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The New Interactive: Reimagining Visual Collections as Immersive Environments

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The New Interactive: Reimagining Visual Collections as Immersive Environments

Abstract
Emerging technologies and shared standards have opened up new avenues for the curation and presentation of data in archives and published
research. Among their many benefits, these developments have made collections across archives more accessible, and have vastly improved the visual experience for users. This paper focuses on the next step in applying technical development and standards to digital collections: improving discoverability and providing a visual product that is simultaneously informative and experiential. The cases presented here
focus on new approaches in these areas, with an emphasis on the utilization of visual search and discovery across a research archive and the integration of data and image into an augmented reality (AR) experience, with discussion of how these approaches can improve the usability of visual material while broadening the user's experience from the purely visual into the realm of the immersive.

Keywords
Interoperability, Visual Resources, Augmented Reality, Virtual Reality, Experiential Interface Design, Geographic Information Systems, International Image Interoperability Framework

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translator of Theocritus and other pastoral Greek poets. Luke has excavated with the Contrada Agnese Project at Morgantina since 2012.

Introduction

Emerging technologies have forced a rethinking of the nature of collections and exhibitions alike, as it is often the digital versions of visual material that are most widely, and most easily, shared with the broadest audiences. In this networked era, materials must not only be discoverable, accessible, and functional on a range of devices, from phones to tablets to laptop and desktop computers, but they must do all these with a speed that borders on the immediate.

In some cases, the digital object in question is the representation of a physical object: a digitization of a page in a book, for example, or of a work of art in a museum collection. This is the class of object most frequently thought of when it comes to digital collections, be they library or museum holdings.[1] However, in other cases, the digital object is the object itself, with no extant physical source underpinning it. While this can be a digital image of an old book or artifact that no longer physically exists, it can also encompass objects that are "born digital," as well, such as a snapshot of a moment in time – an event that happens once, and is recorded only in digital format. As one might imagine, this type of digital object is increasing in number with the growing ubiquity of social media, camera-equipped technology, and other mechanisms for both creating and capturing moments rather than materials.

Access to digital collections is both important and (rightly) expected by the end user, be they student, scholar, or layperson. Additionally, certain levels of interactivity – an opportunity, task, or other operation that makes contact with a digital object a multidirectional experience – are also increasingly expected, whether in the search and discovery process or with the digital materials themselves. The manner in which this experience is provided must, of course, be carefully considered and thoughtfully carried out, as the easy assumptions that more interactivity is always better, and that interactivity for its own sake is a net positive, are not always accurate. This puts a premium on user interface design, which must be thoughtfully and consistently applied with the end goal - what the user expects, and what is expected of them - kept firmly in mind throughout the process of design, implementation, and support. Scholars and researchers have grown accustomed to traditional modes of information search and access, and our interfaces typically reflect these priorities. Sophisticated search algorithms, faster databases, and faceted content draw us simultaneously closer to the information we seek, and away from the information we may not have known existed. It is within this latter category, information not found, that creative applications of interface theory and design can bring new depth to collections and cultivate serendipitous discovery.

The logical next step in the thoughtful application of interactivity is *immersion*, or a level of interaction with digital material that extends beyond simple multidirectionality described above. The idea of immersion as a way of experiencing visual material is not a new one, but the development and application of new tools and approaches has progressed in such a way as to make this goal attainable via multiple modalities. Pseudo-virtual reality applications like QuickTime VR, which were heavily used in the last decade, are being replaced by 3D-capable Augmented Reality engines like Unity, whose barriers to adoption and use are lower than ever (and still falling). At the same time, JavaScript libraries are constantly being developed and adapted to provide lightweight, engaging user experiences on the web. However, as with interactivity, the lowered barrier to the implementation of immersive aspects to an exhibit or experience makes it all the more important that the approach be carefully thought out and clearly targeted toward achieving a specific goal for the material being examined, and for users' experience with it.

In this paper, we present three case studies of digital experience, presentation, and interoperability:

1. Deep examination and comparison of digitized material from multiple repositories via the International Image Interoperability Framework's (IIIF) shared APIs;
2. interaction with a thematic collection of new media content via an experiential interface developed using the Three.js JavaScript library; and
3. 3D rendering of archaeological data *in situ* for the purpose of discovery, analysis, and data sharing.

These cases span the continuum from deeply interactive to truly immersive, with each approaching the presentation of digital visual material in a different way, and toward a different end. Each can inform both our current use and future directions in this area.

Interoperability and Interaction With Digitized Collections: IIIF and Mirador

The rate at which library and museum holdings are being digitized has increased significantly over the last quarter century, for both access and preservation purposes. Policies and procedures are being put in place to ensure quality, efficient storage, and deliverability, while technological developments have improved the quality of digitization. This, by extension, increases the potential for deeper interaction with digital visual material by the end user. However, efforts to share content across institutions (and, in some cases, across repositories within an institution) continue to encounter obstacles. The most significant is the differences in the handling of storage, management, and delivery of digital material across repositories, which frequently use separate frameworks, formats, and applications. This is a widely recognized issue, but efforts to resolve it have all too often fallen victim to what has been called "the not-invented-here syndrome: the conviction that 'you and I will collaborate just fine if you adopt my system and abandon yours.'"[2]

The International Image Interoperability Framework (IIIF) was conceived to address this barrier to access and sharing of content by "promot[ing] the building of a global and interoperable framework by which image based resources could be easily shared and reused across institutions using any combination of image servers or client viewing software."[3] IIIF is a community-developed and -maintained protocol for standardized image retrieval, created in an effort to collaboratively produce both interoperable technology and a common framework for image delivery. Academic and cultural heritage institutions are not going to drop their own tools and development efforts *en masse* in favor of uniformly adopting a one-size-fits-all third-party tool. The growing IIIF effort addresses this reality by focusing on common APIs, eschewing quixotic quests for universal tool adoption in favor of creating a common method of content description and delivery. Put another way, by using this method, "digital image content generated and served up by a range of different image servers could be standardized as output (both the individual image and the structure of an image grouping) for re-use, and could flow, rather than be handed off like plastic water bottles."[4]

