AUGMENTED REALITY HOME DESIGN

Skyler Greenman

Logan Bentley

Baafuor Kwarteng

Hector Lugo

Scott King

Harrison Pusey

Coach: Dr. Richard Helps

BYU Information Technology

Senior Capstone Project

Class of April 2017

Sponsored by:

Holoture

Holographic Home Design

EXECUTIVE SUMMARY

With the project sponsor, Holoture LLC, the members of this BYU Information Technology Senior Capstone Project team created an augmented reality platform that enhances the experience of buying and selling furniture. The prototype platform created by the team consists of a web application and an augmented reality application. The web application allows users to select furniture from an online catalog uploaded through a Node JS API to a MySQL database. The augmented reality application, developed for the Microsoft HoloLens, downloads the furniture selections made and allows users to move, position, and change the appearance of these holographic furniture models. A Microsoft Surface tablet computer can be connected to the HoloLens through the HoloLens Portal to provide another person a live video feed of the application in use on the HoloLens.

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INTRODUCTION

Descriptions of the project objective and project motivations.

PROJECT OBJECTIVE

The project objective for April 2017 was to create an augmented reality home design platform that allows users to select, customize, view, and position holographic furniture in any room with the intent of enriching the furniture sales experience for customers.

MOTIVATION

The sponsor of the project, team leader and founder of Holoture, LLC, Skyler Greenman, identified some of the key motivations for the project: the potential for market growth, the chance to work with new technology, and the opportunity to create an enhanced customer experience.

The immense market potential of AR given market forecasting is very exciting--some estimates anticipate a $83 billion market by 2021[1]. Companies like Lego, IKEA, Converse, and Lowe's are beginning to use augmented reality to market and show off their products in new ways. Microsoft, Google, and Apple are all currently working on wearable augmented reality technologies that will be available to consumers very soon. The potential for major growth in this surging technological sphere was very appealing to the team.

The opportunity to work with cutting-edge technology was another motivator for the design team. The Microsoft HoloLens is a powerful augmented reality headset and was considered to be the most suitable device for the solution platform. Mr. Greenman was able to secure nearly exclusive access to a Microsoft HoloLens owned by the BYU Marriott School for use in this project. With development kits starting at 3000 dollars, access to a HoloLens is not a common occurrence for college students, so the team was very excited to work with such a device.

The furniture market in the United States is huge; the furniture industry enjoyed 101.41 billion dollars in sales[2] in 2013. There is great opportunity for technology to enhance the sales process for customers and for furniture retailers. Customers often research great numbers of potential purchases online while retailers strive to draw more customers to their stores. The team analyzed various sources of difficulty for retailers and buyers. The team was motivated to come up with a technical solution that benefits both customers and retailers while innovating the furniture retail experience.

PROBLEMS TO SOLVE

This section identifies important difficulties for furniture buyers, furniture sellers, and furniture sales models that Holoture LLC worked with this Capstone group to resolve. These difficulties with furniture buying experience revolve around time constraints and physical demands; design and sales efforts; and the risks associated with augmented reality technology and equipment.

PHYSICAL CONSTRAINTS

Many furniture buyers find it difficult to estimate the fit, look, and position of furniture in a room without having the physical furniture piece in the room. Interior designers try to solve this by preparing diagrams, photorealistic/digital models, room measurements, color palettes, material samples, and floor plans to create an approximate representation of a new furniture's appearance in a room. Such efforts still might not lead to complete customer satisfaction when the actual furniture pieces are physically moved into place--which itself might also be very difficult and physically taxing. Additionally, customers are often obliged to make multiple visits to furniture stores throughout the design and sales process before making a purchase. This might be inconvenient and dissatisfying to some shoppers.

DESIGN AND SALES

Some furniture companies and interior design firms offer in-home services that improve customer satisfaction and increase furniture sales. While providing in-home consultation service, a salesperson does not have access to furniture inventory, accessories, or other items of interest beyond those materials or models the salesperson previously prepared to show the customer. The salesperson might lose an opportunity for greater potential sales because he or she cannot immediately show the customer the item of interest.

RISKS

Given the nascent and experimental nature of augmented/virtual reality, high-quality technology is typically expensive, uncommon, and fragile. Augmented reality software is likewise somewhat expensive, uncommon, and unstable. Adoption of augmented reality systems is not yet widespread because complete systems require more technical stability and proven business application than what is currently available. Thus, relatively few people personally own augmented reality equipment or work on augmented reality software. There are only a few existing, emergent systems that can provide significant and immersive experiences in retail, design, or educational capacities. Because private ownership of such technology is not ubiquitous, some corporations are seeking to develop augmented reality applications for technology platforms that customers already own and use or for systems that the corporations can provide to customers in-store. Therefore, these organizations need complete technical systems that combine reliable hardware and software with solidly proven cases for business advantage and customer satisfaction. Corporations are wary to invest in such systems without proper risk mitigation.

SOLUTION SYSTEM OVERVIEW

Descriptions of the specifications for a minimally viable solution, the solution delivered to Holoture LLC, and the justification for the proposed solution.

SPECIFICATIONS

- An acceptable deliverable will include an augmented reality application that can make a furniture company's inventory options accessible to customers and design consultants in a realistic, three-dimensional, and holographic format.
- The system must be flexible enough to work equally well in a customer's home as in the furniture store.
- Furniture models should be moved around with hand gestures and aesthetically customized with the point of a finger.
- An online furniture catalog should allow customers to easily select any number of models he or she finds appealing for in-home preview.
- Designers should be able to use the preferences of customers to create expansive design schemes with greater ease than manually prepared measurements, diagrams, and presentation materials.
- Customers could be shown any item of interest almost instantly without being limited to the physical inventory at the showroom.
- The holographic furniture models should blend into the physical environment with high fidelity to existing surfaces, lighting, and depth perspective.

SOLUTION

Holoture LLC, in coordination with the members of this Capstone project, has created an augmented reality system that provides these solutions. The two main components of the prototype solution are an augmented reality application developed for the Microsoft HoloLens and a web application which provides a user interface to for online furniture catalogs.

The proprietary Holoture HoloLens application places holographic, three-dimensional models of furniture in the operator's field of vision. Placement, selection, and customization of the holographic furniture models are performed with hand gestures and body movements recognized by the HoloLens and a graphical user interface within the application.

The Holoture web application provides a user interface to view a furniture catalog with numerous categories and options. A user will make selections according to his or her preference to be saved in a personal portfolio. These customer portfolios and the catalog are available to the the Holoture HoloLens application.

The Holoture HoloLens application is paired over a private network with a Microsoft Surface tablet to provide a real-time video feed of the HoloLens viewing perspective and access to the Holoture web application.

SOLUTION JUSTIFICATION

WEB APPLICATION

The web application was developed using the ReactJS framework and a NodeJS API to connect to a MySQL database hosted in Microsoft Azure. ReactJS is useful for creating responsive and dynamic web applications. NodeJS provides powerful methods for server applications and communications. MySQL is a stable, well-known product and was a suitable database choice considering the skills of the team. Having a web application built with these tools allows a customer to create a personalized furniture folder containing their selected furniture preferences. This folder will be downloaded to the Holoture HoloLens application to allow the customer to view their favorites easily during a design consultation. With the web application, Holoture LLC believes that customers will have a better furniture buying experience by allowing the customer to choose their favorite furniture. As the design consultant can also view the customer's furniture folder, they will have opportunities to upsell a customer by showing them like furniture during the design consultation.

AUGMENTED REALITY HEADSET AND PERIPHERALS

Many existing technology-assisted design tools rely on photographs and measuring aids to give a rudimentary base for augmented reality home design. These tools are not capable of providing the solution that Holoture LLC developed using the Microsoft HoloLens. While a smartphone or tablet camera may have higher resolution than the HoloLens cameras, a single photographic lens cannot provide accurate depth perception in still images or in video recordings. No suitable multiple-lens camera attachment exists for smartphones or tablets. Three-dimensional depth perception is critical for high-fidelity holographic modeling in augmented reality. The HoloLens provides an optimal hardware platform for this purpose. Holoture LLC believes that increased customer confidence in purchasing as a direct result of using this platform has the potential to quickly outweigh the significant costs of purchasing a HoloLens.

As the HoloLens is somewhat bulky and fragile, only design consultants will be trained and permitted to use the HoloLens. A Microsoft Surface tablet will display the viewing perspective of the HoloLens in real-time to the customer. This will provide the customer with a more comfortable, simpler augmented reality experience with less risk and liability compared to a system that would require the design consultant to teach customers how to wear the HoloLens and use the application properly.

