Augmented : Reality :: Architecture : Interface

Noushin Radnia[1], Alireza Karduni[2], Isaac Cho[3], Zachary Wartell[4], Eric Sauda[5]
School of Architecture, UNC Charlotte
Charlotte, NC, USA
[1]nradnia@uncc.edu, [2]akarduni@uncc.edu, [5]ejsauda@uncc.edu
Charlotte Visualization Center, UNC Charlotte
Charlotte, NC, USA
[3]cho1@uncc.edu, [4]zwartell@uncc.edu

ABSTRACT
We present research on the integration of augmented reality and architecture using a design science research methodology. Our goal is to consider the design of architectural space and augmented reality (AR) applications simultaneously. The architectural brief is an archeological museum/excavation site that directly confronts issues of occupation, circulation, form, and access to large archives of information. Combining the efforts of twelve architectural designers with a team of AR developers, we develop a taxonomy of affordances, feedback mechanisms, and output/display options. This taxonomy constitutes preliminary usability heuristics for the use of AR as an embodied device for interaction in architectural settings.

KEYWORDS
Augmented Reality, Architecture, Interaction, Design, Interface

1 INTRODUCTION

Augmented reality (AR) is not a new field; it is possible to trace ideas focused on mixed reality back to the beginning of the 20th century. Active research has been conducted on augmented reality in computer science since the 1970's, often in conjunction with research on virtual reality (VR). Until recently, latency and registration issues significantly limited AR implementations to low resolution fully registered images or handheld applications with an arms length gap between real and virtual worlds. But advances in head mounted displays (HMD) and software funded by Microsoft, Google and others have made the use of AR feasible in widely expanded contexts and content.

In architectural design, AR is of particular interest because it is inherently spatial and can lead to an understanding of architecture as an interface, marrying space and information [ChI]. The release of advanced and accessible new AR devices such as the development versions of Microsoft Hololens [Avila] has provided us with the opportunity to study how AR could intersect with the architectural setting, which we call the architecture interface.

There is a strong inclination within computer science to view AR as a technology that can adapt to any existing spatial settings; technology is developed and dropped into an architectural setting. However, designing AR applications and architectural settings together will allow for exploration of a full range of affordances, feedback mechanism and output/display options, leading to a generalized set of usability heuristics for AR. It can become one example of Dourish's call for embodied interaction [Dourish]. By this he means that the historical emphasis in HCI on symbolic systems ignores the importance of the setting, both social and architectural, in which interaction takes place. An understanding of architectural space and place is not circumstantial, but rather essential to an understanding of how interaction can be meaningful to users.

In this paper, we present our research focused on creating architecture that takes full advantage of AR technologies and designing AR interactions that are configured to change the way architectural space is understood and used. We chose to design for a setting that would present considerable challenges both in terms of spatial and architectural dimensions as well as AR issues centering on access to very large archives of data. Our choice for the architectural setting for this project was the Mount Zion Archaeological Park in Jerusalem that has been the site of ongoing excavations by archeology researchers [Tabor]. Archeological work on the site is close to completion and a design for a museum and park preserving and explain the site is being contemplated. Huge amount of data have been generated during the eight years of the excavation (type of object, location, relationship to other objects) as well as possible connection to the larger archaeological record across the middle east and the world.

In a studio setting, our team of 12 student architectural designers, 3 computational designers, and faculty from departments of architecture, archeology, and computer science went through the process of developing tightly coupled AR interactions and architectural spaces.

Our design process started in a relatively conventional manner, beginning with gathering information about the site. Then through a list of spatial and informational requirements for an archeological museum, we developed AR applications using the hololens, allowing each architecture designer to develop a museum design and AR interactions. Finally, we developed a novel tool for architectural representation that allows for exploration of architectural space and AR interactions. In this paper, we present the following contributions:

- We present our lessons learned from a design process that is beyond traditional interaction design or architectural design practices.
- We introduce four design cases of archaeology museums that each come with unique AR interactions and novel architectural spaces.
- We present a taxonomy of interactions developed by our architectural designers and offer our discussions on ones that can be best fitted into design of architectural spaces.
- We present our digital interface that allows for exploration of proposed architecture spaces as well as dynamically understanding their embedded AR interactions.

In the next section of this paper, we will have an overview of previous work and research at the intersection of architecture and AR. Next, we will define our design process and describe how we managed to merge practices of interaction and architectural design followed by 4 cases of such designs. Finally, we will offer our findings in the realms of AR interaction design, architectural design, and architectural representation.

2 LITERATURE REVIEW

Recently, rapid hardware and software development spurred by major investments by Microsoft, Google and Samsung has led to integrated systems at price and performance levels that have the potential for widespread adoption [Avila]. Many of the systems for display, location, registration and computer generated imaging have been reduced in size to fit in a head mounted display.
Ronald Azuma, a leading researcher, produced surveys of research in 1997 and 2001 detailing the development of AR and its unique technical challenges [Azuma 1997, 2001]. In these researches he explains potential applications and possible usage scenarios of AR that include medical, military and entertainment. However, he does not explicitly discuss the potential applications of AR for architectural design. Besides a scan of potential applications, much of his focus during these formative stage was on issues of virtual/real image registration and latency.

A thorough overview of the application of AR to architecture and engineering by Chi focuses primarily on the applicability during the construction process. [Chi] He names different technologies such as GPS, cloud computing, and mobile devices as potentials of greatly improving different aspects of work during construction processes. The goal of our research is on the incorporation of AR as a media during the design of a building.

Research on the use of AR technology in learning situations has resulted in general principals including challenging, gamification and curiosity. [Dunleavy]. These principles in modified form are applicable to architectural settings. Some research exists providing a comparison of student learning using traditional printed plans versus interactive 3D models using AR technology [Fonseca]. Beginning students were found to develop a better spatial understanding using the AR system. Our research will build on this type of insight by allowing designers to test AR interactions during the design process and then move on to combine them with the spatial elements.