IIIF is currently made up of two APIs: *Image* and *Presentation*. The *Image* API describes image content and attributes – region, size, rotation, quality characteristics, and format. The *Presentation* API, based on the Shared Canvas data model,[5] provides sufficient viewer-agnostic structural and descriptive information about the image's context – structure, layout, and other critical metadata – to appropriately render it in a web-based viewing environment. This allows same data to be used for many purposes: simple image presentation, enhancement with

annotations and transcriptions, or embedding images in blogs and other third party web applications. If multiple repositories supported the same APIs for access to images, metadata and annotations, one can envision the beginnings of an ecosystem that leverages shared application code across different sites and interoperable image-based resources, enabling simultaneous access to multiple scholarly repositories through a single interface.[6] In this way, images and collections from repositories around the world can be accessed and interacted with just as easily as objects from a scholar's home institution, allowing for individual study or side-by-side comparison (Fig. 1).

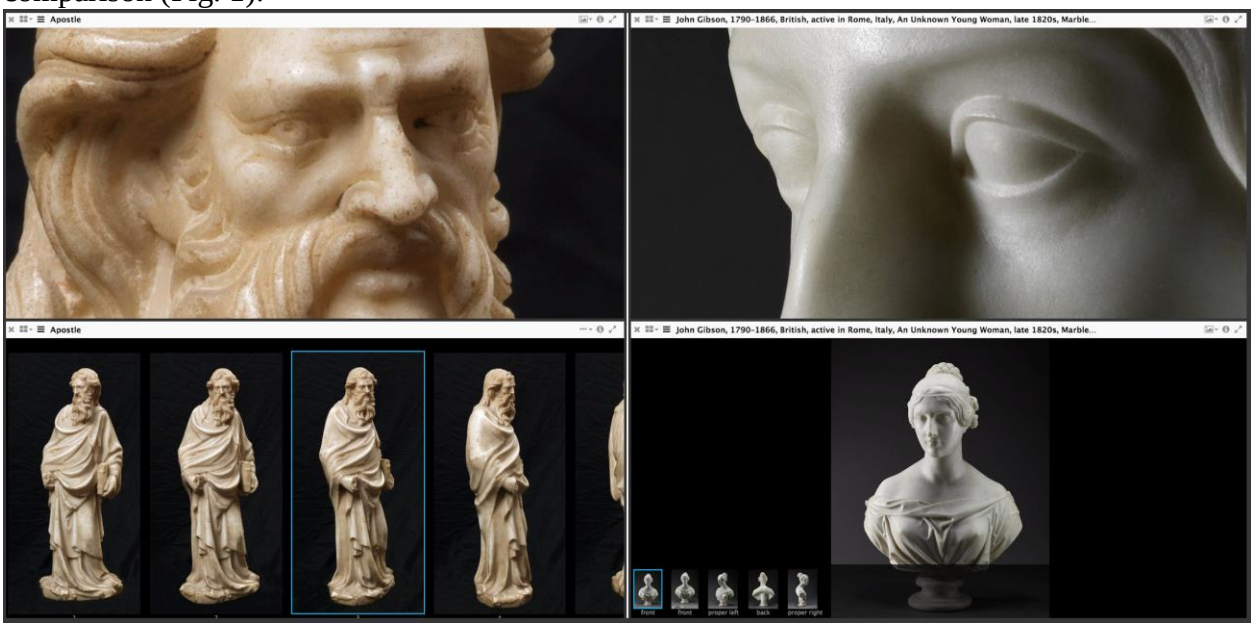


Figure 1**.** Side by side comparison of digitized statues from two repositories, the Harvard Art Museums (left) and the Yale Center for British Art (right), accessed via IIIF API and displayed in the Mirador viewer.

Individual institutions have exposed different portions of their collections via IIIF. Within Harvard, a multi-organizational effort has resulted in digitized content from multiple sources being made available, including tens of thousands of digital objects held by the Harvard Art Museums and Library, image collections from residential courses within the Faculty of Arts and Sciences, and image content contained in the learning experiences offered by the University's massive open online course (MOOC) provider, HarvardX.[7] Over three dozen other repositories are currently exposing their collections via IIIF, including the British Library; Bibliothèque Nationale de France; Princeton, Stanford, Yale, and Oxford Universities; the National Gallery of Art; and the J. Paul Getty Trust.[8] As this community grows, the world's digital archives are made even more available and accessible to scholars both within and across institutions.

One IIIF-compliant viewer, used for this visual material by Harvard and several other institutions, is an open source JavaScript application called *Mirador*.[9] Primarily developed by Harvard and Stanford Universities, Mirador is a "multi-repository, configurable, extensible, and easy-to-integrate viewer and annotation creation and comparison environment for IIIF resources, ranging from deep-zooming artwork to complex objects."[10] It "provides a tiling windowed environment for comparing multiple image-based resources, synchronized structural and visual navigation of content using OpenSeadragon, Open Annotation-compliant annotation creation and

viewing on deep-zoomable canvases, metadata display, book reading, and bookmarking."[11] In briefer terms, Mirador currently provides scholars who work with digitized objects with a responsive, high-resolution viewer for digital objects.[12] Images from any repository that have been made accessible via the IIIF APIs can be viewed individually or together as a slideshow, while books can be viewed as individual pages or displayed in two-page view, complete with "opening" to emulate what has historically been one of the most important experiential aspects of the codex.[13] OpenSeadragon's deep zooming functionality allows large objects to be viewed with ease, while the layout of the viewer can be altered by adding and removing "slots," creating a grid of separate images so that multiple items from one or more repositories, or multiple aspects of a single item, can be examined in a single window.