HOLOLENS APPLICATION

The HoloLens application was developed on Unity, a platform that existing HoloLens developers actively support and promote. Because of this, the open-source Microsoft HoloLens framework, HoloToolkit-Unity, gave the Holoture application access to the most up-to-date and comprehensive HoloLens tools (wrapper functions) available. HoloToolkit-Unity handles headset features such as input recognition, spatial identification, and depth perception--a major advantage over creating and implementing these necessary capabilities individually. The HoloLens application was written in C# since the Unity community gives preference to it over JavaScript for the HoloLens. Additionally, most HoloLens tutorials are written in C#.

USER INTERACTION

The combined platform of the web application and the HoloLens application was developed with designers, salespeople, and their customers in mind. A potential buyer simply visits Holoture.com and makes selections for furniture they might like to preview in their home. The buyer can sort the furniture options by categories. By clicking on an image, more details about that particular item are made visible. Whether the customer makes selections online from home or with a sales representative in the store, the customer has access to the full digital inventory of the furniture company. This flexibility suits a range of customers: those who might prefer to shop online before going to a store, as well as those who might first go to a store.

To accommodate the schedules of potential customers and design consultants, an in-home appointment can be arranged after making selections of furniture. The sales representative or design consultant can use the web application to see the furniture selections made by particular customers and to add more furniture items that may be of interest to a customer. This extension for a consultant's design and sales skills will increase the likelihood of selling more furniture items and accessories and increase customer satisfaction.

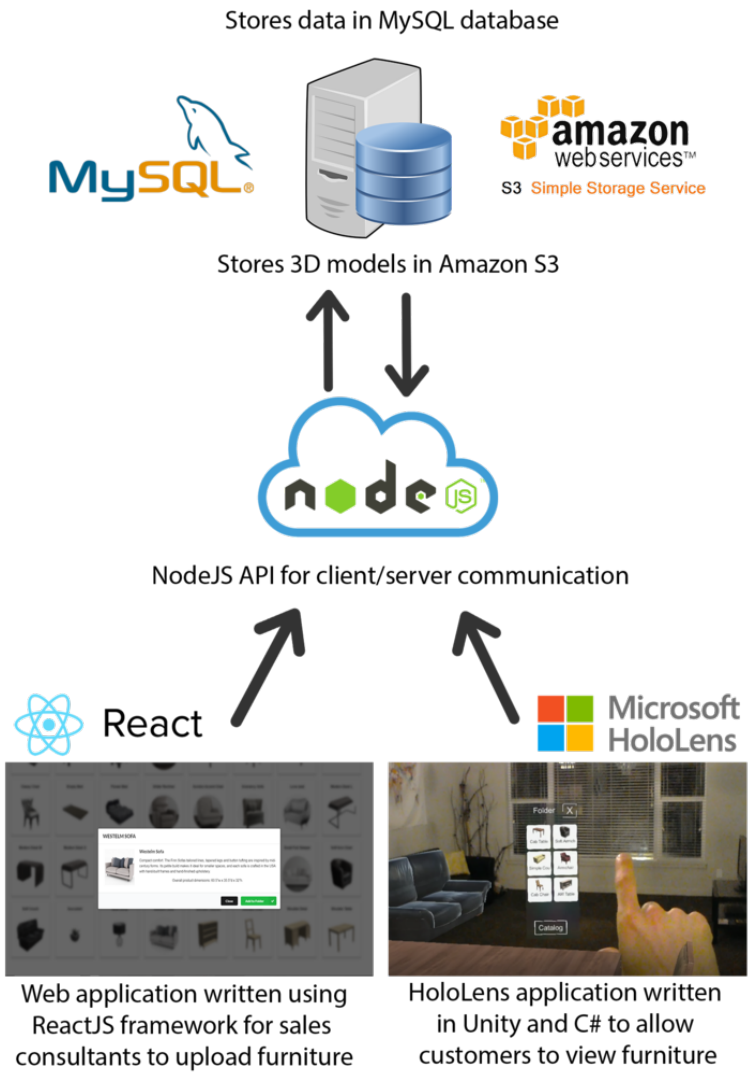
Because in-home consultation services often increase overall sales, the Holoture in-home consultation visit is meant to help customers feel confident in their purchases by providing customers a better idea of what the furniture will look like in their home. When the time of the in-home consultation arrives, the design consultant will bring a Surface tablet computer and a HoloLens with the user's personal selection portfolio uploaded to the HoloLens application. The consultant will operate the HoloLens because customers may be uncomfortable wearing such an expensive and unfamiliar computer. The consultant will start the HoloLens application and the video feed on the Surface tablet. The video feed allows the customer to see on the Surface tablet what the consultant sees in the HoloLens. The consultant and the customer can discuss the placement and look of the furniture models and can more easily make decisions about what works best for the customer.

User interaction in this manner takes into account existing capabilities of augmented reality technology while minimizing costs, accommodating preferences of various customer demographic groups, and allowing business practices to adopt new technologies without drastically changing current business practices.

SOLUTION SYSTEM COMPONENTS

System Component	Description	Platform
Holoture Application Software	- Holographic representation, movement, placement, and manipulation of virtual furniture objects - Recognize physical surfaces - Graphical User Interface - Virtual Furniture Object storage connection	- Microsoft HoloLens - Unity game engine software - C# Language
HoloLens-Surface Tablet paired connection	Display the video feed of the field of view for the Holoture application	- Microsoft Surface tablet - Holoture application
Virtual Furniture Object Collection/Storage	- Store and access 3D virtual furniture objects for use in Holoture application - Associate colors, materials, textures with 3D furniture objects	- FBX objects - 3D furniture scans - AWS S3
Holoture Web Application	- Provide web interface to virtual furniture catalog - Organize customer furniture preferences for sales consultation	- AWS - React JS - Azure - MySQL - Node JS
Microsoft Azure Database	-Database to hold 3D objects and material examples for HoloLens to use.	-Microsoft Azure -MySQL

SOLUTION SYSTEM DESIGN



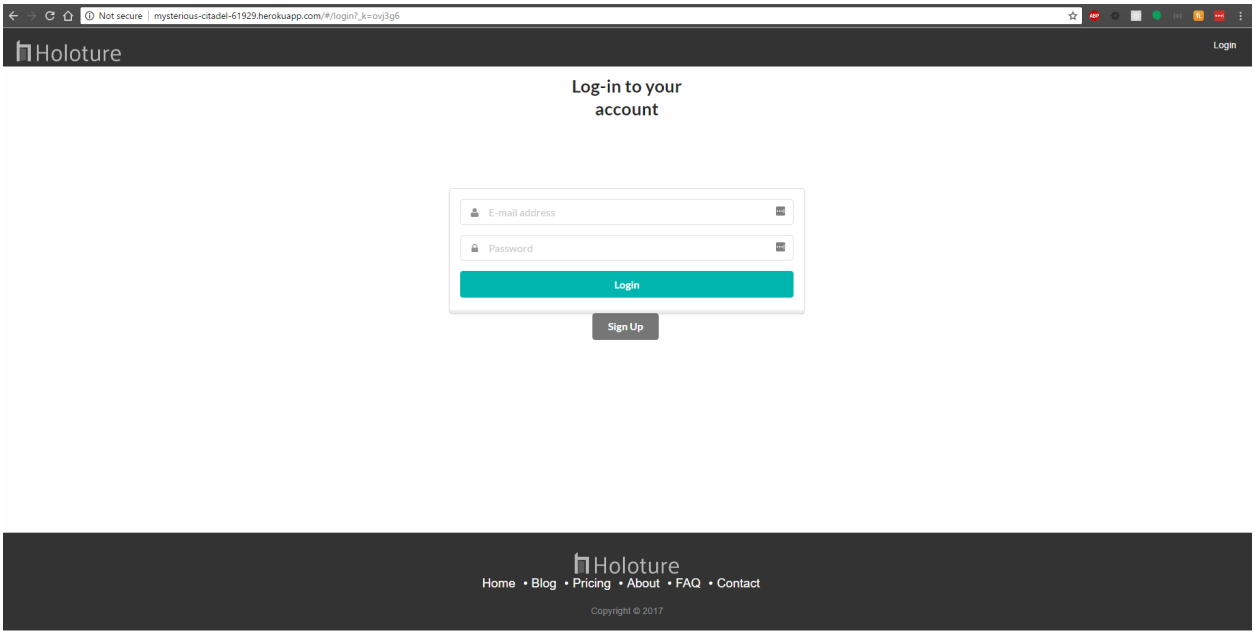
The web application was written in JavaScript using the ReactJS framework. It communicates with the MySQL database through an API written in NodeJS. The database was hosted in the Azure cloud. The HoloLens application was written in Unity and C# and it also communicated to the database through the NodeJS API. All of the 3D models were stored in Amazon S3 so that they could easily be downloaded to the HoloLens application.