Work from media studies situates AR in a broader cultural and historical context. [Bolter] Any understanding of the use of AR must include how it compares with existing methods of engagement. MNEMOSYNE is a system that delivers a personalized, interactive multimedia experience to museum visitors through the use of computer vision [Bagdanov]. Although AR will differ in it technologically, the issue of personalization is central to its use. Work on ideas of a personalization of museum visits are important for the use of AR in architectural settings. The Transformative Museum project [Kristiansen] is an important framework for this understanding in a broad context.

The development of AR applications in architectural and urban settings has increased with these expanded technical capabilities. Earlier attempts to embed AR into architectural and urban environments [e.g. Feiner] integrated the salient elements of the Hololens system (gps locational service with the generation of text labels and a head mounted display) but in a form that required a large backpack and bulky GPS receiver.

3 METHOD

We employ a design science research method that generates knowledge and insight of complex problems by the process of design [Hevner]; further, within this knowledge paradigm, multiple designs can serve to uncover an expanded range of possibilities. Our research was conducted by a team of eleven advanced architectural design students, a team of three computational design student, and faculty from architecture and computer science. This resulted in the design of 12 distinct designs, each of which proposed a specific architectural form and specific uses of AR technology. Furthermore, the computational design research resulted in AR prototypes for the hololens, as well as an interactive desktop application that allowed exploration of architectural design as well as AR interactions specifically design for each space.

Design of architectural space that takes full advantage of the opportunities of AR technology requires a process that is different than traditional architecture or interaction design processes. To address this issue, we first conducted precedence studies of AR technology, archeological museums, as well as the rare examples of AR integration into architecture. Using these precedent studies, we developed a list of required spaces for an archeological museum. Each architecture student would then have the freedom to create new innovative spaces that would make the integration of AR technology seamless within their design.

Creating specific AR interactions turned out to be a challenging task for architecture students who are mostly trained in creation of form and static space. To rectify this problem, we experimented with integrating various prototyping and diagramming methods within the architectural design process. This required an iterative process of deeply integrated architecture and interaction design. As the architecture students made progress in developing spaces and programs for the museum, they also developed scenarios for re-inventing the ways archeological information would be embedded into the architecture using AR.

We evaluated the architectural designs using both normative architectural evaluations methods (geometric clarity, circulation, views, lighting and enclosure) as well as interaction evaluation (digital building models and interaction simulation). These evaluations were conducted through a hands-on architectural studio where faculty, architecture, and students improve the designs and interactions. AR interactions were developed using various methods. Our team started with using storyboards, then moved on to add spatial diagrams to better communicate AR interaction in architecture space (we call this step the analog step). Next, we used storytelling and presentation by the designers to both conceptualize and articulate the architecture and AR designs. We finally designed an interactive desktop application prototype that would allow exploration of proposed architectural design, as well as the proposed AR interactions within the space (we call this step the digital step).

The analog step started with each architecture student brainstorming and developing a list of ways they would like to integrate AR within their architecture. At this stage we specifically asked the students to not focus on limitations of available technologies. At this stage, each student developed diagrams and models for their museum design as well as descriptions of their proposed AR integrations. These descriptions were not completely useful in communicating the designer's' ideas about how the technology is embedded within the space. We employed storyboarding as our next design experiment.

Students were asked to develop storyboards on how AR would be used within the space. These storyboards were created using sketching or design software the students were comfortable with. These storyboards proved to be more useful in communicating the innovations but they mostly lacked spatial information. Therefore we decided on a “spatial storyboard” technique which consists of schematic maps that are accompanied by sketches of interactions by linked to each significant space.

At this stage we were able to develop different categories of interactions some of which were shared within different architectural designers’ proposals. The computational design students then started developing sample interactions for the Hololens based on the proposals made by architects designers (see Figure 1, Left). The modelling of the 3D artifacts was completed in Rhino3D and the programming of the Hololens was in Unity3D using the C# programming language. This marked the beginning of our digital stage.

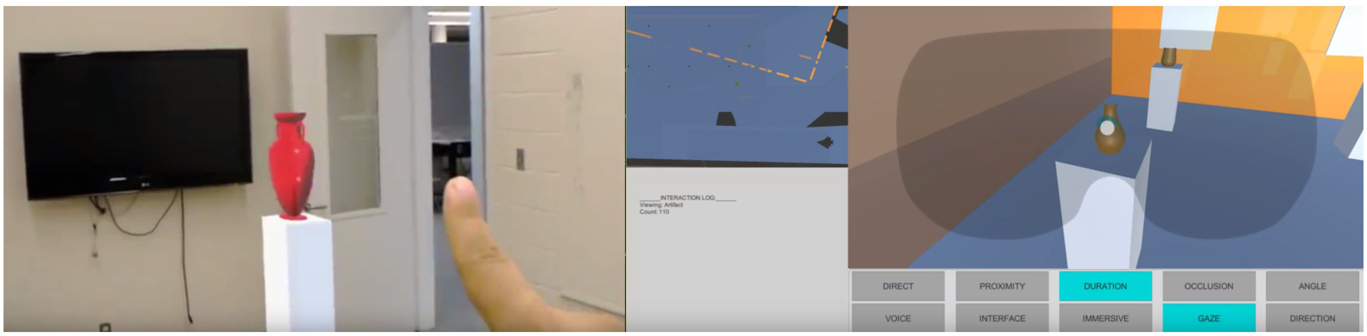

Figure 1: Left, Preliminary testing of AR interactions designed by architecture students using the Hololens. Right, Interface for augmented reality design in architectural space. Note the spatial model view in the supper left, the augmented view of the use in the upper right and the selection of interactions at the bottom.

Testing the AR interactions with the Hololens proved to be extremely helpful for the architectural designers to better understand the role AR would play within their designs. However, there was still a large gap between what the architects envisioned for their buildings and how AR would integrate within it. More specifically, it was impossible to show the huge amount of building details developed by the architects using software such as Autodesk Revit as part of the AR experience. So our team brainstormed to create an alternative method to both represent the AR interactions as well as to demonstrate the space in which these interactions take place in.

