A New Design Paradigm in Mixed Reality – using HoloLens for Architectural Design

Michael Shyu
Perkins + Will

Iffat Mai
Perkins + Will

Fei Xie
Perkins + Will

Learning Objectives

- Learn an easy workflow to create a Mixed Reality model using Revit, 3ds Max, and Unity 3D
- Explore a new design paradigm using Mixed Reality
- Learn how to use Mixed Reality to engage your clients and project team
- Learn how to use HoloLens’ spatial mapping for model placement in Mixed Reality

Description

Mixed Reality (MR) combines the virtual and the physical realities into one space and offers an exciting new design paradigm for Architects. By projecting BIM model directly over physical site in Mixed Reality, architects can communicate design ideas to the team and clients in an immersive and interactive way. This session will demonstrate case studies of Mixed Reality, using Microsoft HoloLens, applied for different phases of architectural projects. We will share our exploration on the process of precision alignment of BIM model with the physical project site. Followed by using Mixed Reality for virtual mock up and review of design options. Finally, we will examine the potential of Mixed Reality tools for construction administration and envision on-site Mixed Reality clash detection using Microsoft HoloLens.
Speakers

Michael Shyu

Michael Shyu began his research in smartphone applications and its interface with physical architecture in 2009 with his bachelors of architecture thesis at Syracuse University. He then carried his research at Columbia University GSAPP where he participated in design studios focused on augmented reality and space planning, where he developed application interfaces and designs for various projects types.

Fei Xie

Fei Xie started augmented reality research since his internship at Adrian Smith + Gordon Gill in 2013. He successfully developed an app via AR-Media SDK allow clients to compare different design options with AR technology. In 2014 he began a project which allow people create their own augmented reality portfolio. Fei holds bachelor degree in Physics before receiving his master of architecture from Washington University in St.Louis.

Iffat Mai

Iffat Mai is the Firm wide Design Application Development Manager of Perkins and Will. During her twenty plus years of working in the AEC Technology field, Ms. Mai has shown leadership in making strategic technology decisions, developing innovative solutions and integrating cutting-edge technologies into AEC design workflow. Her recent focus has been in weaving Virtual Reality, Augmented Reality and Mixed Reality with Building Information Modeling into professional Architectural practice. Ms. Mai leads an innovation team in developing immersive AR and VR experience that enables design team to engage project stakeholders and expedite design review process on projects. As an authority on Innovative Technology and BIM custom development, Iffat has presented at various technical conferences on topics related to Computational Design, Custom Revit API and Python development. Ms. Mai holds a Bachelor of Science degree in Architecture from Massachusetts Institute of Technology.
Design Communication is advancing rapidly. Using tools such as Virtual Reality has become a commonplace practice for design teams. Mixed Reality (MR) offers additional benefit to Virtual Reality by overlaying virtual objects onto real physical environment. This could be a game-changing tool for all phases of design and communication. By integrating the Microsoft HoloLens, BIM modelling, with the real world sites, Mixed Reality offers new possibilities for architects to communicate design ideas to the team and clients.

The project began as an incubator proposal initiated by Michael Shyu and Fei Xie. Once the proposal won as an incubator project, we formed an ad hoc team to work on the research, design and building of a Mixed Reality tool. The objective was to explore new opportunities that Mixed Reality could provide for our design and construction industry. We hope to use the Mixed Reality tool in all phases of design, from initial concept and site analysis to construction administration. It will include design model options, interior designs applied to physical sites, and clash detection for construction administration.

**Objectives**

Explore design communication using Mixed Reality for all phases of Architectural design
- **Concept Design:**
  - Small scale building modeling
- **Schematic Design**
  - Interior space designs, spatial alignment and options
- **Construction Administration**
  - Clash detection for interior spaces, spatial annotation and recording data.

**VR vs AR vs MR**

Virtual Reality (VR) uses computer to create a simulated environment that is completely isolated from the actual physical environment around you. It offers you an immersive experience, but it also blocks out any relationship between the virtual and the physical world. On the other hand, Augmented Reality (AR), which is a technology that has been around for decades, presents virtual information on top of real physical environment. AR gained notoriety for its popular Pokémon GO app where users can see virtual Pokémon as they walk around town using their mobile phone. On the other hand, Mixed Reality using HoloLens falls between the AR and VR, where one can experience the virtual objects merged with the physical objects, not by looking at a mobile phone or tablet, but through the transparent lenses of a HoloLens headset and interacting with the virtual object using natural interface.
HoloLens

1. Camera
2. Computer
3. Lenses
4. Vent
5. Sensor
6. Buttons

Mixed Reality App

What separates our idea from other Mixed Reality tools is that our goal is not simply to represent the BIM model in real time, but have the machine learning algorithms align the model to the site and determine what in the project would really call for the architects and contractors attention via the HoloLens.