DEVELOPMENT OF SYSTEM

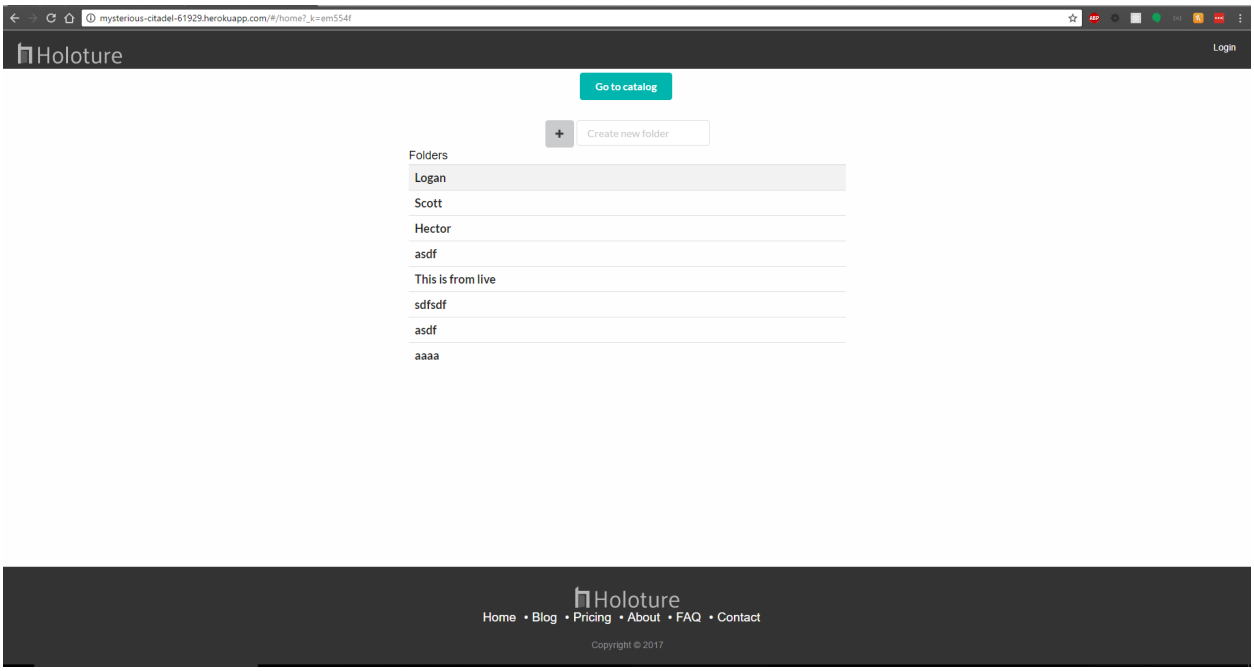
WEB APPLICATION

The web application was written in JavaScript using the ReactJS framework. This framework was chosen because of its ability to build reusable web components and how it renders the page using a virtual DOM. The reusable components make it very easy and clean to build dynamic web pages and the virtual DOM makes smart decisions about when to re-render content on the page. This smart re-rendering results in a faster, snappier web application. Along with ReactJS, Redux was used as a state manager. The backend API was written in NodeJS. This was done because it was simpler to keep the entire code base in JavaScript and there are many libraries that make it easy to have the server communicate with a Microsoft SQL database hosted on Azure. For styling, SASS and SCSS with Semantic UI were used. This allowed the team to create a consistent design throughout the web application. The web application included various other libraries and frameworks as dependencies to improve the performance and quality of the code. The web application was deployed to Heroku. Heroku allows users to push code using git and then it will build and deploy the code--performing what is known as continuous integration. This was used because of how simple it is to get started, maintain, and host a web application in production.