The results of our work to create this alternative method is a prototype for an interface (see Figure 1, Right) that enables users to explore designed spaces proposed by students as well as to simulate the AR interactions embedded within the building. More specifically, the interface would enable us to import 3D models of buildings and create a walkthrough in the proposed space, as well as to embed the proposed interactions. Our interface allows users to view the space in both perspective and top view and interact with proposed AR objects and information. It also consists of complementary views that show a user’s interaction log and finally a view highlighting different AR interactions as a user experiences a proposed intersection of AR and architectural space.

The interface was useful for the students to develop the depth of their ideas, as well as for other design critics who regularly reviewed the designs of the students to understand and critique the integration of AR technology within architectural design. The interface consists of two views that show information that is used in most architectural representations: perspective view and plan view. Two complementary views would show the interaction category and a log of all interactions conducted by users. Together these views would allow anyone to explore each proposed museum and also interact and understand how AR would change the way architecture is developed and used. A vital part of the process was the generation of videos for each project that demonstrated the nature of both the architectural space and the interaction simultaneously. (see Figure 2)

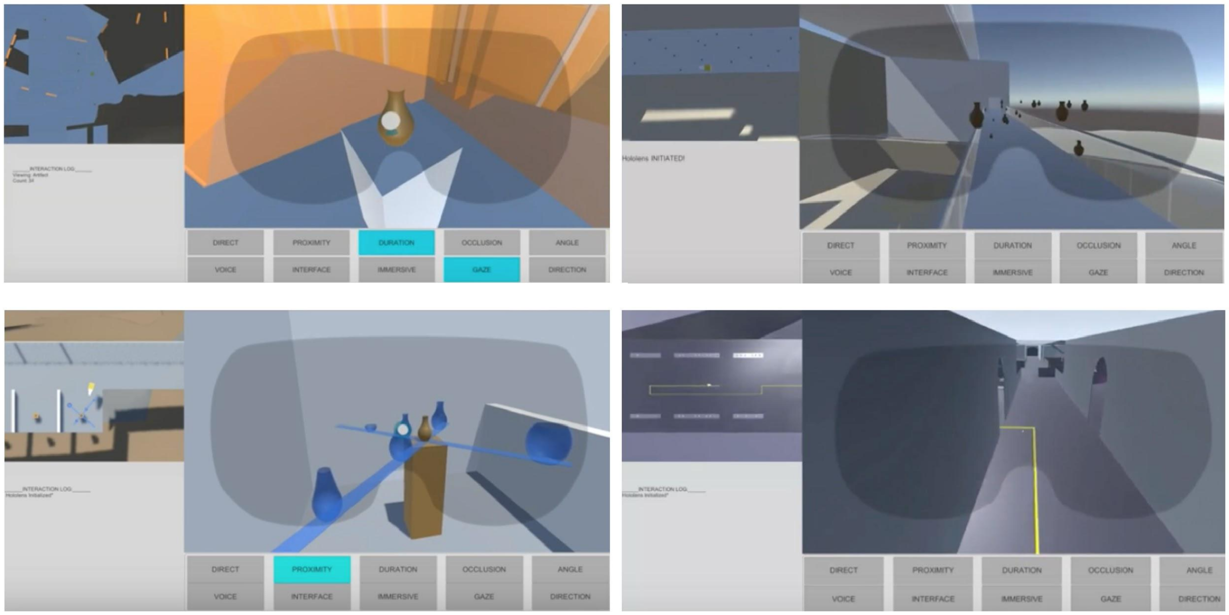

FIGURE 2: Four case studies showing both the architectural setting and the interactions simultaneously using an interactive interface.

Experiments with the interface allowed our team to refine the different affordances to fit best with a designer's vision and to easily implement the proposed interaction affordances for Microsoft Hololens. A taxonomy was developed from these experiments and became available to all designers. In the next section, we will explore four designs that demonstrate the range of ways AR interactions and information can be embedded within architecture.

3 CASE STUDIES

Eleven architectural designers participated in this design studio. We present four examples of these designs that are illustrative of the range of AR and architectural approaches. In each case, we will start with explaining the direction of the architectural design influenced by AR, followed by narratives from the designers that indicate their design process as well as drawings and diagrams of the design proposals. Documentation of the work of all eleven designers as well as complete descriptions of all aspects of this project are available at www.xxxxxxxxxxi

The architectural spatial program included preservation of the archeological excavation, a gallery featuring selected important artifact from the site, an extended archive of all of the artifacts discovered on the site and a suite of offices and research laboratories for research.

Noushin Radnia

TECHNOLOGY + HISTORIES + PERSONAL EXPERIENCE

The location of the archeological site in the city of Jerusalem in Israel defines a unique site that carries layers of history, culture, religion and individual life stories in a consistent time frame. This design is inspired by two concepts. First, the connections to important Christian, Jewish, and Muslim sites on Mt. Zion which are used to form a structure of corridors that terminate in virtual view toward these sites. Second, The movement of individual users are collected and projected on an information dome, allowing each individual to see and understand both their own interest and those of other visitors.

