmented Reality (AR) offers new and exciting opportunities to enrich museum and art gallery visits and provide additional interactions and experiences for visitors [1-4]. AR can also provide digital heritage visualization opportunities, for example, for archaeological finds [5] and reconstructed artefacts such as glass plates [6], as well as affording the potential for engaging educators and student learners in cultural heritage experiences [7].

Notable museum AR examples include Saltzburg's Museum of Celtic Heritage 'Speaking Celt' historical AR avatar [8], Cleveland's Museum of Art ArtLens AR app that provides enriched tour experiences of displayed artworks [9] and The Franklin Institute's AR app that enables visitors to interact with virtual 3D models of Terracotta Warriors [10]. These AR apps enrich the in-museum experiences of displayed artefacts [11, 12] but, like other heritage AR apps, they do not support interaction with artefacts that are not on display or enable the creation of virtual exhibitions. More broadly, amongst art and digital heritage AR apps, there is scope for improved personalization and better ways of revealing non-visible components and communicating artefact information [13].

The Virtual Museum 'Takeouts' and DIY Exhibitions project [14] evolved from The Virtual Cuneiform Tablet Reconstruction Project [15] whose original ambitions included support for virtual access to museum artefacts and the creation of tools to support artefact reconstruction [16] as exemplified by the virtual reconstruction of the Atrahasis cuneiform tablet [17-19]. The aims of the Virtual Museum 'Takeouts' and DIY Exhibitions project were (i) to create technology demonstrators that could supplement the co-design of useful and easy-to-use AR apps aimed at benefiting diverse user groups that include scholars, citizen scientists and the interested public, and (ii) to provide interactive, informative and personalized views of individual artefacts and virtual reconstructions. The creation of technology demonstrators was important because co-design improves technology outcomes [20] and functional technology demonstrators can support the process by helping to inspire ideas [21]. In addition, technology demonstrators are useful when some user groups may be unfamiliar with a new technology.

2 AR Apps for Museum 'Takeouts' and DIY Exhibitions

The requirements for the AR apps were to incorporate functionality to demonstrate:

- virtual presentations of museum artefacts that may or may not be on physical display,
- the collection and arrangement of virtual life-sized artefacts in augmented reality exhibitions,
- alternative point cloud and wire mesh views of artefacts for interest and for educational insights into the structure of 3D models,
- the optional display of artefact information,
- artefact rotation to provide all-around views,
- the option to display individual artefacts or to view them in their assembled or reconstructed forms.

2.1 3D-Model Acquisitions

The models for the AR apps were acquired in 2018 and 2019 from National Museums Liverpool (World Museum), UK using the Virtual Cuneiform Tablet Reconstruction

Project photogrammetric turntable system [22] and an Einscan-SP 3D scanner with Discovery Pack. The models included a ‘shabti’ figurine and cuneiform tablets.

Shabtis are small funerary figurines that were placed in Egyptian tombs to act as servants for the deceased. The shabti scanned for use in the app is over 2,500 years old and was once owned by Florence Nightingale who spent several months in Egypt in 1849-50.

Cuneiform tablets are early written records from Mesopotamia, created by making impressions in clay tablets. The tablets scanned for the app included one with an accompanying envelope bearing cylinder seal impressions. This envelope originally secured a silver purchase recorded on a tablet within (which had been removed and the envelope resealed). The scanned cuneiform tablets are included in the collection of World Museum Liverpool tablets published in [23] and in the Cuneiform Digital Library Initiative (CDLI) database [24].

2.2 AR App Development

The Android AR app was developed using the Processing for Android AR Java library, which itself uses the Google ARCore library. The iPhone AR app was coded in Swift with Xcode using ARKit. The apps were tested in development by researchers and testers accessing pre-release versions in Google Play test track and the Apple App Store Test Pilot. Both apps require minimum device specifications; Android’s ARCore, at the time of writing, requires Android 8.1 or later [25] and the iPhone app requires iOS11 and an A9 or later processor [26]. Example screenshots of the Android and iPhone apps are shown in Fig. 1.

ARKit and Swift for iOS.

ARKit is Apple’s library for iOS device augmented reality development, supporting motion tracking, surface detection and light estimation. It uses the smartphone’s camera to identify and track features in the environment and estimate ambient light so that it can position and illuminate selected objects in the camera view of the environment. When running, ARKit extracts features from the camera images and builds a topographic map of the real world.