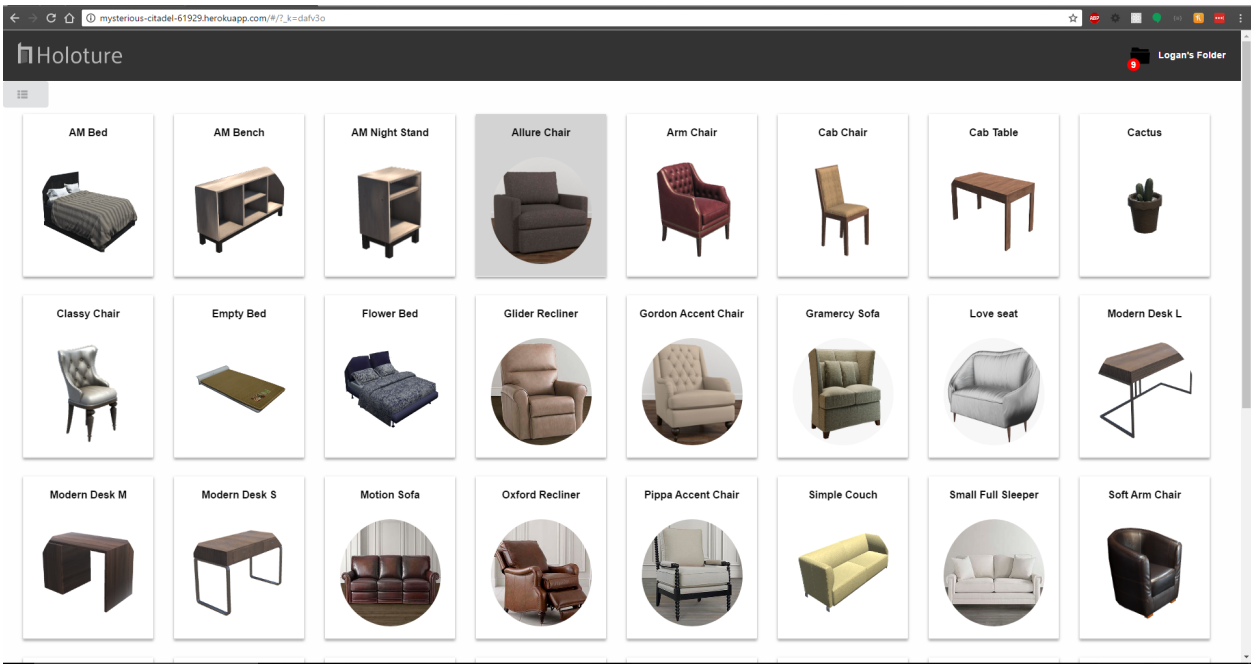
Login Screen



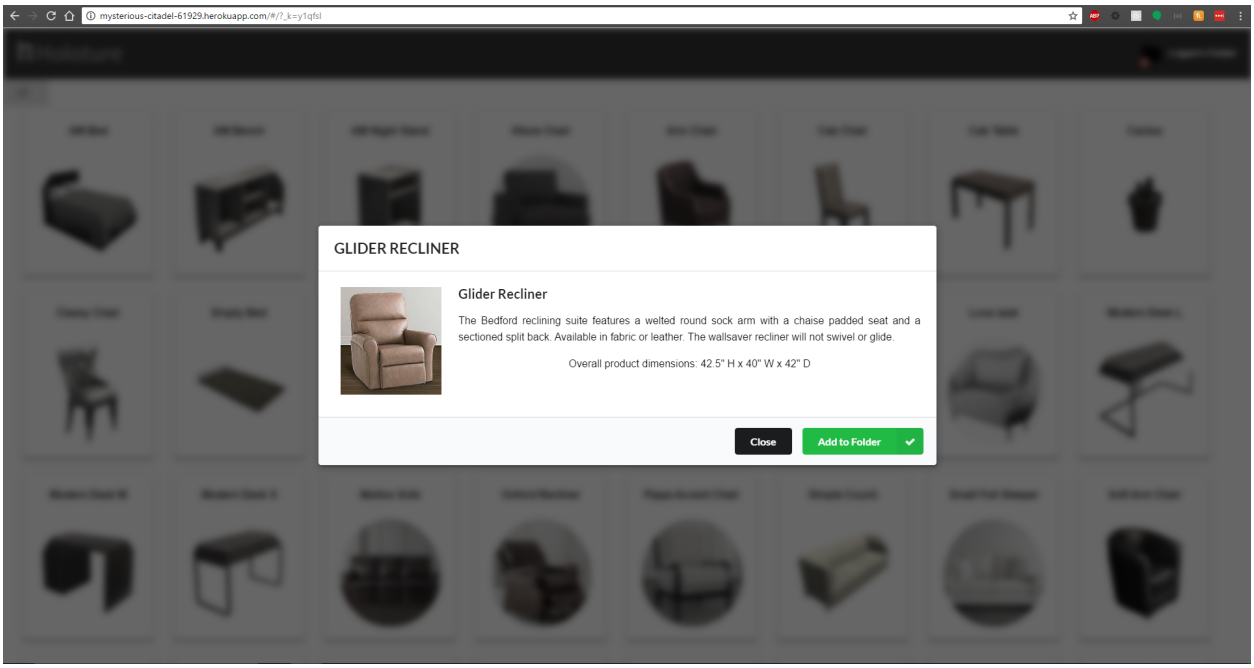
Folder Creation Screen



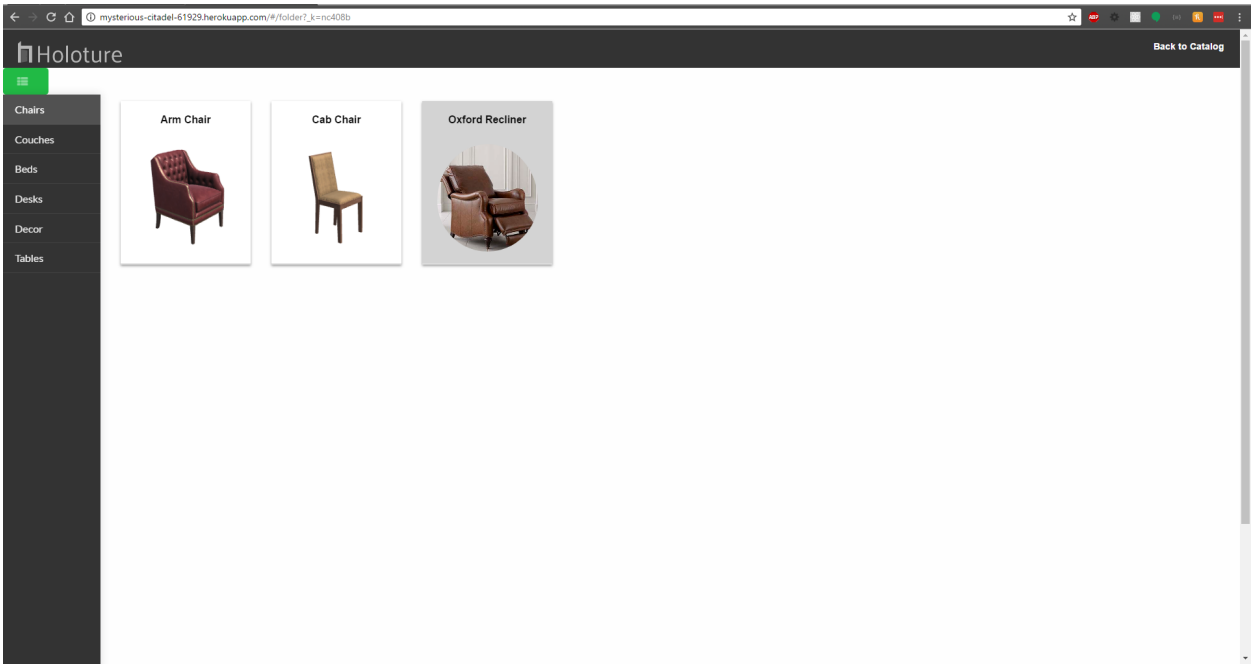
Catalogue Screen



Detailed Furniture Screen



Folder Screen



HOLOLENS APPLICATION

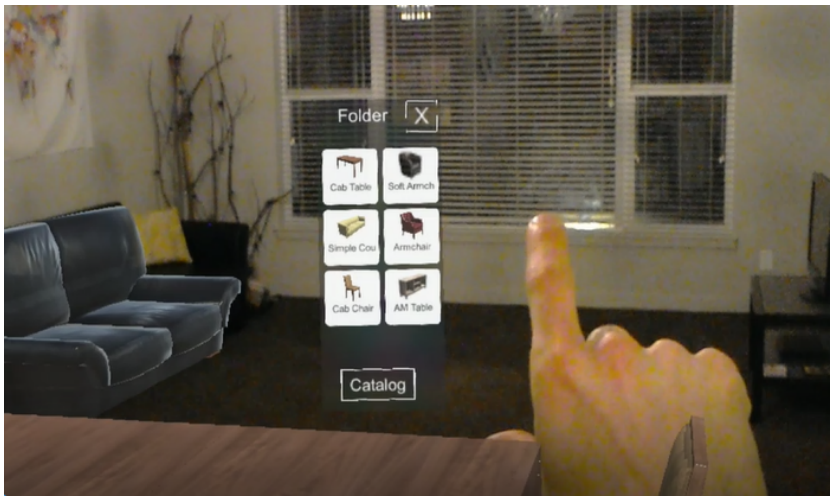
The HoloLens Application is built on Unity Engine and written in C#. We used the Input System provided in the Microsoft supported HoloToolkit-Unity package found here. We used managers to handle customer, furniture, and texture assignments. The application begins by sending a request to http://mysterious-citadel-61929.herokuapp.com/api/customerRegistry.

This is an example of the return JSON object:

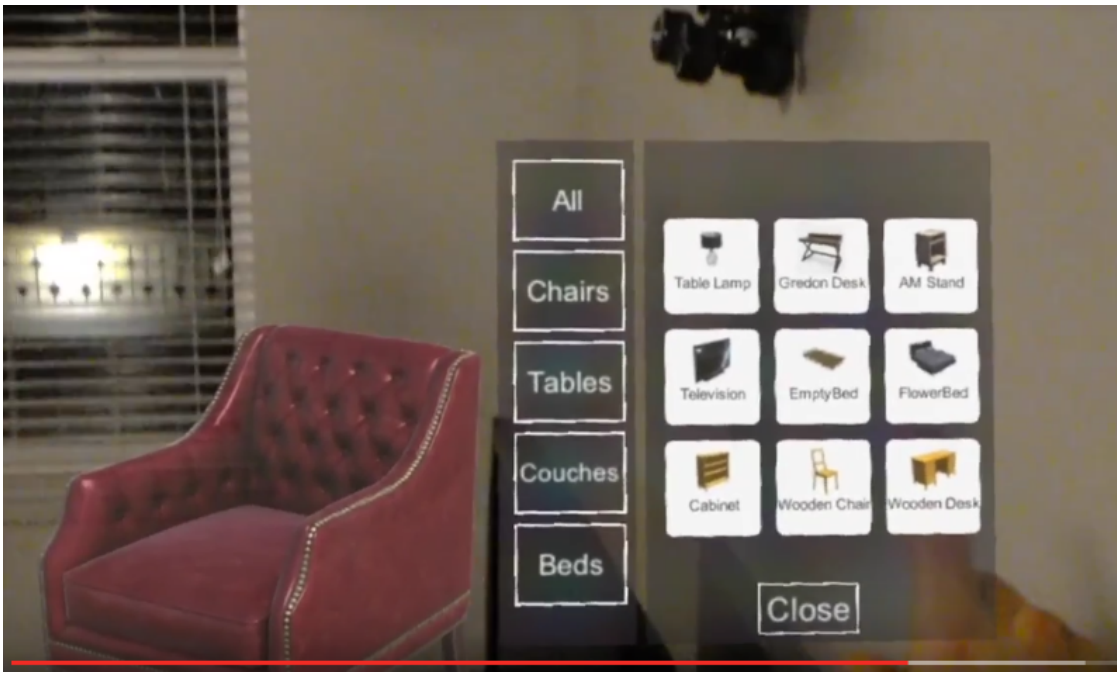

```
{"customerList":[{"CustomerName":"Logan","CustomerID":1,"furnPref
s":[{"FurnitureID":10,"MaterialIDs":[12,5,9]},{"FurnitureID":12,"
MaterialIDs":[12]},{"FurnitureID":13,"MaterialIDs":[1]},{"Furnitu
reID":14,"MaterialIDs":[1]},{"FurnitureID":15,"MaterialIDs":[13,1
,2]},{"FurnitureID":16,"MaterialIDs":[12,5,9]},{"FurnitureID":19,
"MaterialIDs":[1]},{"FurnitureID":20,"MaterialIDs":[1]}]}]}
```


The application then parses the JSON and manages them with the Customer, Furniture, and Texture Managers. These furniture pieces are displayed in the opening menu of Holoture.

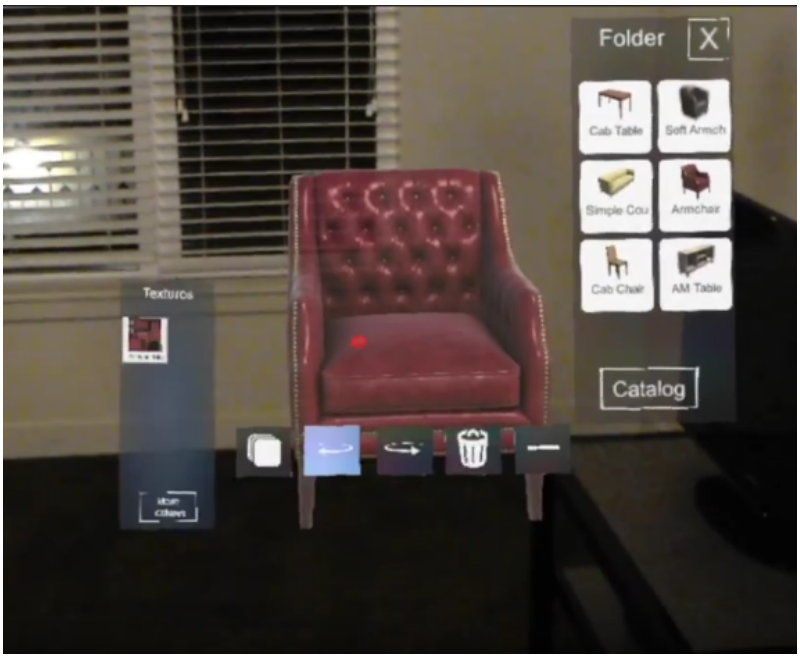
A screenshot of the Open Menu



The Furniture Manager automatically catalogs the rest of the furniture that isn't displayed in the open menu.