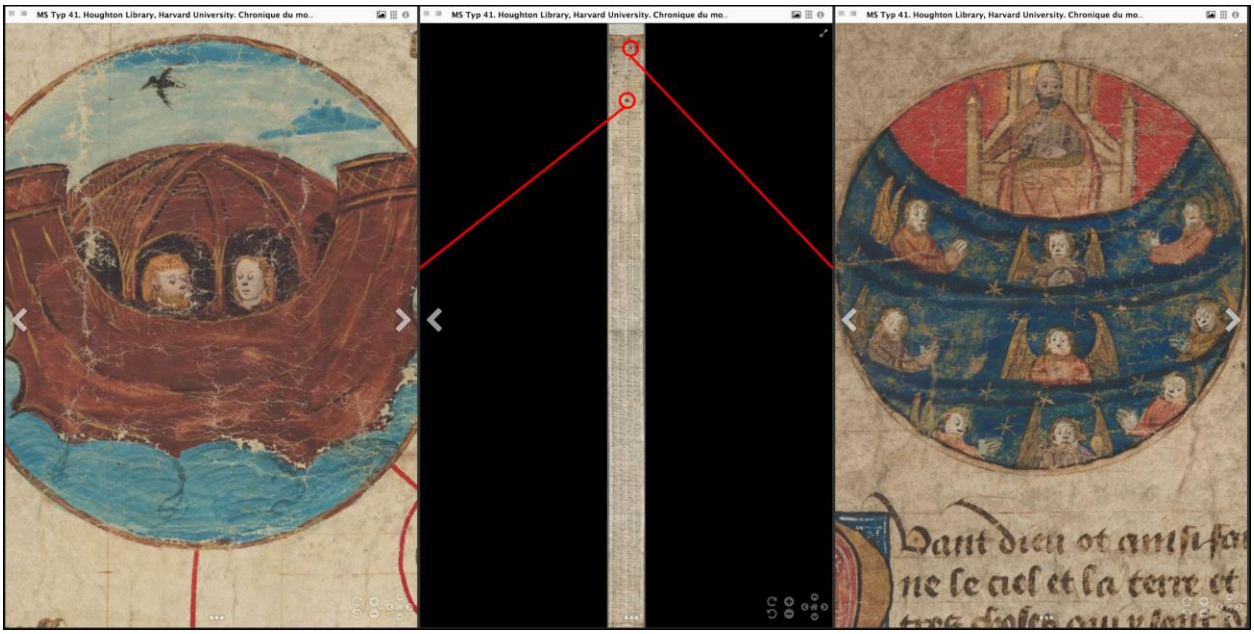


Figure 2**.** Multi-slotted Mirador workspace allowing the simultaneous viewing of three elements of the same object. The full scroll (MS TYP 41, Chronique du Monde Depuis la Création, Houghton Library, Harvard University) is nearly 12 meters in length. The roundels at left and right of the full scroll image are displayed at full zoom level (emphasis overlaid).

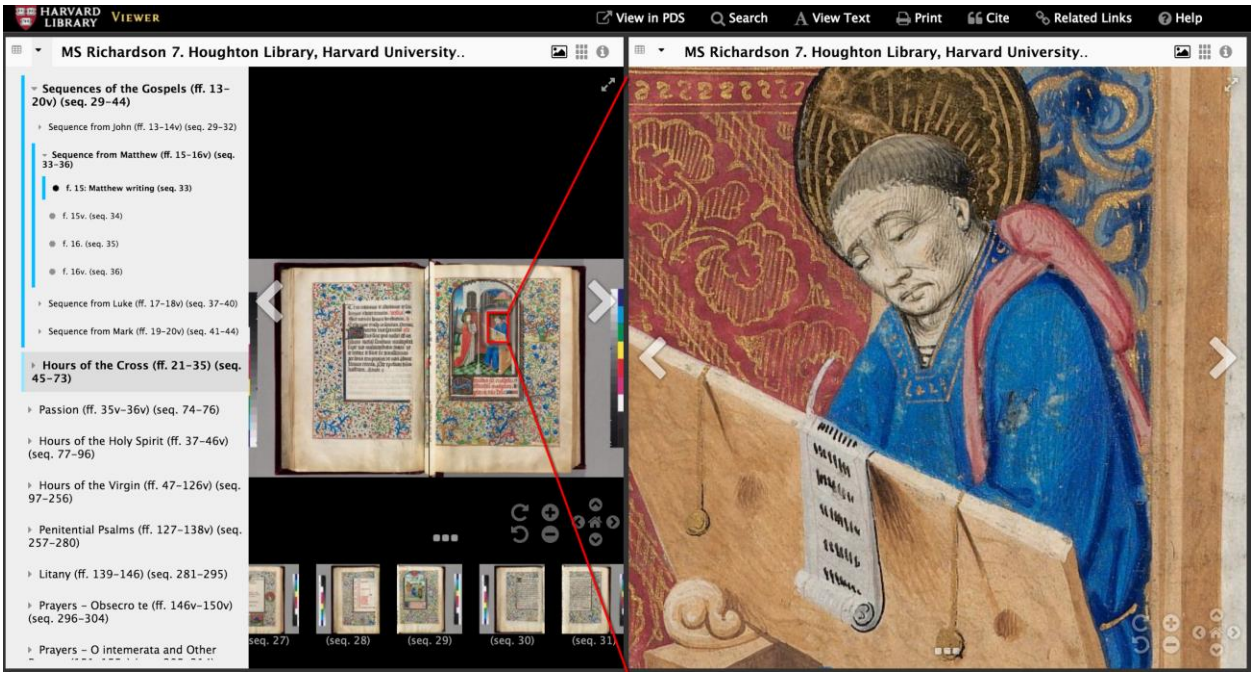


Figure 3. A medieval Book of Hours (MS Richardson 7, Houghton Library, Harvard University) displayed in the left slot in Mirador's "Book View," with page thumbnails and table of contents included. In the slot at right is the denoted portion of the illumination on folio 15 recto, displayed at full zoom level (emphasis added).