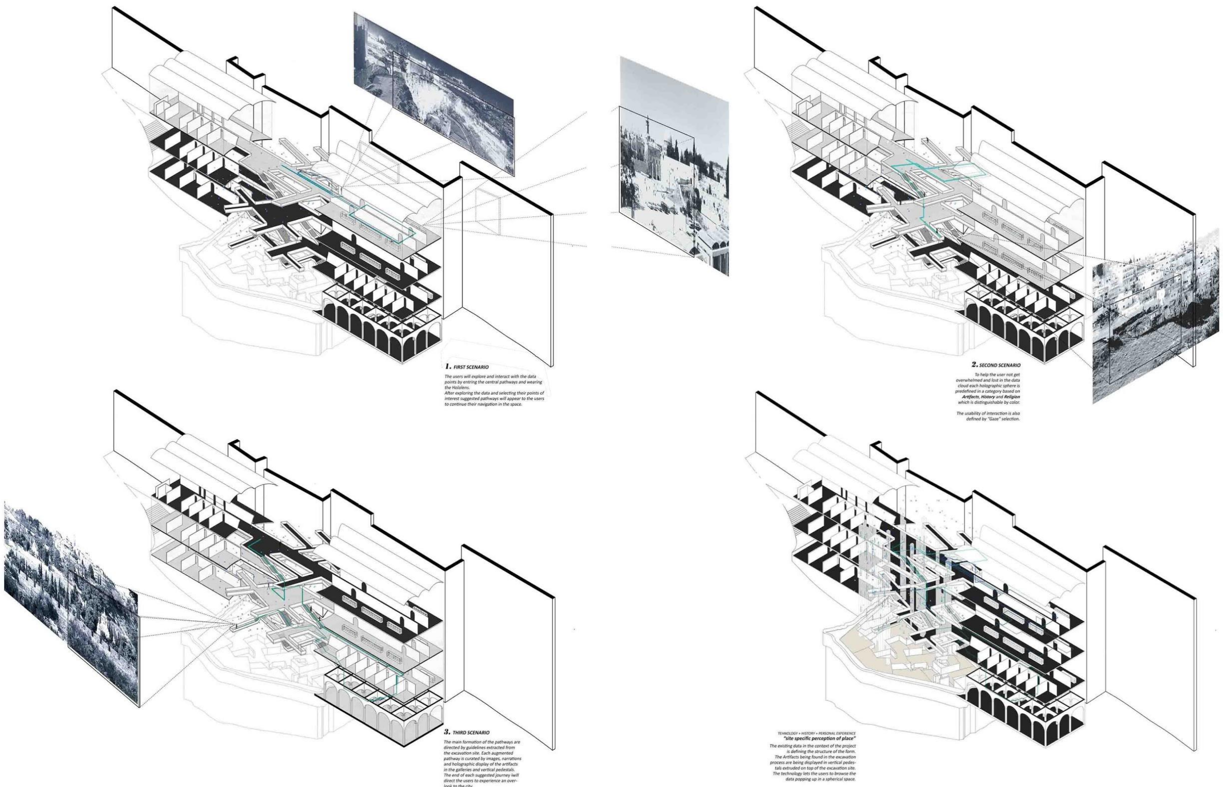

Figure 3: (Noushin Radnia). Exploded axonometric drawing, showing images of important adjacent sites and orientation of “x-ray” virtual views.

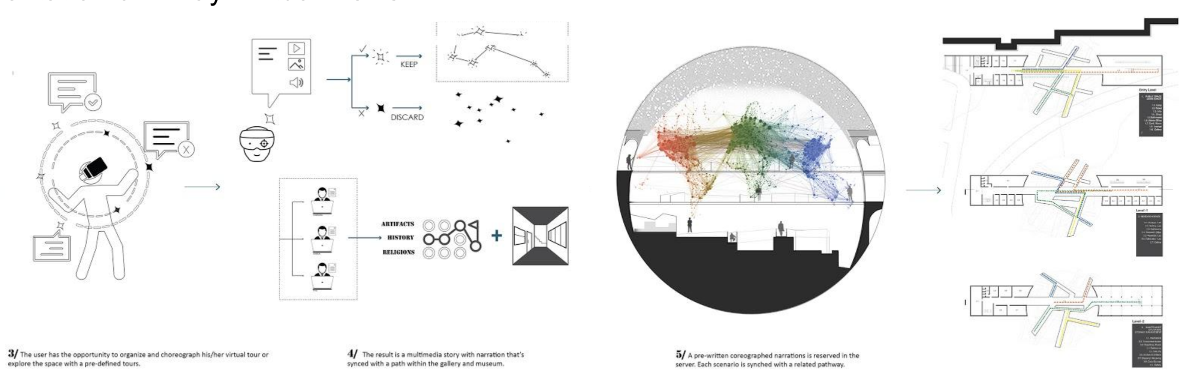

Figure 4: (Noushin Radnia). Storyboard, left to right; gaze detection and control, diagram superimposed on architectural space, development of 3D display of complex data, and layout of corridors oriented to important sites in proximity to the museum.

Excavation of this location adjacent to the West wall and Old city can afford views to significant locations in other parts of the city, leading to the use of sight lines as an organization strategy for the project. Walking toward or seeing on axis with the Dome of the Rock mosque or Church of the Holy Sepulchre, for example, could be made obvious by a spatial connection and could reveal specific kinds of information when you are oriented on that path. When multiple paths cross, they form the circulatory structure of the design (see Figure 3).

In addition, visitors are given the opportunity to sort and organize different layers of artifacts that have been discovered on the site, which has been occupied by Jews, Christians and Muslims at different times. The use of Augmented Reality gives an opportunity to explore history either by selecting from a rich database of objects and locations that suit a particular visitor's preferences or by observing a set of professionally curated objects . The resulting cloud of data represents the rich history (both qualitative and quantitative) of the context, letting users choose and sort the type of data that matches their interest. Each visitor can be offered a journey to explore and experience what they've selected. Visitors can both send and receive; while they're selecting data, they're also producing individual data that can be visualized on the excavation site and connected to other visitors. Data from the site is displayed selectively throughout the site but also in its entirety in one central location (see Figure 4). This corpus of data completely fills a dome placed at a critical location in the building. The configuration of the dome is purposely reminiscent of the historical precedent of the cenotaph for Newton by Etienne Boulee.