Xcode is Apple’s iOS Operating System Integrated Development Environment (IDE) [27]. Xcode (IDE) version 11.7 (11E801a) was used to create the prototype application with Swift being the predominant coding language. The app was developed using SwiftUI (iOS 13). This allows for the building of user interfaces for any Apple device using just one set of tools and APIs

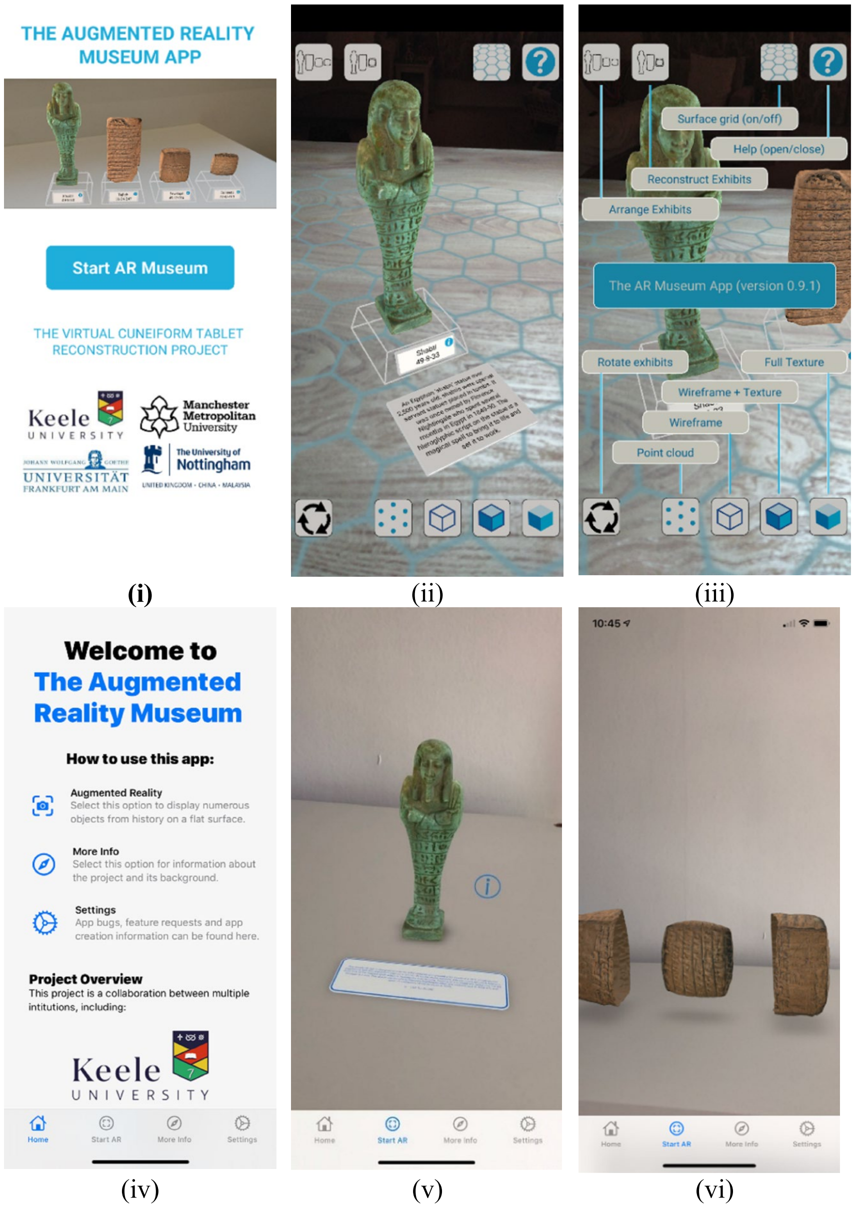


Fig. 1. Android and iPhone AR app screen examples. For Android: (i) initial Android splash screen, (ii) a positioned shabti and (iii) help menu explaining interface buttons. Below for iPhone: (iv) the splash screen, (vi) positioned shabti artefact with information display ON and (v) a screenshot from the opening/closing animation of the cuneiform envelope that reveals the cuneiform tablet within.

ARCore and Processing for Android.