The next step of this process, currently in the requirements-gathering and planning phase, is to construct a IIIF-compliant scholars' workspace that will allow users to take full advantage of IIIF and Mirador while affording them the ability to collect, store, share, annotate, and arrange high-resolution digital images from multiple repositories worldwide, for the purposes of both teaching and research. Drawing on the remarkable interoperability afforded by IIIF and the deep interaction that Mirador brings to the study of digital visual material, this workspace would provide users the equivalent of a digital office or library carrel holding personal images, as well as references to, and notes on, as many web-accessible digital works as their research or class projects require.

Experiential Interfaces: The Charlie Archive at Harvard Library

Experiential Interface Design is an emerging trend among digital content curators that reimagines content search and discovery through new modes of interactivity.[14] The *Charlie Archive at Harvard Library (CAHL)* is one such experimental archive. Founded by Virginie Greene, Professor of French and Chair of the Romance Languages and Literatures (RLL) department at Harvard, and Nicole Mills, Senior Preceptor in RLL, CAHL contains a growing collection of digital and physical materials relating to the Paris attacks on the Charlie Hebdo headquarters and on the kosher supermarket Hypercacher in January 2015. Additionally, the archive also houses material relating to the Paris attacks of November 13, 2015.

The CAHL team is comprised of faculty, students, technologists, and librarians, and has been supported since the archive's early development by Harvard's Arts and Humanities Research Computing group (also known as Digital Arts and Humanities, or "DARTH"). The

project endeavors to collect materials that "represent diverse perspectives through different media responding to the events themselves or contributing to the debates around the events."[15] In addition, the team is particularly interested in the physical and digital ephemera, which was generated after the attacks, as a part of the ongoing conversations about these moments in history. As a result, the archive contains thousands of born-digital items, from cell phone images to tweets — items that lack any physicality whatsoever. With this in mind, DARTH has experimented with dynamic ways of exposing some of this content while also enabling an interactive experience.

The section of the DARTH website dedicated to the CAHL project contains an interactive 3D gallery designed primarily using Three.js, a javascript library that supports 3D rendering directly in the browser.[16] The Three.js library leverages the power of WebGL (Web Graphics Library), a JavaScript API designed to render interactive 2D and 3D graphics directly in the browser. It was built with HTML5-supported OpenGL ES 2.0, a "royalty-free, cross-platform API for full-function 2D and 3D graphics on embedded systems - including consoles, phones, appliances and vehicles."[17] This allows designers to create everything from 3D galleries to interactive musical experiences and more.[18]

The CAHL gallery can be controlled by mouse, trackpad, or touch, and was designed to support a tactile visual browsing experience. The layout is in the format of a multi-layered grid, allowing users to zoom in and out, rotate the gallery, and pan across images. Although experimental, the underlying design goals are clear: to create an embodied experience of the archive through touch, to reveal a holistic view of the content that users can navigate without privileging any type of search algorithm or method, and to serve as a launching point for the incorporation of visual search in large-scale projects with a wide variety of content.

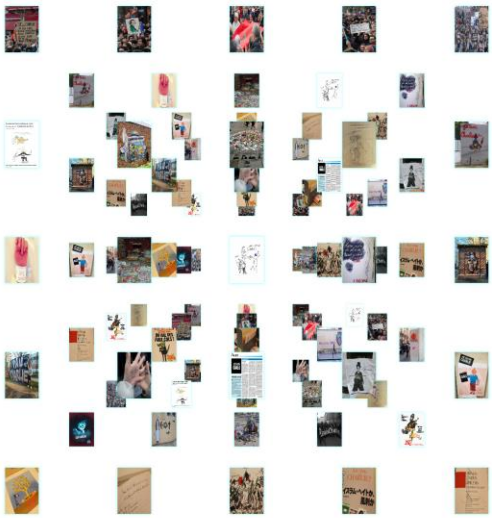


Figure 4. Front view of the interactive 3D gallery on the DARTH website—images are ordered in a multi-layered grid for browsing.

Experiential Interface Design encourages us to embrace the embodied nature of cognition. This is described by Fishwick as a twofold process, which involves adopting sensory technologies (keyboard, mouse, touchscreen, headset, etc.) to mediate interaction, and creating a

subjective sense of presence amidst the material being viewed.[19] Instead of a typical goal-oriented search environment, which may require the input of keywords or subjects, or a series of selections to be made as part of a faceted search, the goal of the visualization is to allow users to explore the interface as a virtual art gallery. It is a constellation of shared grief, anger, stories, art, and community that coalesced during the immediate aftermath of the Paris attacks, a window into a transformative experience where the digital representations of the artifacts being preserved *are* themselves the artifacts as well.

Figure 5. Image examples from within the various layers of the gallery.

All too often, user interfaces suffer from *functional fixedness*, a cognitive bias that inhibits creative exploration by limiting our sense of an element's use to the traditional functions for which it was designed. Bolter and Gromala remind us that looking solely *through* our interfaces prevents us from making sense of the ways that the interface shapes our experience and that "to design a digital artifact is to choreograph the experience that the user will have."[20] Amidst a constant stream of new media being created and shared globally, digital content curators have an increasing responsibility to design experiences that give fresh perspectives on archives and other media collections.