Emily Clodfelter

CURATION + SPATIAL LOCATION + PHYSICAL COMPUTING

This design explores the use of visitor preference, artifacts relevance, gaze direction and physical computing in three different areas of the museum: gallery, dig site, and archives. (see Figure 5)

Visitors to the gallery will interact both with the physical artifact on display as well as augmented reality information. As the user approaches a specific artifact they will first be provided with text information including the name of the artifact, time period it is believed the artifact originated, and the location of similar artifacts that can be found in the archives. When the visitor moves closer to the artifact 3D holograms of similar found artifacts will appear. At this point you have the ability to use a pinch selection of the hologram artifacts to display the same text info that appeared on the physical artifact. The Hololens will begin to curate the interests of the visitor based off the amount of time spent viewing each physical artifact as well as the additional selection of the artifact holograms. As the user moves beyond the artifact the Hololens will automatically reset itself in preparation for the user to interact with the next physical artifact.

Visitors to the dig site will have access to the site on a constructed pathway. As the visitor proceeds along the pathway, holograms of artifacts will be activated based on the location that they were unearthed in the dig site as well as the physical proximity of the visitor to areas within the excavation. When the user turns their view range from the pathway to the excavation the holograms that were floating above the pathway will move into place of the exact location they were found. The Hololens will continue to curate user interests based off the amount of time spent viewing any particular artifact.

Before the visitor enters the archives they will return their Hololens unaware that their individual experience has been curated. As visitors proceed through the archives specific storage drawers and cabinets containing artifacts of individual interest will automatically open, displaying the artifacts. As the visitor moves past the storage unit of the opened artifact, the unit will automatically close.

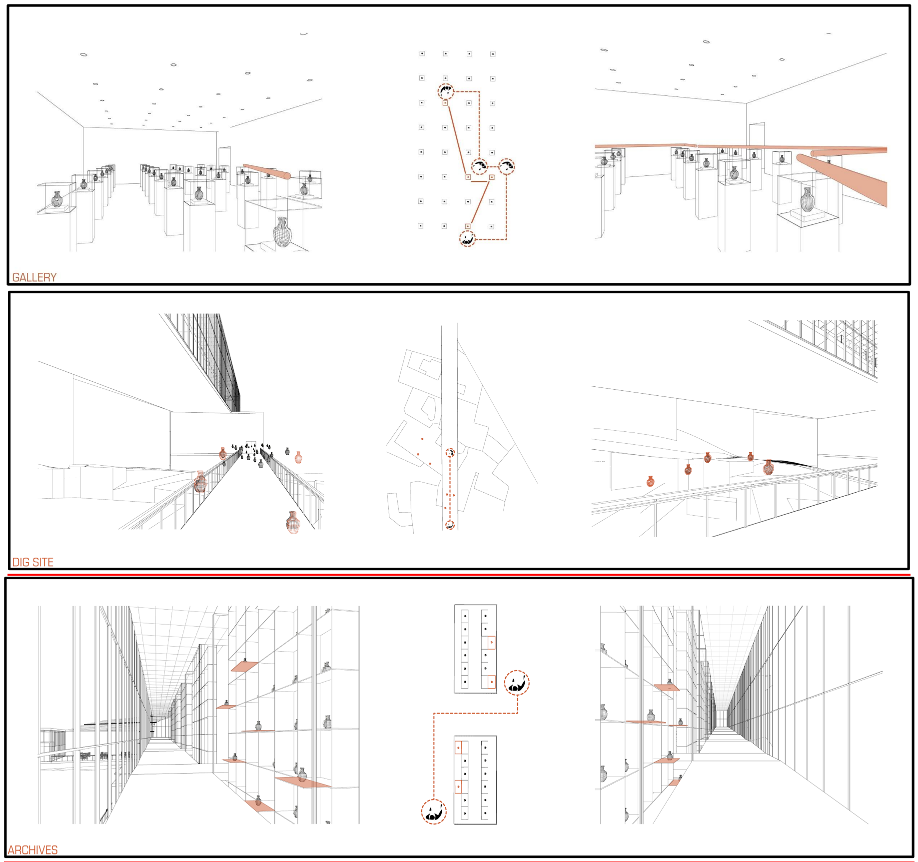

Figure 5: Emily Clodfelder. Top, gallery with relevance overlaid on displayed objects. Middle, bridge over excavation aligning excavated objects from site with either other similar objects or in their original locations depending on orientation of the visitor. Bottom, using physical computing to display relevant objects from the collection based on user's preference understood from their choices in the museum.

<u>Dean Crouch</u>

ORIENTATION + COGNITIVE MAP + ON/OFF

This design engages concepts of visitor spatial position, selective use and absence of AR technology and the development of cognitive maps for individual visitors. These concepts are mainly applied in three locations: gallery, virtual room, and dig site.

The gallery contains carefully curated artifacts representing the most important and iconic artifacts excavated from the site. Approaching an artifact will trigger more information; moving closer to the artifact incrementally shows interest and text about the object. Individual interest will be recorded by the system.

In the virtual room, all of the artifacts that one has viewed will be synthesized and a cognitive map will be displayed. The map will have three to five locations displayed in context to the dig site, with the immediate context recreated to show the usage of the artifact in daily life. After the cognitive map has been understood, a visitor will remove the Hololens and place it on the carousel and proceed to the dig site.

The dig site is shielded on all sides by the building and becomes in effect of courtyard. There are moments where one can view the site from above, without the Hololens, exposed to the elements and climate of Jerusalem, equipped with only the memory of what they have seen to experience the archeological dig in a completely different way.