ARCore [28] is Google's library for Android smartphone augmented reality development, supporting motion tracking, surface detection and light estimation. It uses the smartphone's camera to identify and track features in the environment and estimate ambient light so that it can position and illuminate selected objects in the camera view of the environment. When running, ARCore extracts features from the camera images and builds a 3D map of the real world. A collection of features located on a horizontal or vertical plane is known as a 'trackable' and can have virtual objects attached to it using an 'anchor'. The Android AR app was created using 'Processing for Android' [29] which enables the creation of Processing 'sketch' programs for Android devices and includes support for 'AR in Processing' [30] via the ARCore library.

Processing for Android has an advantage over development using Android Studio in terms of ease-of-use and the simplicity of the code. A rudimentary demonstration AR Processing app can be produced using less than 30 lines of code whereas an equivalent Android Studio project would require the creation and navigation of a folder structure containing 50 or more different files. However, the ease of getting started in Processing for Android should not trivialize the coding required of full app development. At the time of writing, the current version of the AR Museum app comprises six files that add up to approximately 1200 lines of code (much of which is required for the loading and interpretation of 3D object files).

There are also limitations to the Processing for Android approach; not all of the features of the ARCore library are exposed to programmers by the Processing interface. For example, depth mapping, augmented images and cloud anchors [28] cannot (at the time of writing) be utilised in Processing. Additionally, the multiple 'activities' made available by Android Studio are not available in Processing for Android. For example, implementation of an initial 2D splash screen could be easily achieved in Android Studio by creating a new activity. In Processing, however, an overlay is needed to obscure the main activity. The Processing splash screen screenshot is shown in Fig. 1(i).

To enhance the functionality of the app, user interface control buttons overlaying the 3D display were added. No library functions for this are provided. Normally, implementing a 2D overlay on a 3D view in Processing would simply require the 'camera' to be placed in its default position meaning a 3D coordinate of (x, y, 0) would correspond to a screen coordinate of (x, y); then, the controls can be drawn using standard 2D graphics functions. When using the AR library, however, camera positioning is disabled so a lower level approach was required. Instead of utilizing Processing's camera placement function, the OpenGL projection matrix coefficients were directly reset to achieve the same effect.

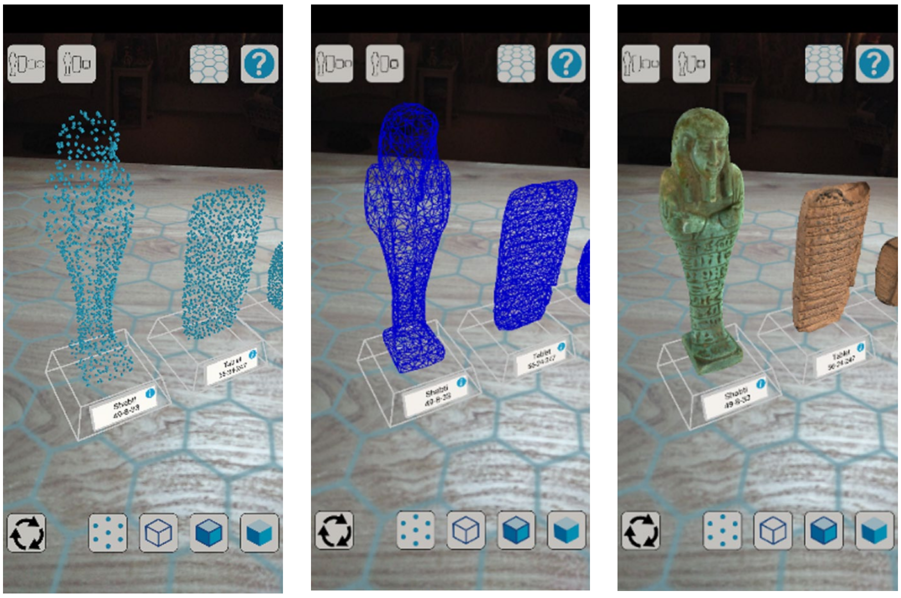
3 Design Decisions and View Options

Several design decisions were required during app development. For example, Android's ARCore library enables the detection of *any* flat surfaces, which would allow objects to be impossibly attached to walls or suspended from ceilings. To simplify the surface detection process, only horizontal surface detections were permitted. Additional decisions were required to create a functional user interface. This was achieved using intuitive icon designs based on past research [16]. The icons were placed away from the centre of the camera view and artefact information was placed so that it remained in view of its ON/OFF control. Improving the usability of user experience of AR apps [31] is an important goal of further research and co-design. In addition to improving the interface to the objects, it is also important to guide users in the basics of getting started with the use of AR apps. For example, making recommendations on ambient light levels, smartphone movement and surface selections because dim lighting, rapid camera movement and smooth featureless surfaces all make surfaces difficult to detect.