The field of human-computer interaction (HCI) has become increasingly focused on the user interface and how it shapes our experience of digital content, sometimes called *affective interaction*. In affective interaction the underlying desire is "to make systems more natural and responsive to the goals and expectations of the user, so as to improve usability and user

experience."[21] The CAHL 3D gallery endeavors to emulate this fundamental idea by giving the user the ability to view the content from multiple angles through changing fields of view and aspect ratios created by the Three.js perspective camera functions. In this way, born-digital objects can be experienced as if they were artwork on a wall or objects within our hands.

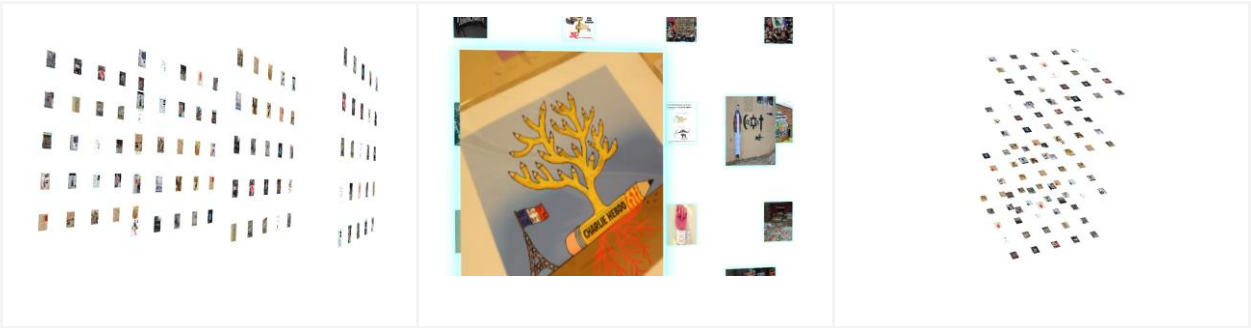


Figure 6**.** Pan, rotate, and zoom views of the gallery showing different perspectives.

The CAHL seeks to not only catalog the items themselves, but also the affective realities that permeate them: stories, anecdotes, and other meaningful connections that inspired the creation of the content in the first place. Greene envisions a living archive that draws upon these connections, a unique collection that will "document a peculiar moment in the early twenty-first century, when the word 'Charlie' all of a sudden took on tragic significance, and became charged with conflicting emotions, opinions, and agendas."[22] The 3D gallery is one of many innovations that has arisen since the start of the project, and will certainly not be the last.

Virtual and Augmented Reality Interfaces: Discoverability for Mixed Media Datasets for the Contrada Agnese Project at Morgantina

Innovations in digital recording have caused the amount of data collected during an archaeological excavation in 2016 to dwarf that collected only a few years ago -- let alone those from the previous century. This increase in data collection, however, is of little value if the data are not shared in a meaningful way:

> The intensification of data collection is only useful...if the data are accessible. Traditional forms of documentation can be published in print, but the contextual relationships expressed through a dynamic database and GIS exist only in digital form. To put the results of such systems to the service of the wider archaeological community, it is imperative to develop strategies for their digital presentation.[23]

The nature of archaeological data makes it a natural entry point for virtual reality (VR) and augmented reality (AR) dataset exploration: the data are inherently three-dimensional, while a GIS point and associated find connote a possible shape, model, and texture. This advantage has been embraced by the *American Excavations in Morgantina: Contrada Agnese Project* (CAP), a research and excavation project launched in 2013 in the urban areas of Morgantina (Sicily). Led by Alex Walthall, assistant professor of Classics at the University of Texas-Austin, CAP utilizes VR and AR tools as a means of sharing data from the excavation, both across the project's three teams (excavation, museum, and geospatial) and with outside researchers and the general public.

In partnership with CAP, Archimedes Digital has developed applications that join three-dimensional geospatial (GIS) data joined with museum records and images, photogrammetry of trench models, and interpretive 3D reconstructions of monuments, and present them in multiple environments in order to increase the discoverability of the work done by excavation and museum teams.[24] With the continually transforming digital recording in archaeology, Archimedes's specific goal is to offer tools that visualize as much data as possible in three-dimensional environments.

Three applications are currently employed for data presentation, each offering a different level of functionality and aimed at a different audience:

1. a traditional browser-based web application for managing content across CAP teams (http://atlas.archimedes.digital)
2. a virtual reality application using Google Cardboard to allow the general public to explore reconstructions of the site, and
3. an augmented reality application using the Google Project Tango development kit tablet, which enables area learning and fine motion tracking. In this application, each stratum of the site is reassembled virtually to allow for the exploration of excavation trenches by the project team and by outside researchers.

The application ecosystem follows a microservice software architecture design pattern, with independent services and applications that render data or consume APIs in order to export, join, and expose various datasets across members of the CAP team. The browser-based application was primarily built in JavaScript, using the Node, React, and Meteor libraries. A consolidation layer retrieves data from various services, including an ArcGIS shapefile-to-GeoJSON conversion service and a Filemaker-to-MongoDB syncing service. These data are then exposed through a simple user interface and Representational State Transfer (RESTful) API.

Virtual and augmented reality allow archaeological data to be exposed to a wider community of users, including both specialists and laypersons. The applications created for CAP in the Unity3D gaming engine query datasets made available by the consolidation layer API, visualize the data by instantiating game objects in the virtual scene for geospatial point, and fill out the model with relevant descriptions, images, and 3D models. In the Google Cardboard application, the consolidation layer web application includes an administrative backend for managing data in the application. Content administrators may select a point from a Google Maps interface and associate text, images, audio, or a 3D model, and the Unity application queries the consolidation layer API and instantiates an information point in the reconstruction at the latitude and longitude the content administrator selected. The consolidation layer also enables the platform to be reused for other historical and archaeological sites where a content administrator wishes to curate data and present them to end users using geospatial markers.