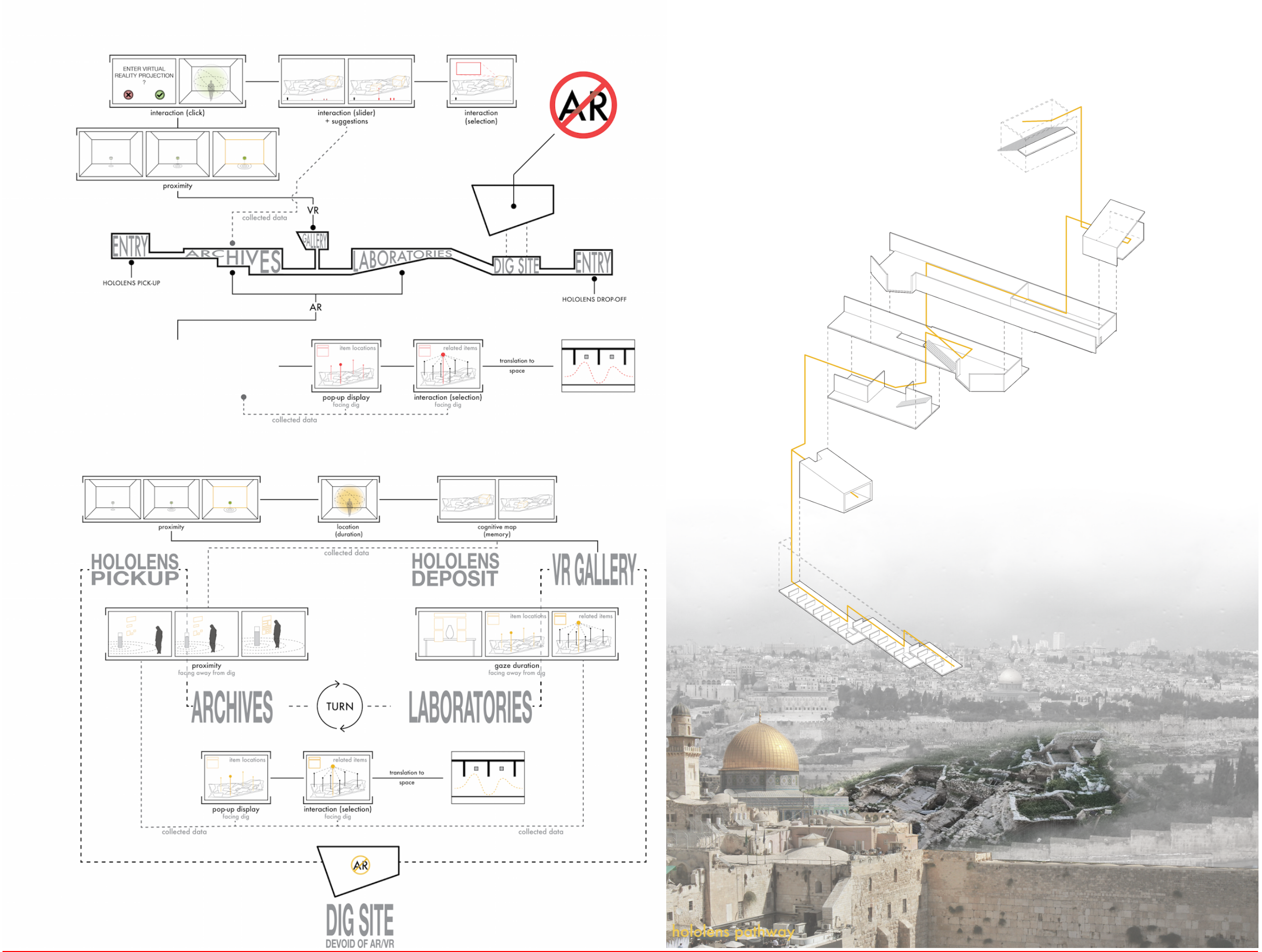

Figure 6: Dean Crouch. Left, diagram of data, locations and interactions, including plans section and program. Right, architectural diagram of the circulation within the museum overlaid on the site.

Augmented reality drives the circulation, as one turns to address an artifact pulled from the earth, its data and place in the larger archaeological record is displayed and once one turns and faces the dig to ponder the relationships of the artifacts to the site, the most studied artifacts are overlaid onto the view from the galleries above, giving visual and interactive lenses through which to understand the artifacts relationship to the site's history. A moment of virtual reality allows complete immersion into the past realities of the dig site and a hypothetical interpretation of its architecture, uses, and significant moments in history. While one inhabits the architectural space, the experience is digitally augmented. (see Figure 6)

Once a patron of the museum steps onto the dig site, they must engage with its current state. A pile of partially uncovered rubble and ruins that indicates a window into the possibilities of the past. The tactile and phenomenological experience of being unplugged within the dig site and augmented within the building sets up a series of binaries that conceptually drive the experience in the building.

PHYSICAL SPACE + VIRTUAL SPACE + CONNECTION

In this design, the architecture will incorporate augmented reality into its design through the articulation of spatial relationships between the dig site and the gallery spaces using virtual reconstructions and the implementation of virtual partitions to direct attention to artifacts on display. Only the galleries and dig site spaces will feature AR capabilities. Visitors will receive a hololens upon entry and thereby meander throughout gallery spaces and the dig site, where artifacts will be positioned in a grid on display. This grid arrangement, rational and unbiased in nature, will render the gallery as a field condition whereby the AR will offer the visitors information about the artifacts they view, based on their own user preferences or ones by previous museum visitors before them (see Figure 7).

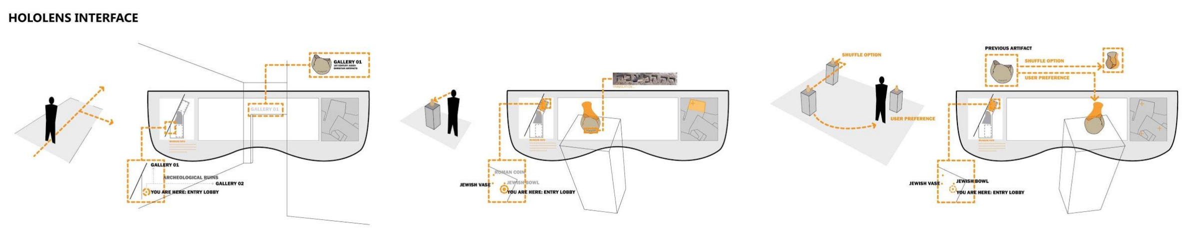

FIGURE 7: Matt Allen. Storyboard of interaction in three locations in the museum.