Our methodology first starts with alignment. Utilizing SLAM (Simultaneous Localization and Mapping) technology embedded in the HoloLens, it is able to recognize surfaces and thus we are able to align reference points from the BIM model to the real space. We created a simple user interface, where the user with no prior experience with the HoloLens, will be able to experience their design model both as site models and as full-scaled interiors spaces. The user interface of our Mixed Reality tool uses the designer’s gaze for cursor control, a voice command system for designers to interact with the model in a hands free fashion. And a simple gesture control series of command using a simple air-tapping gestures.

Tools

Before starting the project, it is important to secure all the necessary hardware and software tools needed for the project. The HoloLens headset is the primary device that will be used for the project. We also needed a laptop that meets the minimum system requirement for Mixed Reality development.

- 64-bit Windows 10 Pro, Enterprise, or Education (The Home edition does not support Hyper-V)
- 64-bit CPU
- 8 GB of RAM or more
- In the BIOS, the following features must be supported and enabled:
  - Hardware-assisted virtualization
  - Second Level Address Translation (SLAT)
  - Hardware-based Data Execution Prevention (DEP)
- GPU (The emulator might work with an unsupported GPU, but will be significantly slower)
  - DirectX 11.0 or later
  - WDDM 1.2 driver or later
Software Tools

- Visual Studio 2015
- Unity 3D version 5.6
- Holographic Emulator and Holographic Templates

Note: As of October 17, 2017, Microsoft has released the Windows 10 Fall Creators Update which works with the newer version of Visual Studio 2017 and Unity 3D 2017. If you choose to use the newer version software, be sure to use all the newer version tools to maintain the compatibility of software and drivers.

Mixed Reality Workflow

Here is the workflow steps on how to import 3D models from Revit to Hololens:

- Export Revit model as .FBX
- Import the .FBX file in the Unity Gaming Engine
- Build as a Windows store App
- Open the Microsoft Visual Studio Solution in “Visual Studio Program”
- Deploy the app from Visual studio to the Hololens


The Site

Our initial proposal called for using an active project that included an interesting renovation and addition as our onsite test case. However, after gaining a better understanding of SLAM, and the construction schedule of the project, we had come to realize it was better for us to test out the Mixed Reality tools in a more controlled environment before going on an active project site. The tools that needed to be specifically developed and programed, were alignment, layering, and annotation. We anticipate that after the steel structure is erected, that the HoloLens will be a much more effective tool in that it can virtually tie itself to the superstructure and begin to overlay augmented virtual information on the site.

If we were to use the SLAM technology to align to an exterior foundation footing, the sensors might have a hard time locking the edges in place and the model would experience severe drift. In addition, the visual limitations of the screen itself lends itself to a more interior oriented Reality experience. What we decided was the best testing ground for our experiments was the 12th floor of 225 Franklin Street, which happens
to be the floor directly above the Perkins and Will Boston Office. Which also happens to be an empty office space that is easily accessible to our team.

Windows Mixed Reality Academy

Windows Developer center provides many helpful tutorial and resources to guide newbie developer with sample codes and best practice. Another useful tool was the HoloToolkit, which is a free downloadable tool kit from GitHub (https://github.com/Microsoft/MixedRealityToolkit.Unity)

Tutorials

Holograms 100: Getting started with Unity

Holograms 101E: Introduction with Emulator
Using SLAM for model alignment

The Model Alignment between the virtual and the physical world was the first step needed to anchor the model onto the exact location in the real world. In order to align the two space, it is necessary to lock three virtual points to a three physical points in order to lock the X, Y, Z axes. The initial sketch below shows the first steps of the process.

Light, Transparency, and SLAM Limitations.
One critical point to understand about HoloLens is the way it creates virtual holograms through an additive process utilizing light to create the holographic projections. It essentially cannot subtract information, and the color true black would read as transparent. Shadows can be achieved through greys and dark blues, but active shadowing is very computationally intensive for the HoloLens at this time.

SLAM Limitations: Exterior
Alignment is the critical first step in being able to project a believable hologram. In order to align a virtual object the HoloLens essentially utilizes SLAM to recognize edges and subsequently allows it to anchor the virtual object into place. When edges are not present, like in an exterior space or there are too many shadows, the sensors cannot read the correct edge for appropriate alignment and essentially cannot anchor the model down. This technological limitation hampered our ability to pursue the original scope of the incubator. In the future, we imagine it would be possible to tie exterior models into place with GPS in conjunction with SLAM, however it would require hardware development and external sensor tools that communicate with the HoloLens to achieve this result.