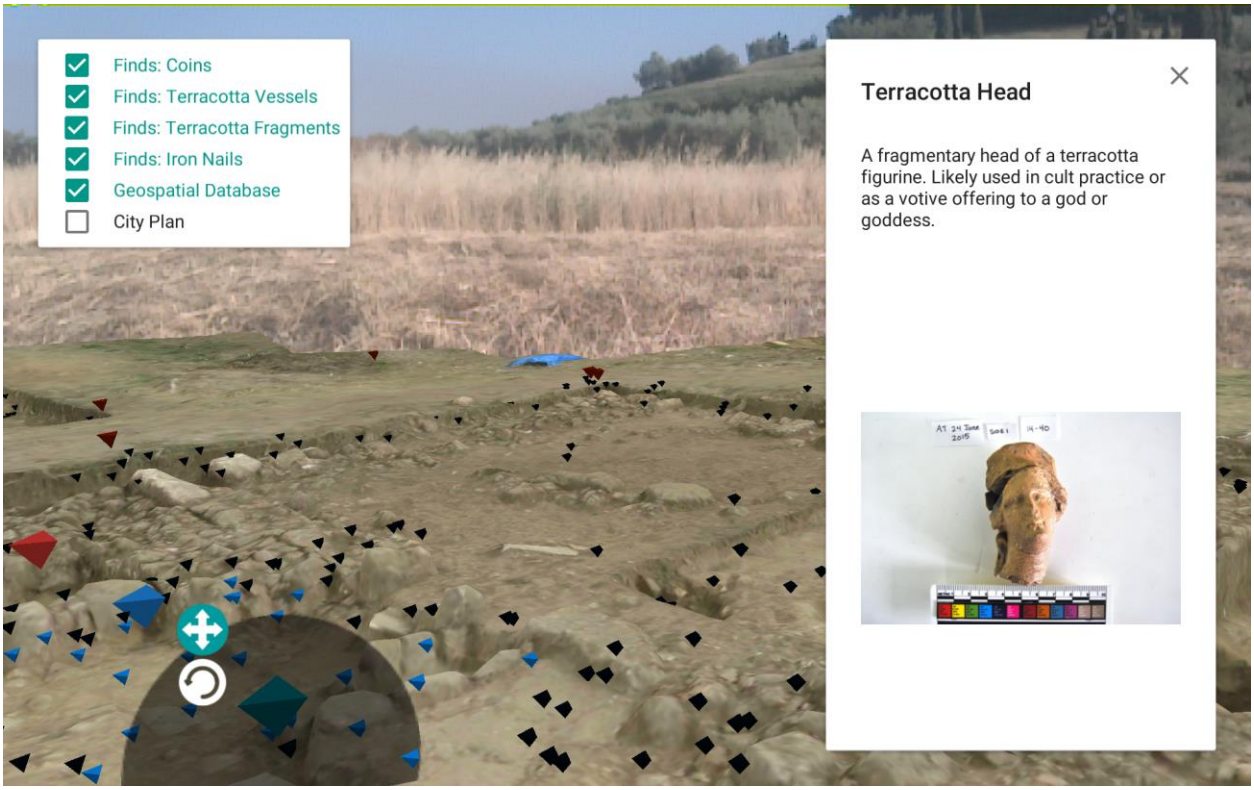
The VR application for Google Cardboard has the greatest amount of custom pre-arranged content, which requires 3D artists to render detailed but low-poly reconstruction models and terrain based on survey data. Because only foundations remain of all but two of the primary monuments in the agora at Morgantina, the VR exploration application is most useful for allowing users to visualize the original appearance of the Hellenistic agora. Because geospatial datasets are inherently tied to a single place in the global coordinate system, our team thought it would be important to bridge between virtual reality and augmented reality by accessing the device (smartphone or tablet) GPS information for users on-site in Morgantina. Though there is no motion tracking with conventional smartphones, users may look through their phone as they