By using the hololens as a search mechanism, virtual partitions group artifacts to direct visitors to their desired search results. In turn, the galleries spatial qualities become a dynamic component in the museum experience. By allowing the data to define the spatial experience, connections between disparate artifacts can be made, allowing for a continually evolving experience (see Figure 8). In addition to the hololens experience within the interior of the museum, a cell phone app is available for pedestrians to use on the exterior of the building. Pedestrians passing by the museum will be able to view the archeological site through architecturally designed apertures. These apertures will offer views into the building whereby cell phones can access data created about museum visitors to the site during the day.

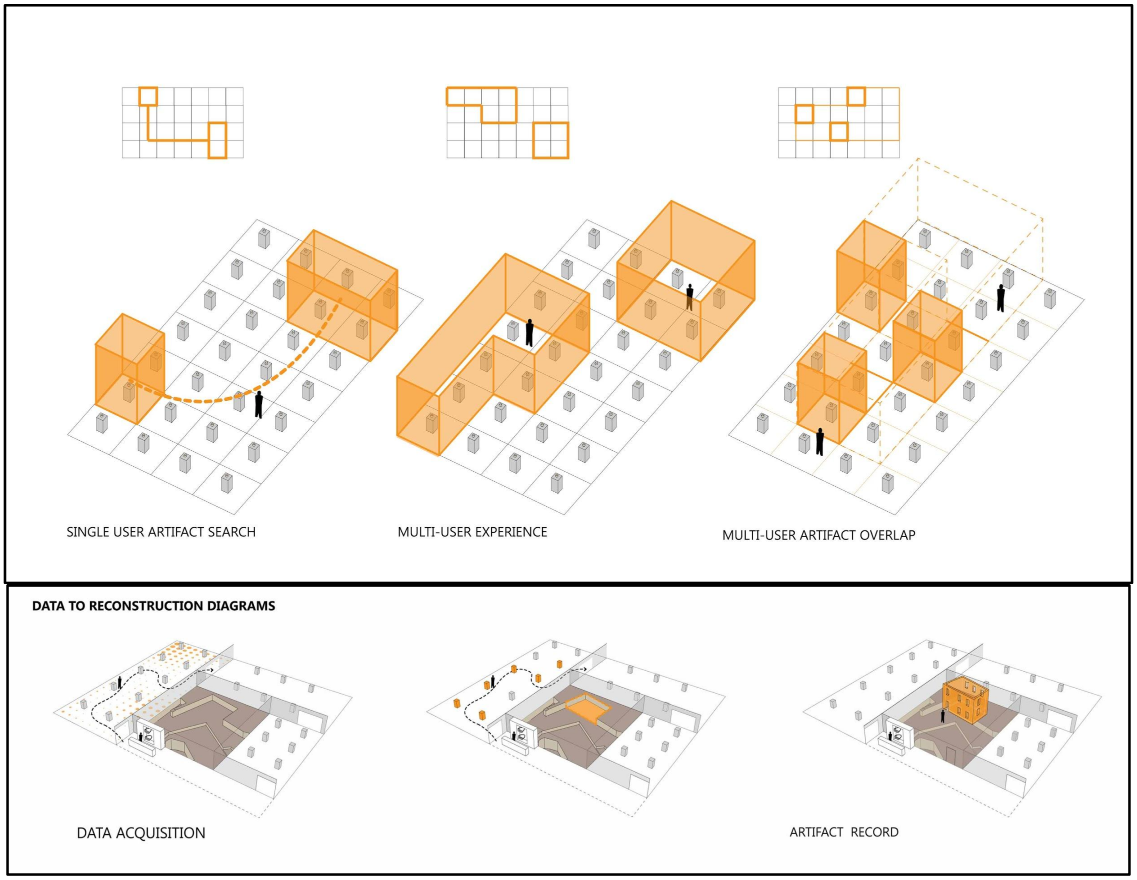

FIGURE 8: Matt Allen. Top, diagram of space and interaction in gallery showing virtual walls that create distinct spatial patterns for each users based on preferences. Bottom, virtual reconstruction of buildings placed in correct spatial position using the Hololens.

The building form is tailored to the narrow site geometries and limited space available to the ancient remains. In turn, the form evolved into an elongated volume bent at the middle to open the interior of the building to the dig site below, harness views to prominent site elements and create open gallery spaces throughout the museum. The research component of the museum was placed at the top level allowing for the public museum component to be unobstructed enabling fields of artifact pedestals to be displayed. Additionally, sectional opportunities arose by opening floor plates for views between galleries and the ruins creating a user exigence based on subjective interpretation and objective scientific analysis. At the base of the architecture is the archeological dig site representing the rational scientific nature of historical study. This rationality however, translates into a subjective interpretive experience as one enters the gallery spaces where artifacts are on display. Additionally, the ancient city wall was used as a circulation mechanism for the user experience; the galleries and dig site connected via a pre-existing path along the wall, integrating the ancient fortification into the contemporary architecture.

Conceptually viewing the relationships between the archeological dig site, city wall, artifacts and museum as a palimpsest, the augmented reality can be incorporated as an interstitial connecting layer. Within palimpsests, the act of erasing allows the superimposition of other layers to occur, thereby enabling multifaceted interpretations of information to occur simultaneously. Conceiving the augmented reality as an erasure-like mechanism, multiple readings of the architecture, dig site and city wall can be generated to create a continually evolving interpretation of history.

Only the dig site and the gallery spaces will feature AR capabilities. Visitors will receive a hololens upon entry and thereby meander throughout gallery spaces and the dig site, where artifacts are positioned on display. The AR will offer the visitors information about the artifacts they view, also offering either suggestions based on their own user preferences or ones by previous museum visitors before them. These two options can be comparable to a personal playlist on iTunes; the playlist played in order of tracks listed or by shuffling them. Contrary to a typical shuffle option however, one that would continually rearrange user preferred artifacts, this hololens option will shuffle their preferences with other user generated data, creating a wiki-like interpretation of the site. By allowing two data options, connections between otherwise disparate artifacts can be made, allowing for a continually evolving experience.