SLAM Limitations: Interior
Through hands on testing, we determined the SLAM boundary for HoloLens to be about twenty feet by ten feet (20’ x 10’) area. This is critical to understand in that will place a limit on how far the HoloLens can keep its alignment.

Two Point Alignment system
With the help from our team member Ryan Zhang, a researcher from the MIT Media Lab and GSI, we developed a two-point alignment system that enables the user to easily place a virtual model and align it to the physical world. The user would identify two coordination points in the real world and the virtual world. To align the spaces, one would place the first anchor point (represented by a white ball) at the first coordination point using the SLAM to snap to the exact point, then drag the second point (represented by a red ball) to the second coordinate point, which will then define the scale and orientation of the virtual model. Our UI designer, Chance
Heath developed a nice series of User interface menus to guide the user on how to use “Airtab” gesture select and place the coordination points.

HoloLens Design App
Our final HoloLens Design App starts with a simple visual instruction on how to use airtap to select the functions. The menu will show three distinct modes that offers Model Observatory for concept design, Design Options for schematic and design development and Construction Assistant for CA phase.

Model Observatory
The first mode is the Model Observatory, where the designer can show a preloaded model appearing as a scaled down desktop model. The designer can then place the model onto a desktop space using HoloLens’s SLAM capability, the model will snap to the selected surface. The designer can then, and interact with the model and click on the buttons to review different options. This mode is very useful for designers to view the entire model at a smaller scale.
**Design Option**
The second mode is Design Option, where designers would place the virtual model using the two-point alignment method so the model is at full scale anchored correctly onto the real world. Then using the design option buttons, the designer can review the various different design models at full scale. Being in full scale, the designers can walk around it and experience the space in an immersive fashion. The design option materials—marble, wood, concrete.

**Construction Assistant**
The final mode is the Construction Assistant mode. Currently, this section is in the design phase, where we are showing potential functions that our Construction Administration Managers could utilize during that phase of the project. After interviewing with our construction manager, Heather Miller, who had completed numerous construction administration work on projects.

Here are some input and feedback from her:

- **CA would like the ability to Export to Jpeg**
  - Share Jpegs and aid Field reports.
  - Take pictures with model and without model
  - Possible tie in with a document management system (ex: NewForma)

- **Voice Command and Notations**
  - Typing in HoloLens is cumbersome. Super links will save voice comments, and you will be able to create video reports.
  - You want to be able to put icons in the video so you can question the contractor, but don’t want to directly talk to them immediately.
  - Sharing views is incredibly important, possible sync between tablet and HoloLens or HoloLens to HoloLens. A multi user experience is very important.
  - Referencing is also important. You want to be able to find the right detail from the contract documents quickly.

- **Architect Liability:**
  While it is good to know all of the information and anticipate clashes, it is important to note that the architect has to show judgment as to whether to act on it. It is better to check and verify first before pursuing change orders. HoloLens vs Tablet, HoloLens gives a degree of privacy so the HoloLens can review drawings with the architect alone, whereas the tablet shows all info to all parties.
• **Precision**
Understanding the precision for the HoloLens will be important, as different construction types require different degrees of accuracy.

The technology for the HoloLens is truly amazing, and there is no other MR product on the market that combines its rapid SLAM recognition, fast tracking, untethered portability, and ability to upload high fidelity models and programs. If we combine the HoloLens with machine learning and BIM modeling, in the near future the sensors detecting the SLAM boundaries will be able to extrapolate that into actual object recognition.

The power for a computer to recognize an object from different angles and be able to actually process what that object means in terms of its inherent data is immensely important step. Imagine in the near future when you go to a job site with the HoloLens, you scan a piece of duct work which will then cross reference automatically back to the BIM model. Using machine learning, the HoloLens then recognizes that the physical object is indeed a return duct, and will automatically provide you will all information associated with it, what kind of duct is it, how much air does it move, where does it run in the overall building. Or better yet, you aren’t even actively looking at the duct, but the HoloLens automatically detects that the duct is not in the correct location and brings up the contract documents for you to review as a reference! After it detects the anomaly, you are able to produce a field report recording your findings for review when you return to the office.

Another hypothetical experience is if you are trying to communicate this clash to the general contractor, and you want to compare what you see to what the contract documents state. You both put on a pair of HoloLens and are instantly able to see what the intent is on the physical site, clearing up any potential confusion or mistakes thus saving money for the project. The future is bright for the technology, and the shared experience is one that will dominate the market in the coming years. It takes a lot of effort to develop the tools needed. However, once you develop the tools, your initial investments will instantly pay dividends for years to come.