The Menu Manager displays the manipulation toolbar when the furniture piece is selected. The toolbar can display textures, rotate the piece, or remove the item from the scene or from the folder.



We opted to use Unity's SendMessage() system instead of the Delegation system in the HoloLensToolkit-Unity framework in order to simplify the input routing and avoid the bugs that Microsoft had implemented in their open source code.

CONCLUSION

Description of the outcomes of the project, achievements made by the team, and ideas for future development.

PROJECT RESULTS

Working prototypes of the web and augmented reality applications met acceptable design requirements and were delivered to the sponsor, Holoture LLC. The prototype web application consists of a ReactJS front end user interface, a Node JS API for client-server communication, a MySQL backend database hosted in Microsoft Azure, and AWS S3 storage. The prototype augmented reality application was written in C# using the Unity Game Engine. This application uses Microsoft HoloLens Toolkit resources for user input, holographic object construction, spatial mapping, gaze management, and gesture recognition. The Unity Game Engine facilitated the creation of a holographic user interface display for the application. For ease of use, the HoloLens is paired with a Surface tablet computer. One person wears the HoloLens and operates the application to manipulate holographic furniture models. On the Surface tablet computer, a different person can view the video feed of the viewing perspective of the HoloLens and see the manipulations performed on the holographic furniture models. These applications met the feature requests outlined in the initial system specification document.

ACHIEVEMENTS

Delivery of a working prototype occurred a month before the goal date of April 14th, 2017. This early delivery was spurred by the sponsor's desire to enter the BYU Mobile App Competition and the BYU Student Innovator of the Year competition. Holoture's entries took 6th place in both competitions and received $1000 in awards.

FUTURE WORK

Holoture LLC is looking at negotiating a deal with Bassett Furniture Company to obtain their 3D models for a pilot program in Orem and Salt Lake City, UT.

Future versions of the application could vastly improve user experience by sharing holographic objects between the HoloLens application and the Surface tablet computer. Such sharing is possible between HoloLens headsets, but not yet with a Surface tablet. That ability to share would eliminate the need for a shaky and disorienting live video feed from the HoloLens to the Surface tablet. Customers could hold the Surface tablet and walk around the room while seeing the holographic objects be manipulated by the wearer of the HoloLens. This is not yet feasible, but if this ability were realized, such a platform could magnify the retail practicality of augmented reality technology.

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10. http://stackoverflow.com/

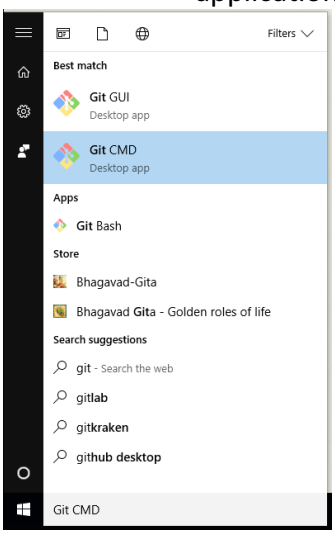
APPENDIX A: USER MANUAL

The following sections explain how to set up and use the Holoture application on the Microsoft HoloLens and its accompanying web application.

HOLOTURE WEB APP -- SYSTEM ADMINISTRATOR

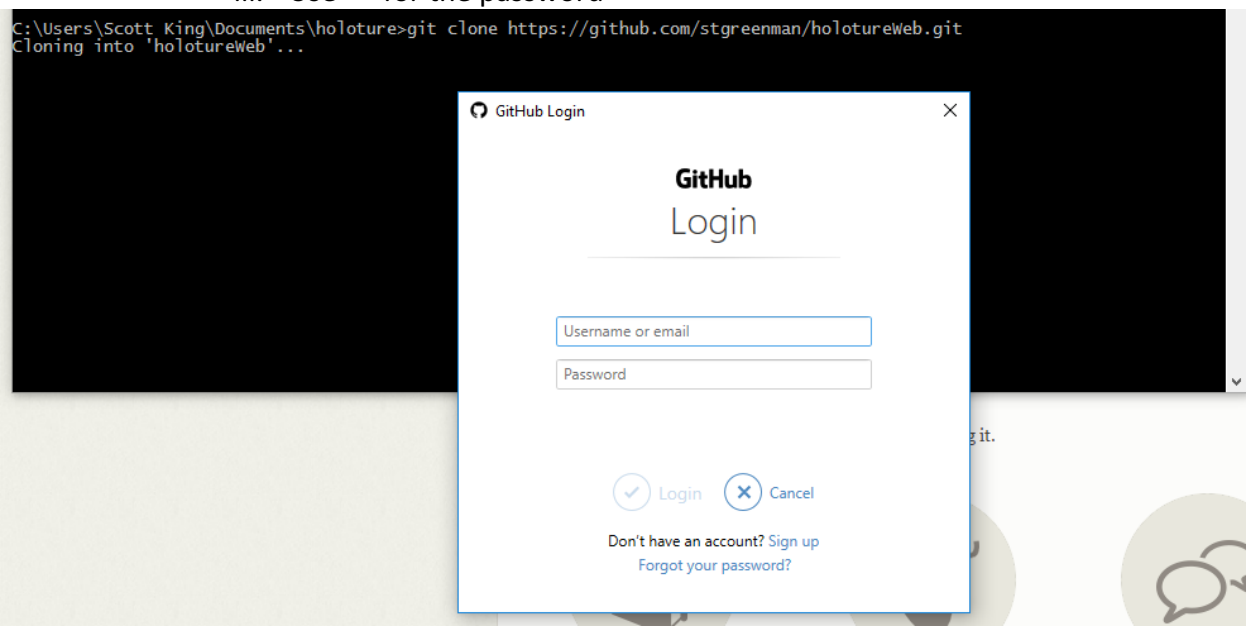
WEB APP INSTALLATION INSTRUCTIONS

1. Download and install node.js for Windows.
    a. Navigate in a browser to https://NodeJS.org/en/
    b. Download V6.10.0 LTS Reccomended for most users
        i. Direct download link: https://NodeJS.org/dist/v6.10.0/node-v6.10.0-x64.msi
    c. Install NodeJS using all of the default options in install GUI
2. Download and Install git
    a. Navigate in a browser to http://git-scm.com/download
    b. Click on the appropriate download button for Windows
    c. Once Downloaded open the .exe and follow prompts using all of the default options selected.
    d. If additional instructions are needed follow install guide on http://www.thegeekstuff.com/2012/02/git-for-windows/1
3. Clone holotureweb git repo
    a. Open start menu and type “Git CMD” as shown below, then open the application.

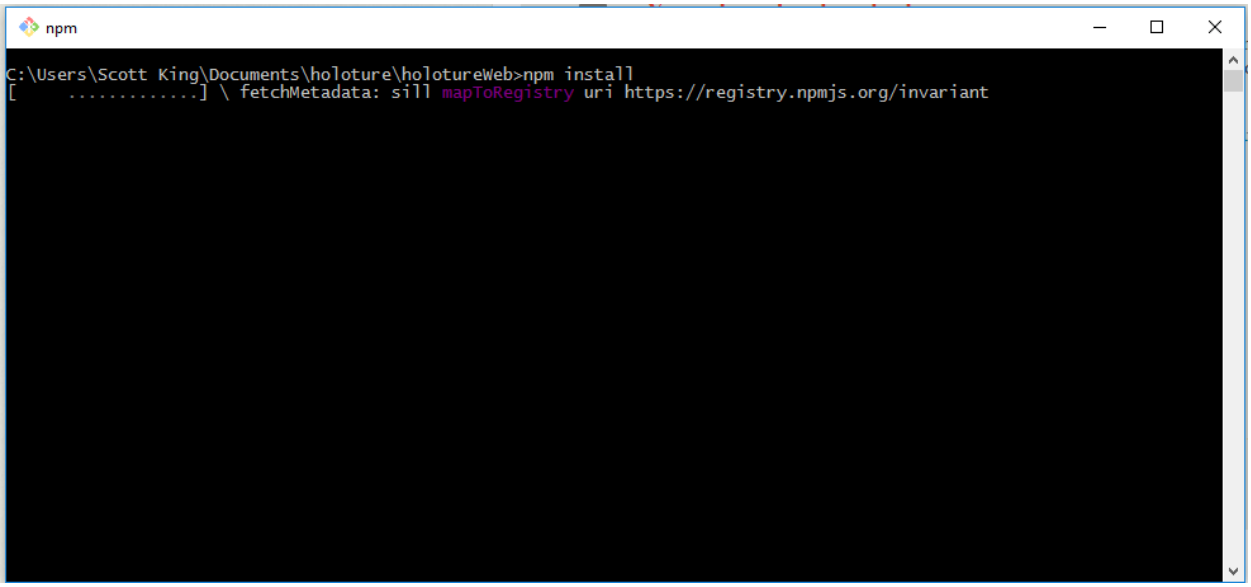


    b. Choose an appropriate location to clone the holoture web repo
        i. I chose c:\Users\<name>\Documents\holoture\
    c. Run the command < git clone https://github.com/stgreenman/holotureWeb.git>