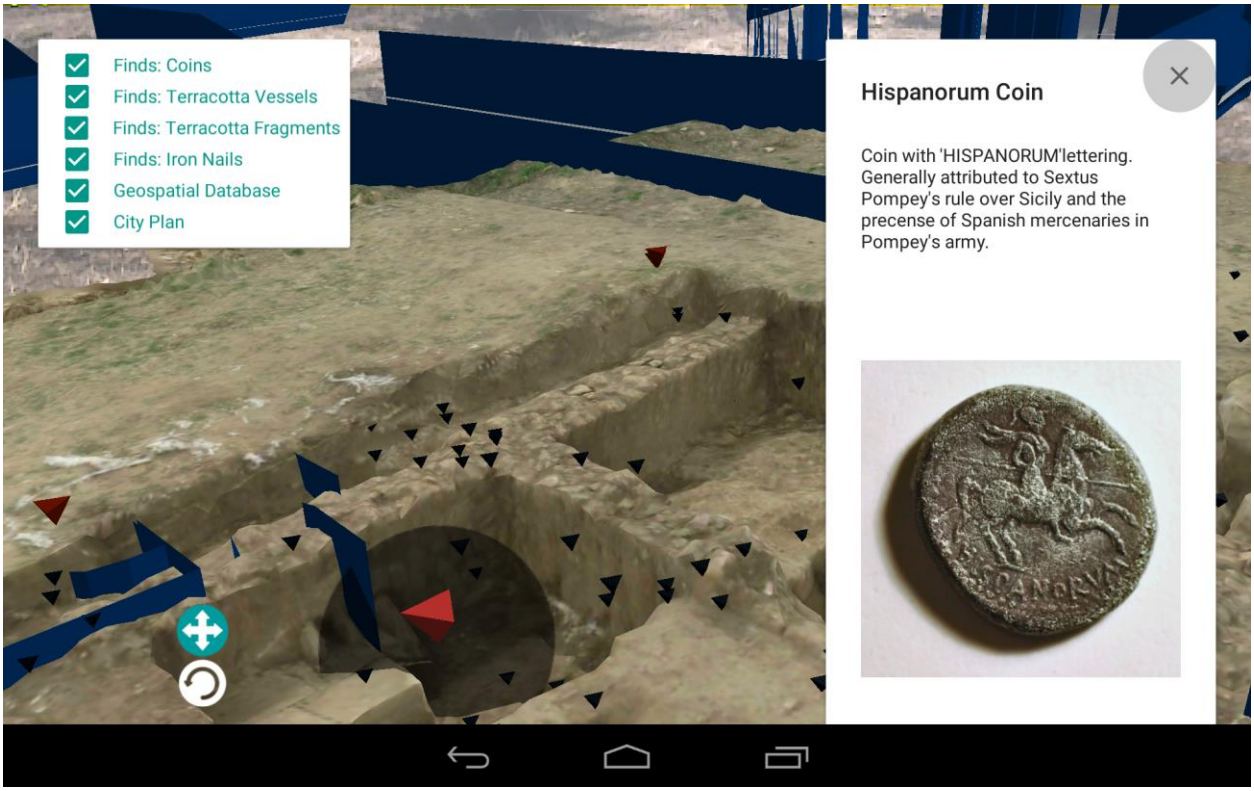
stand near monuments onsite in Morgantina in order to see the reconstructions of the ancient monuments at different time periods in the history of the city (Fig. 7).

Figure 7**.** A screenshot from the Atlas virtual reality application for Google Cardboard showing artists' interpretive reconstruction of a stoa in the agora at Morgantina

In addition to Google Cardboard, the CAP team utilized the Project Tango software development kit for a more enhanced mixed-reality experience. With the Tango tablet, users can interact with excavation trench models created through photogrammetry. AR applications have historically been used in archaeology for exploration rather than interpretation. This holds partially true for CAP's use of the Tango, as one major presentation is a day-by-day journal of the excavation, wherein geospatial and museum data are presented together in a user-friendly AR interface (Fig. 8).


Finds: Coins
Finds: Terracotta Vessels
Finds: Terracotta Fragments
Finds: Iron Nails
Geospatial Database
City Plan