4 FINDINGS

Based on the 12 architectural designs, we developed a taxonomy based on inputs (afforded and interactive) and outputs (display and physical). Investigations involved the creation of specific architectural designs paired with the use of AR to deliver supplemental data and perspective. As we proceeded, each designer evolved a set of connections between the architecture interface and AR. We compiled these examples into a taxonomy of possibilities.

Afforded or passive inputs are those that because of physical or cultural factors are understood without need for visual feedback. These include:

- **proximity**, moving closer to or further from an object in the model was understood without the need for feedback.
- **gaze target**, the direction of a user's gaze was immediately apparent to user of the system
- **gaze duration,** because obvious after a few minutes of use by the Hololens
- The **orientation** that a user faces is apparent in at least two ways; inside/outside can be understood wherever the architecture makes it obvious; geometric orientation is made obvious when the architectural arrangement is strongly delineated.

Interactive inputs require some visual feedback from the Hololens to make it cognitively present:

- **angle of view**: head motion can be understood as an input in either the vertical or horizontal direction, but require visual feedback to be understood.
- **hand gesture**: the standard interface in Hololens of finger or hand gesture require significant feedback to be obvious
- **voice**: the use of voice recognition can be used to provide rich input to the system; feedback verifies the system is engaged.

The output of the architectural/AR system can assume either display or physical aspects.

- **physical computing**: the rearrangement of physical objects based on a user's position

- **overview/detail**: details can be made to appear to come closer to user and be available for inspection
- **transparent/opaque**: virtual walls can be selectively closed and opened
- **"x ray vision**": one can creates display that appear to allow users to see into other rooms or into the city beyond
- **virtual space**: it can be generated around a user as they move through space, guiding or circumscribing movement
- **heat map:** it can show the locations of classes of objects.
- **cognitive maps:** these can capture the interest of an individual that later guide a customized tour of the site
- **text**: explanatory text can appear at appropriate locations, and can become more detailed as one approaches
- **virtual objects:** these can appear in the space to connect other objects from the site (or from a larger corpus)
- **wayfinding direction path:** it can be created to guide users

Equally important to these affordances is the changes to the way that architectural space must be conceptualize and understood. The normative standards of architectural design, emphasizing geometric clarity, simplicity or uniqueness, will be less important than the ways in which places connect with the meaningful activities of the users of the space. This idea of programming human occupation in architecture is not unknown, but is almost always understood as preliminary to the main preoccupation of architects with form and geometry. Our work emphasizes the importance of considering these issues as co-equal sources for design.

In the work of all of the designers on this project, heuristic evaluations by teams of practicing architects consistently found significant experimentation with unique architectural forms that provide important and novel ways to engage with AR on the site. One measure of this innovation is the surprising forms of the design solution that would be difficult to understand without an appreciation of the affordances of AR combined with spatial and architectural logics. In at least a provisional way, they provide a foretelling of the embodiment call by Dourish and others.

During our design process, we realized that our goal of creating architectural spaces that inherently take advantage of AR technologies, requires a rethinking of traditional architectural design processes, interaction design methods, and how these designs are represented in these fields. We developed an interface that allows for simultaneous exploration of architectural space and AR interactions. However, creating such interface requires more efforts in usability studies and development, as well as more interoperability between architectural design software and this interface.

Our work has used Hololens technology but it applies more broadly to any form of AR. For, if AR aims to create new forms of interactions that engage both technological and social factors, design methods must be able to represent both the architectural setting and information interaction simultaneously. This will involve expanding and transforming methods both in HCI and in architectural design. Otherwise they will remain separate from the life of the places they occupy.

ACKNOWLEDGEMENTS
The authors want to thank the xxxxxx at xxxxx for the loan of a Microsoft Hololens for use in this research. In addition, we want to thank the following student for their contribution to this research; xxxx, xxxx, xxxx, xxxx, xxxx, xxxx, xxxx, xxxx, xxxx, xxxx, xxxx, xxxx, xxxx, xxxx, xxxx.

REFERENCES

Avila, Lisa, and Mike Bailey. "Augment your reality." *IEEE Computer Graphics and Applications* 36.1 (2016): 6-7.

Azuma, R. T. A survey of augmented reality. *Presence: Teleoperators and virtual environments*, 6, 4 (1997), 355-385.

Bagdanov, Andrew D., et al. "MNEMOSYNE: Enhancing the Museum Experience through Interactive Media and Visual Profiling." *MM4CH*. 2011.

Barfield, W. *Fundamentals of wearable computers and augmented reality*. CRC Press, 2015.

Bolter, J. D., Engberg, M. and MacIntyre, B. Media studies, mobile augmented reality, and interaction design. *interactions*, 20, 1 (2013), 36-45.

Calderon, Carlos. *Interactive architecture design*. Harvard Graduate School of Design, 2009.

Chi, Hung-Lin, Shih-Chung Kang, and Xiangyu Wang. "Research trends and opportunities of augmented reality applications in architecture, engineering, and construction." *Automation in construction* 33 (2013): 116-122.

Dourish, P. *Where the action is: the foundations of embodied interaction*. MIT press, 2004.

Dunleavy, Matt. "Design principles for augmented reality learning." *TechTrends* 58.1 (2014): 28.

Hevner, A. and Chatterjee, S. *Design science research in information systems*. Springer, 2010.

Kristiansen, E. "The Transformative Museum." *Proceedings of the DREAM conference*. 2012.

Shi, Jiamin, and Florian Alt. "The Anonymous Audience Analyzer: Visualizing Audience Behavior in Public Space." *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*. ACM, 2016.

Tabor, James. "Mount Zion Archaeological Project." *Mount Zion Archaeological Project*. N.p., n.d. Web. 29 June 2017.