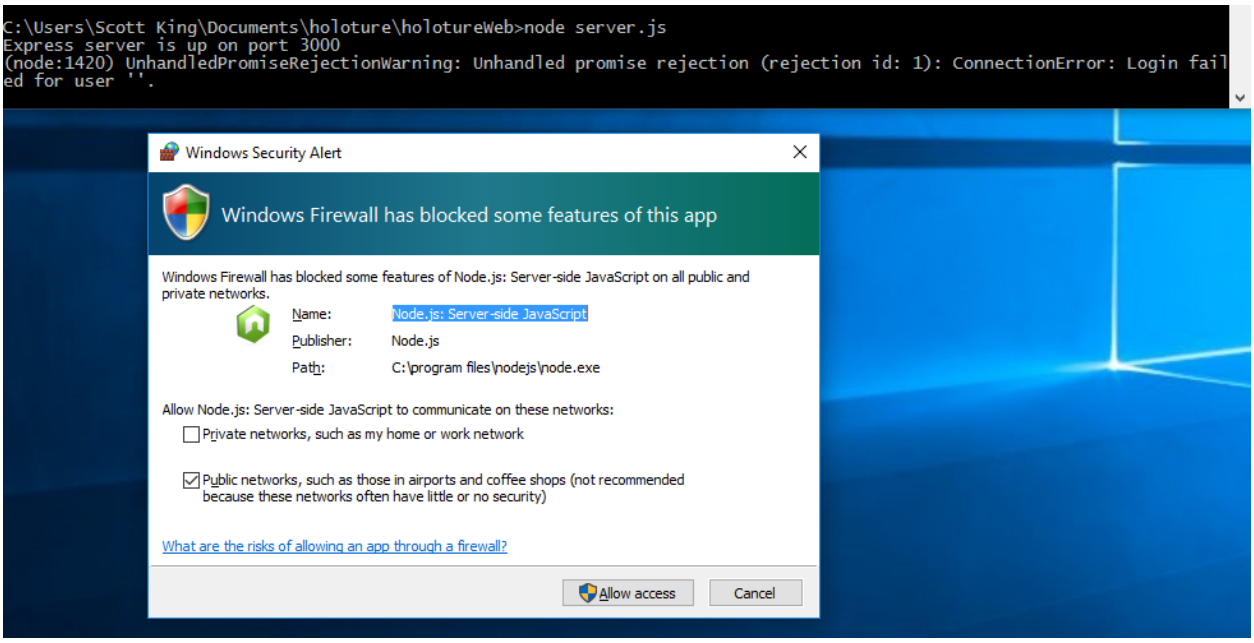
i. This will prompt for a username and password to git.
ii. Use <> for the username
iii. Use <> for the password



d. Change directories to holotureweb <cd holotureweb>
e. Update NPM in order to run the NodeJS server. Use <npm install>



4. Run holotureweb on local NodeJS server
    a. Start NodeJS server with < node server.js>
        i. If Windows security Alert pops up click “Allow Access”



    b. In a browser go to “localhost:3000” to view Holoture web app.

HOLOTURE WEB APP -- DESIGN CONSULTANT

Usage instructions for a design consultant to log in to Holoture.com, create a folder, select furniture, view furniture details, and view furniture selections using the web application.

USAGE

1. In an internet browser, navigate to http://mysterious-citadel-61929.herokuapp.com/#/?_k=rjnzwb and log in with the following credentials
    a. username: < msimaginecup >
    b. password: < holoture2017 >