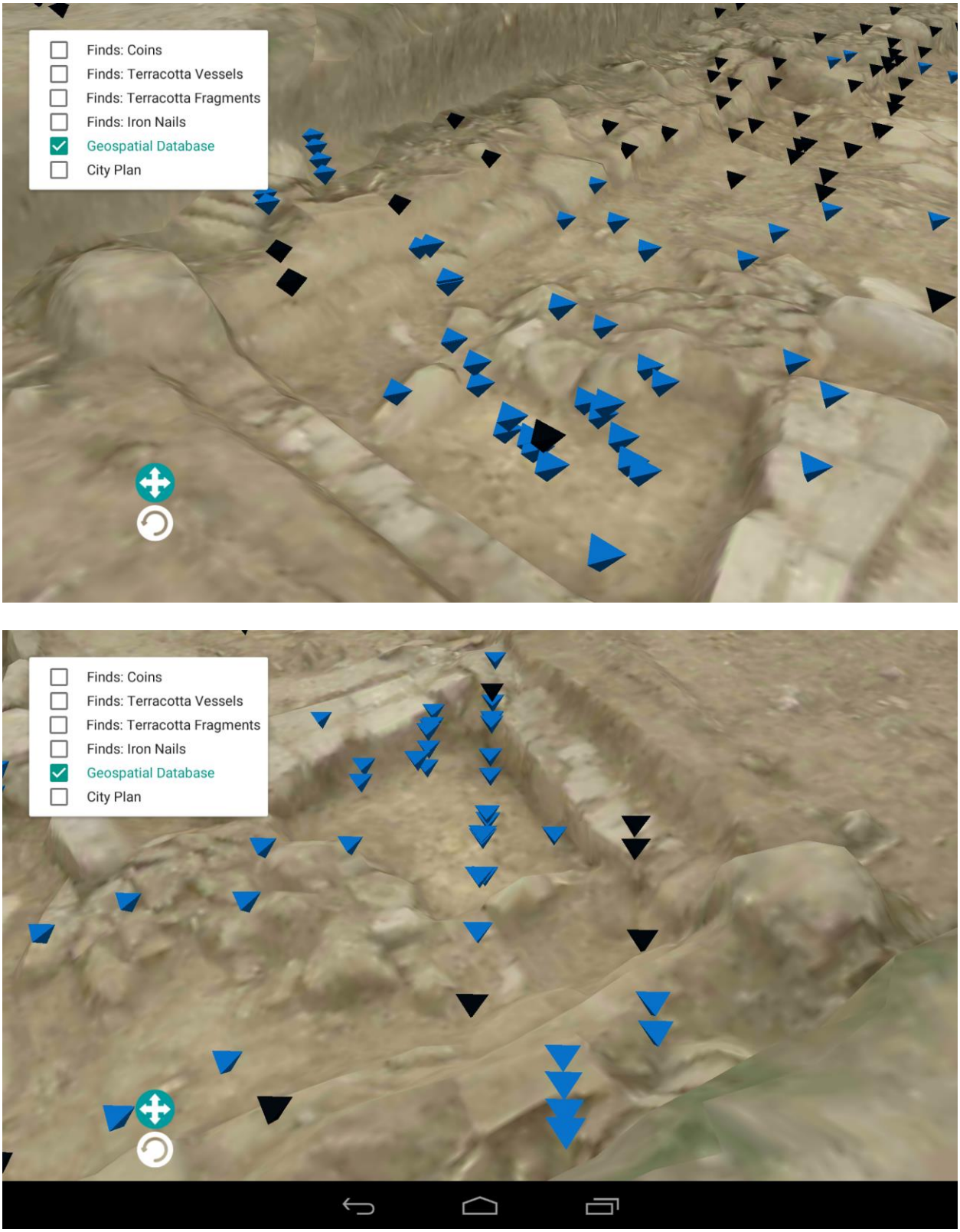

Finds: Coins
Finds: Terracotta Vessels
Finds: Terracotta Fragments
Finds: Iron Nails
Geospatial Database
City Plan
Terracotta Head
A fragmentary head of a terracotta figurine. Likely used in cult practice or as a votive offering to a god or goddess.



Figures 8a-c**.** Data presentation in the Atlas Project Tango augmented reality application as used in the field in the Contrada Agnese Region of Morgantina.

The AR application has also proven helpful for interpreting data at Morgantina. An example of this is the identification of clusters of iron nails in Trench 39. As the cluster patterns were only visible from a specific angle, they were not readily apparent from the two-dimensional Computer-Aided Drafting (CAD) renderings. The ability to explore and interact with this geospatial data in an intuitive AR interface enabled the pattern of nail clusters, in combination with adjacent column discs, to be identified as the remnant of a collapsed roof timber.

2D CAD renderings (and the hand drawings that predate them) highlight the interaction between excavation finds, walls, larger plans. This plays a critical role in archaeologists' interpretation of recorded data. However, this form of data presentation is limited to single snapshots, each of which presents a single context at a single point in time. In the case of the iron nails, the two-dimensional interface on OpenLayers maps on the CAP web application is unable to provide what was needed to interpret this set of finds: the ability to observe from *multiple* vantages within a single context. When viewed in the AR application with Project Tango, a user can walk through the site and explore the data in an intuitive and natural method. As can be seen below, the clustering of nails is completely obscured while the trench is viewed from the northwest (Fig. 9a); however, when viewed from the southeast - only a few steps away - the nail pattern becomes immediately apparent (Fig. 9b).



Figures 9a-b. Screenshots from the Atlas Project Tango augmented reality application showing Trench 39 from the northwest and southeast, respectively.

When constructing three dimensional scenes and displays of datasets, it is imperative that project teams render and present data in an intuitive manner. This means creating interfaces which are familiar to users, while also taking advantage of the innate perception of three dimensional space for presentation and interpretation of data. In order to enable discoverability across large datasets, teams should adopt concepts from similar media to take advantage of spatial-temporal understanding through leveraging foreground, middle ground, and background layering of content and the slippages of information between layers (each of which is a subject of considerable further exploration).

Conclusion

Current trends in technology encourage networked data, interactivity, interoperability, and perhaps most importantly, creativity. In lieu of virtual silos, the creative application of content management systems and interactive experience design, in tandem with the wisdom of methods cultivated by cultural heritage institutions, expose users to a quantum order of bibliographic objects.[25] Going forward, new traditions of dynamic search and discovery, crowdsourcing, generative design, and interactivity will help us contextualize these objects, and will redefine future generations of archive, museum, and library collections.

The three case studies presented here represent a broad spectrum of trending ideas and methodologies for digital content management, design, and function. Each comes from a place where content and interactivity are one and the same, where material "needs to be assessed not only on the quality of its content, but also in relation to how it can be used, shared, repurposed, and integrated into teaching, learning, and research."[26] The immediacy of the networked experience demands new approaches to content curation and management. In a world of ubiquitous new media, a collaborative effort amongst cultural heritage institutions and other digital content creators can reshape the landscape of digital collections into marvelous new forms that prioritize discoverability and a more effective user experience.

Notes

[1] For the sake of differentiation we might refer to this class of object as *digitized* rather than *digital*

[2] Waters 2013: 14

[3] Snydman, Sanderson and Kramer 2015: 17

[4] Ying and Shulman 2015: 5

[5] http://iiif.io/model/shared-canvas/1.0/

[6] Snydman, Sanderson and Kramer 2015: 17

[7] Stern et al. 2016; Bentley et al. 2016; http://harvardiiif.org/

[8] iiif.io/community

[9] http://harvardiiif.org/mirador/

[10] http://projectmirador.org/

[11] http://projectmirador.org/; https://openseadragon.github.io/; http://www.openannotation.org/

[12] Harward et al. 2014

[13] Hamburger 2009: 51

[14] The term *digital content curators* here refers to a wide array of specialists (librarians, archivists, curators, technologists, etc.) involved with archival and exhibition of digital content and experiential new media.
[15] http://cahl.io/#project
[16] http://www.darthcrimson.org/cahl; http://threejs.org/
[17] https://www.khronos.org/opengles/2_X/
[18] See *Orchestre de Paris*: http://www.orchestredeparis.com/resonance/
[19] Fishwick n.d.
[20] Bolter and Gromala 2005: 22
[21] Shah, Teja and Bhattacharya 2015
[22] http://cahl.io/#project
[23] Rabinowitz et al. 2008: 18
[24] http://archimedes.digital. As a collaborative effort across applications, Archimedes partnered with Jarien Sky-Stutts Art, Misc. Labs, and Vermont Digital Arts.
[25] McGann 2004: 412.
[26] Horava 2010: 143.

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