As shown in Fig. 1, artefacts were placed on labelled plinths with clickable information '*i*' buttons in both the Android and iPhone apps to toggle the display of artefact information. Fig. 1(ii) shows the Android interface and (iii) shows the help screen (activated by the top right '?' help button) indicating the function of each of the interface buttons.

3.1 3D Model Views

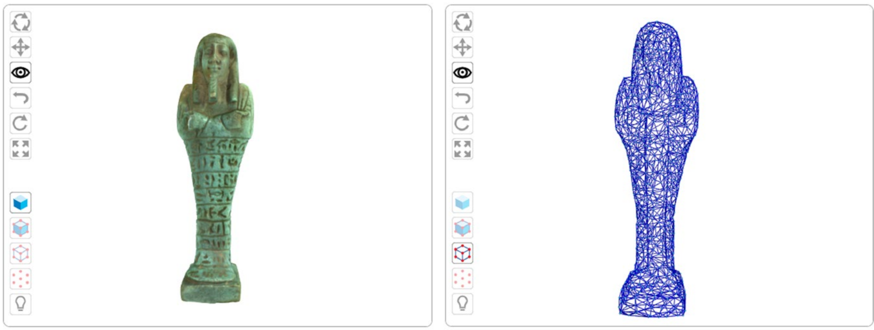
One of the education goals of the apps included insights about the underpinning 3D graphics of virtual objects. For this purpose, we implemented alternative artefact view options to enable users to see low-resolution point cloud views of models and wire mesh views, as well as photographically rendered views, as shown in Fig. 2.



(i) (ii) (iii)

Fig. 2. 3D model views. (i) low-fidelity point cloud view, (ii) wire mesh view and (iii) 3D photographically rendered view.

For the iPhone AR app, which did not implicitly support point cloud and mesh views of objects, 3D models were created comprising small 3D sphere 'points' and meshes made from narrow cylinder 'wires', respectively, to give the appearance of the views. An additional supporting webpage multi-view interface [32, 33] was also created for viewing from desktop computers and other devices, as shown in Fig. 3. The web page also provides links to 3D file downloads for artefact models as both .ply and .stl formats and in low- and medium-resolutions, for example, for printing artefacts at different sizes as shown by the 3D printed shabti models in Fig. 4. Models were also made available for the cuneiform tablet [32].



(i) (ii)

Fig. 3. Interactive desktop browser interface with 3D multi-view options [33]. (i) Photographically rendered and (ii) wire mesh view.

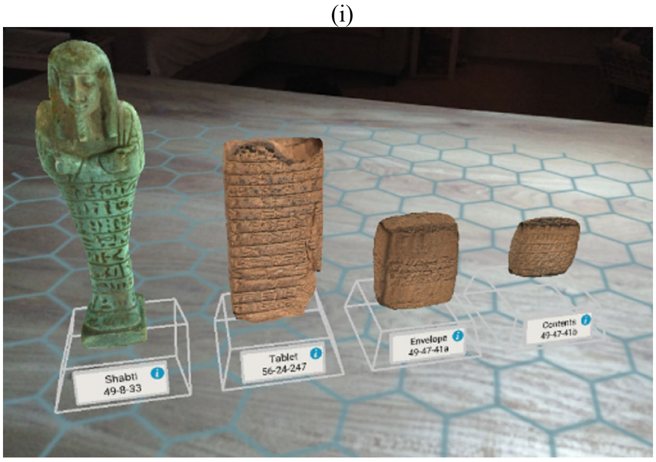
Fig. 4. 3D prints of the shabti figurine. Transparent clear resin prints at full and reduced sizes.

3.2 Exhibition Views and Interactions

As shown in the example screenshots in Fig. 5, users can (i) arrange artefacts on detected surfaces (with or without information display) and (ii) select an automated positioning format to arrange artefacts in line with each other.

The apps also support interaction with the artefacts, for example, with a toggle artefact "rotate" function in the Android app.