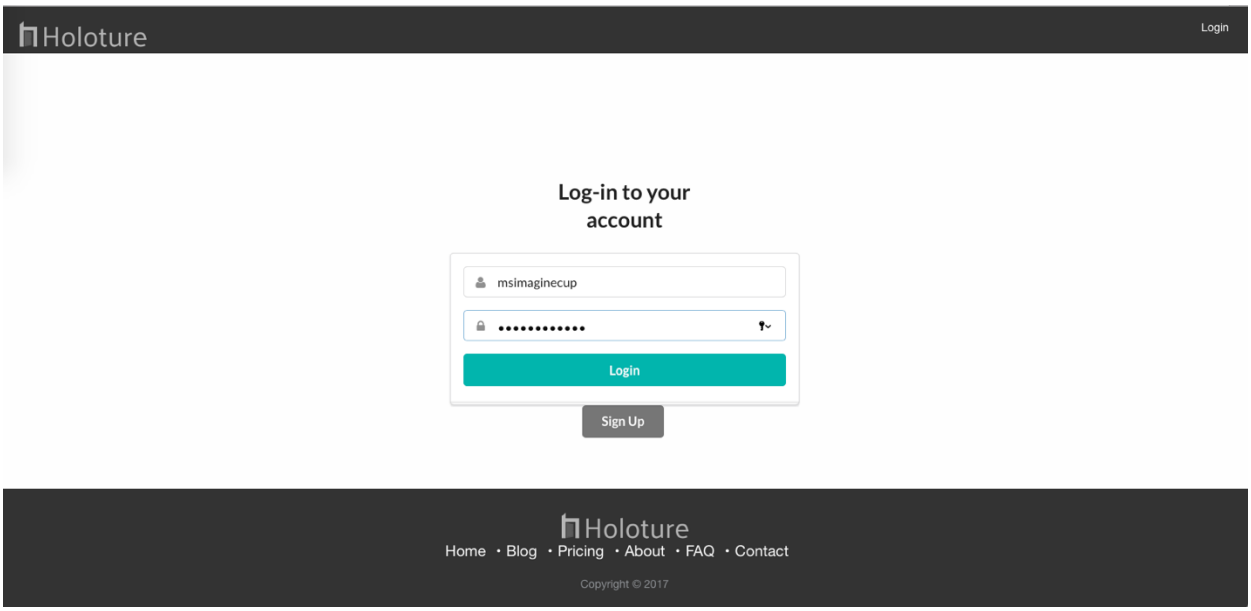


Figure A: Holoture Portal

2. Create Folder
    a. MS Imagine Cup

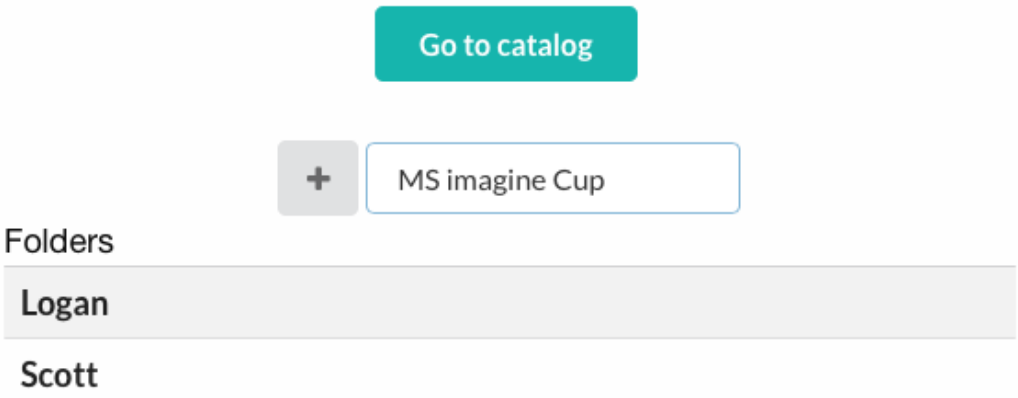


Figure B: Customer Folders

3. Select appropriate folder and click “Go to catalog”
4. Click on furniture to view details and to add to catalog

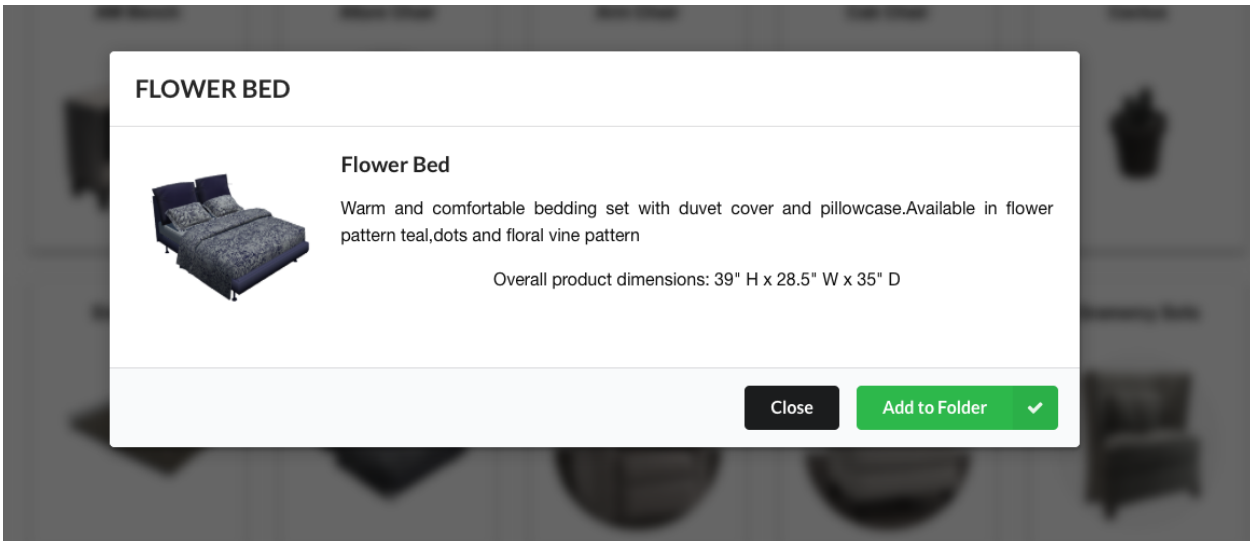


Figure C: Furniture Details

5. Click on folder in top right corner to view folder
    a. Edit folder by clicking on furniture and choosing remove.

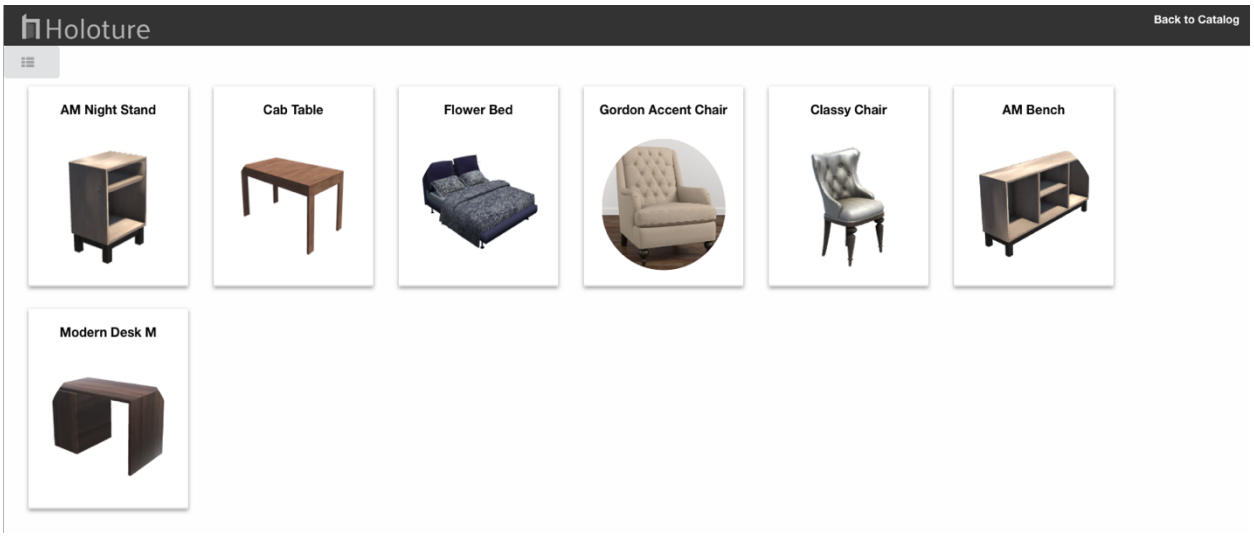


Figure D: Furniture Selection

HOLOTURE APPLICATION -- SYSTEM ADMINISTRATOR

Instructions for the System Administrator for the installation of the Holoture Application on the HoloLens.

INSTALL HOLOTURE

To be able to perform the following instructions, the user must have a functioning HoloLens and must be familiar with its basic operation. To gain knowledge on its usage visit https://www.microsoft.com/microsoft-hololens/en-us

1. Connect to the HoloLens' Device Portal by going to it's IPV4 Address (HoloLens Menu> Settings> Advanced Settings)
2. Enter the HoloLens' IP Address onto the browser of a computer with the .**appxupload** file.
3. Authenticate to reach the portal (see Figure E below)

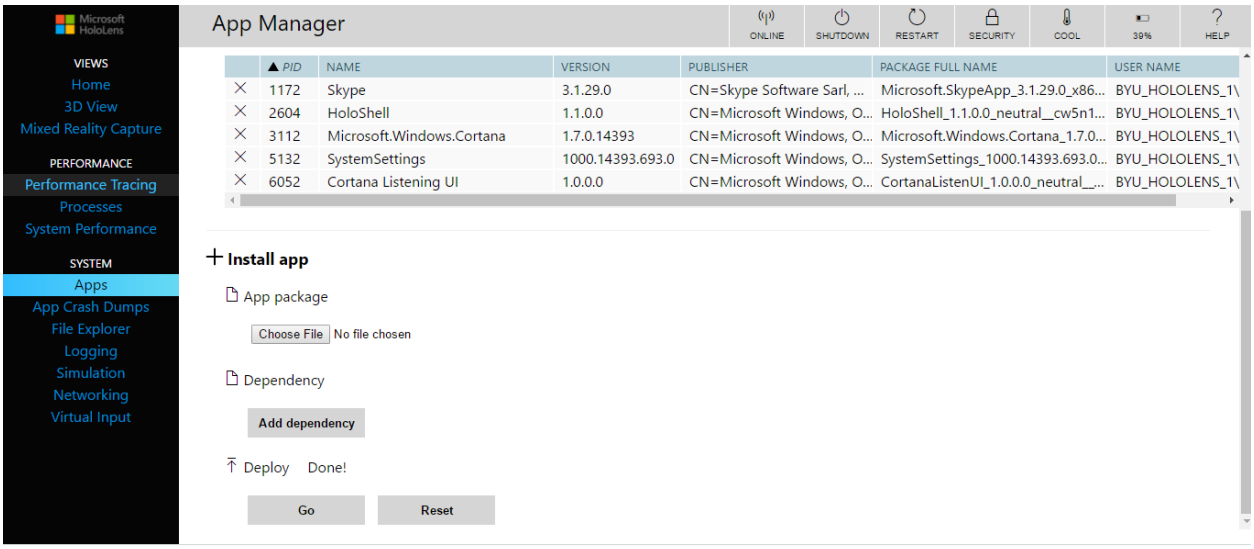


Figure E: HoloLens Device Portal

4. Go to "Apps" on the side bar
5. Click "Choose File" and select the .appxUpload file we submitted and click "Go".
6. Wait for it to install onto the HoloLens.
7. In the HoloLens, do the bloom gesture to open up the main menu. Click on the "+" button to access more apps. Open up the app, "Holoture."
8. Tap to place the application and wait for it to load.

USE HOLOTURE -- DESIGN CONSULTANT

These instructions are meant to explain to a design consultant how to use the Holoture application on the HoloLens.

1. Figure F shows what you will see when you open the Holoture application. To get access to the customer's folder, do the *air-tap* gesture. This will show you a menu with a list of furniture objects.

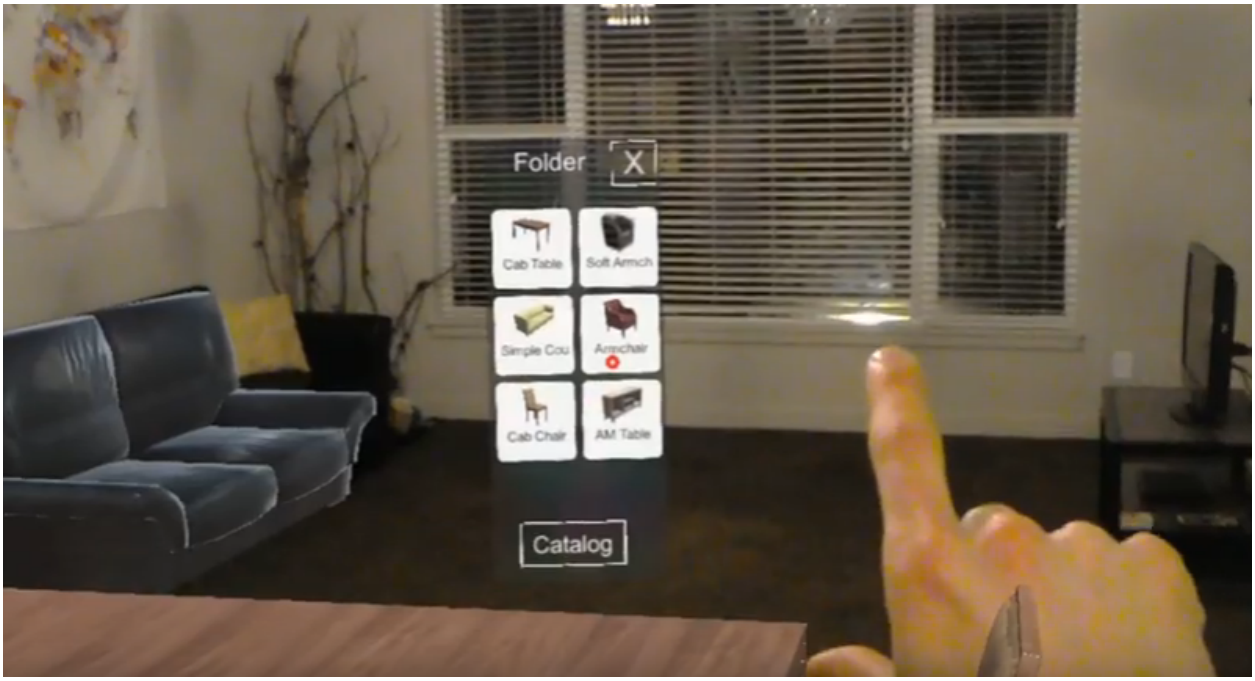


Figure F: Open Furniture Menu

2. The preferred furniture can be selected from the menu by simply directing the red round target to the preferred furniture item in the menu and then pressing and releasing with the *air-tap* gesture. This will drop the selected furniture in space as shown in the Figure G below.

Figure G: Moving Furniture

3. To move the selected furniture around the room, use the *air-tap* gesture to select the furniture. Hold and drag it to the desired position. Release to make the furniture remain at the present/desired position.

4. The Holoture application allows access to more menu options when a furniture object is selected. These include rotate left, rotate right, delete etc. To gain access to furnitures, select the stationary furniture using the press and release *air-tap* gesture and various menus will pop up as shown in Figure H below. These menus will be explained subsequently.

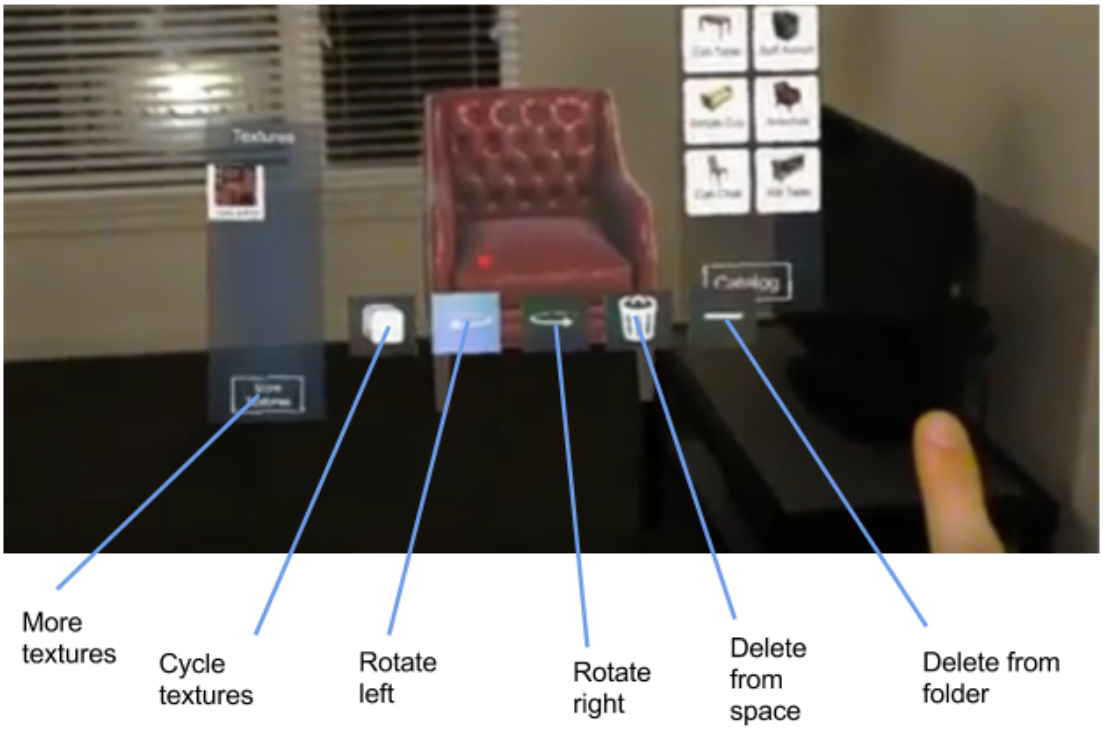


Figure H: Holoture GUI Menus

Figure H shows the menus on the application. The labelled menu buttons and their functions are listed below.

Initial Textures Menu – View the selected textures for the furniture object.

More textures – This is used to gain access to additional textures available for the selected furniture object. This will show a list of more textures as shown in Figure I.

Rotate left – Tap and hold this button to rotate the the selected furniture to the left using the central coordinate of the object as the axis of rotation.

Rotate right – This will rotate the furniture to the right using the central coordinate of the object as the axis of rotation.

Cycle textures – Any time this button is selected the texture on the furniture is changed to the next available texture of that particular furniture.

Delete from space - Deletes the furniture from where it has been dragged and dropped.

Delete from space - Deletes from the customer's folder of selected furniture.

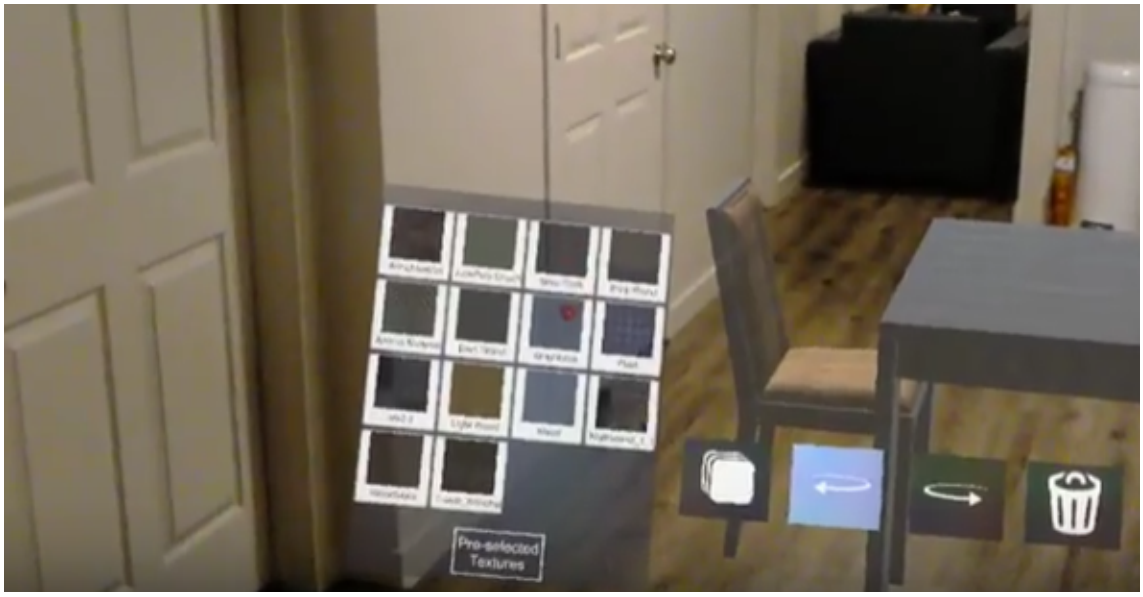


Figure I: Holoture "More Textures" menu

5. The Catalog button gives the user access to more furniture that is not present in the customer's folder. This menu contains additional types of furniture from which the user can choose as shown in Figure J.

Figure J: Holoture "Catalog" folder

APPENDIX B: SOURCE MATERIAL

SOFTWARE PACKAGES

HoloLens Toolkit 1.5.6.0

Unity Editor version 5.5.2f1

Unity Game Engine HoloLens edition

React JS 0.14.7

Node JS v7.2.0

MySQL 5.7

Microsoft Azure Database

Visual Studio 2015 or newer

Microsoft HoloLens app (Windows 10 only)

Internet browser: Chrome and Edge are recommended

HARDWARE REQUIRED

Microsoft HoloLens

HoloLens USB cord

Microsoft Surface tablet

SOURCE CODE

Holoture's source code is proprietary. Holoture LLC is happy to provide access to its code upon individual request.