(i)

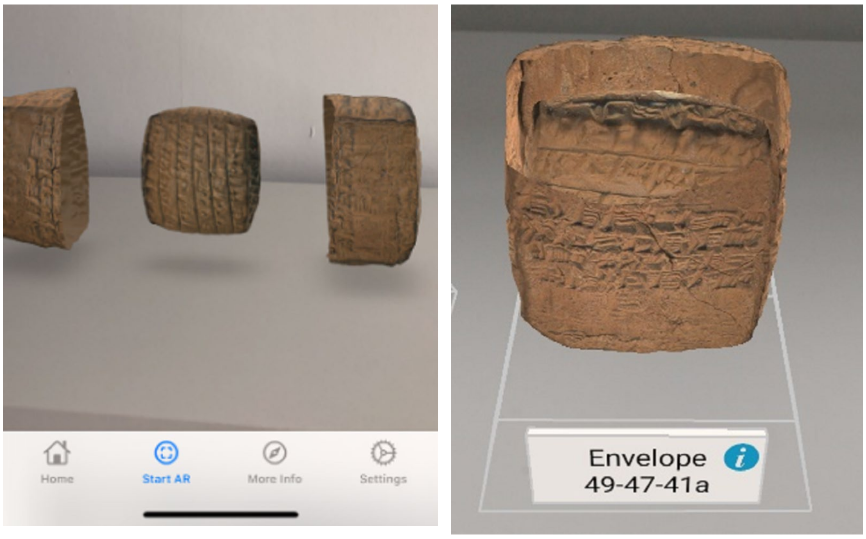


(ii)

Fig. 5. Views of eclectic Android app exhibition arrangements (i) user-positioned artefacts with information display ON and background grid OFF and (ii) Exhibits viewed with automatic line-up ON, information display OFF and background grid ON.

3.3 Individual and Reconstructed Artefact Views

Fragmented artefacts can be separated within collections or between museum collections that may be many kilometres apart [17]. For example, joining pieces of cuneiform tablets have been found separated by 1,000 kilometres, in the British Museum and the Musée d'Art et d'Histoire in Geneva [18, 19]. AR apps can enable the viewing of individual fragmented or component artefacts or their constructed forms. For example, as shown in Fig. 6, cuneiform envelopes and their tablet contents can be shown separately or assembled with the contents (as it would have originally been) inside the envelope. In Fig. 6 (i) the iPhone app animation opens and closes the envelope to reveal the contents, in (ii) the Android app, on close inspection, reveals the enveloped contents to the user.



(i) (ii)

Fig. 6. Reconstructed views showing animated and 'X-ray' inside views, respectively for the cuneiform tablet envelope contents in (i) the iPhone AR app and (ii) the Android AR app.

4 Opportunities and Future Development

4.1 Opportunities

3D models of artefacts offer new opportunities for curators in museum exhibition planning and design. Models provide accurate data for the arrangement of artefacts within the fixed space of a showcase, giving a greater visual impression before installation, conceivably reducing the need for last-minute changes in the days before opening. This is of particular advantage when creating exhibitions that bring together artefacts from numerous institutions and private collections. There is a greater call on museums to extend the legacy of short-lived temporary exhibitions beyond the usual publication of a catalogue. 3D models could be used to enhance a virtual tour of the gallery with inscribed artefacts such as cuneiform and shabtis, offering greater intellectual stimulation for virtual visitors.

4.2 Future Development

The apps and their 3D models make demands of smartphone storage space and, in the current apps, the example models are downloaded as part of the app installation. Ideally, the app and models would be separate downloads and new models would be downloadable individually when selected. This would speed up updates to the app and allow for new models to be downloaded more efficiently. In museum contexts this could be via a local Wi-Fi service to reduce the burden on mobile data transfer limits.

In physical exhibition spaces, QR codes could reveal the details and locations of available AR 'takeout' artefacts, enable easy selection and download, and provide links to more information and multimedia resources. To engage and incentivize visitors, the app could support social media sharing of artefacts, and user achievements could be recognised for artefact collection milestones.

Achieving the functionality of the AR app with a minimal and uncluttered interface was one of the main challenges of the app development. Further work and co-design with different users and stakeholder groups is needed to evolve the apps from technology demonstrators to fully functioning apps. Ideally, the apps would be supported by infrastructure and data repositories to enable the download of 3D artefacts at appropriate scale and resolution, and in suitable formats. Ideally, the apps would also support language options, for example, from Google Translate, so that exhibit information displays could be shown in the user's chosen language. A further enhancement to this would include the option for text to speech delivery of the information.

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