

Majestic Yosemite Hotel Virtual Tour Application and Indoor Model

by

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To my friends and family.

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List of Abbreviations

ADA	American Disability Act
AP	Access point
API	Application Program Interface
AR	Augmented Reality
FCC	Federal Communications Commission
GIS	Geographic information system
GPS	Global Positioning System
IPS	Indoor Positioning System
IR	Infrared
LBS	Location-Based Service
LTE	Long-Term Evolution
MAU	Monthly Active Users
MVTA	Majestic Virtual Tour Application
PaaS	Platform-As-A-Service
POI	Point of Interest
POT	Paths of Travel
RFID	Radio-Frequency Identification
RSS	Received Signal Strength
RSSI	Received Signal Strength Indicator
SDK	Software Developer Kit
TDOA	Time Difference of Arrival

TIMMS	Trimble Indoor Mobile Mapping System
UHF	Ultra High Frequency
USC	University of Southern California
VR	Virtual Reality
WWW	World-Wide-Web

Abstract

The Majestic Yosemite Hotel, formerly known as the Ahwahnee, is a National Historic Landmark located in Yosemite National Park, California, USA. Built in 1927, the hotel attracted rich and wealthy individuals to help gain financial support for the National Park Service idea of protecting wild spaces for future generations. To this day, the hotel stands as one of the National Park Service's most historic lodging units, providing luxury accommodations and services to park visitors. In November of 2016 Yosemite Hospitality, Yosemite National Park's Concessionaire requested a mobile application to educate visitors on the cultural and historical significance of the hotel to support the goals of the Long Range Interpretive Plan. Yosemite Hospitality was the client for this project, and the application was developed in direct consultation with Yosemite Hospitality's Interpretive Services Department from November 2016 until August 2017. Several indoor positioning technologies and Augmented Reality services were tested to deliver educational content based on user mobile device locations and camera orientations. The processes tested the Anyplace indoor positioning service, IndoorAtlas indoor positioning service, BlueCats beacon services, Vuforia Augmented Reality services, and the gaming engine Unity. Testing and development occurred on both Android and iOS devices with development in Javascript, C#, Swift, and Objective C. As part of this thesis work, a historical model with digital furniture scans was also completed to preserve the current conditions of the hotel's original furniture. These scans were based on the Structure Sensor manufactured by Occipital. This thesis documents the development and testing of the Majestic Virtual Tour Application and the historic furnishings model built for the Majestic Yosemite Hotel in fulfillment of the Yosemite Hospitality project.

Chapter 1 Introduction

Yosemite National Park, located in Central California, is one of the most well-known national parks in the United States with over 5 million visitors in 2016 (Figure 1) (National Park Service 2017a). Since its inception, Yosemite has had its struggles with natural resource management, particularly visitor encounters with wildlife. These include visitors feeding wildlife, car accidents involving wildlife, and improper food storage, all things the National Park Service has been trying to significantly reduce or eliminate through educational programs and park signage (National Park Service 2016, 2017, n.d.a). Visitor education through interpretation continues to be a top priority for preserving the park's natural resources, and for the cultural and historical resources in Yosemite National Park.



Figure 1 View from location “Tunnel View” in Yosemite National Park along Highway 41

To preserve some of the park's cultural and historical resources, Yosemite Hospitality, a subsidiary of Aramark and the new concessionaire for Yosemite as of May 2016, requested a

mobile application for the Majestic Yosemite Hotel that would showcase the history, architectural design, and interior design elements (Yosemite Hospitality 2017a). Yosemite Hospitality currently offers a Majestic Yosemite Hotel Historic walking tour available for park visitors, but the addition of a mobile application will provide visitors with more freedom to independently explore at their own pace to learn about the hotel. Another important reason why Yosemite Hospitality requested a mobile application was to provide educational services to visitors in eight different languages. Although these translations were not completed at the time of this writing, this will be touched on in future work.

The Majestic Virtual Tour Application (MVTA), developed as part of this thesis project, tells the story of the hotel and its creation using place-based interaction. Guests are now able to check out Android tablets and iPads preloaded with the MVTA at the Concierge desk. This thesis outlines several methodological approaches for spatial and augmented technologies to meet client expectations and user needs. These include BlueCats Bluetooth Beacon services, Vuforia Augmented Reality (AR) services, Indoor Atlas indoor positioning services, and the gaming engine Unity (BlueCats n.d.; Vuforia n.d.; IndoorAtlas n.d.; Unity n.d.). All of the educational content in this thesis was written for the project, and was approved by the National Park Service and Yosemite Hospitality's Interpretive Services Department.

In addition, several modeling technologies were looked at and used for this project. The main modeling tool used was an infrared (IR) camera developed by Canvas.io. The IR camera is an iPad attachment that can be used in conjunction with an application to scan rooms and objects. Based off of these IR scans, a virtual model of the hotel's first floor, a CAD model featuring the Solarium, Winter Club Room, Mural Room, and Lounge, and a physical version of the CAD model were all developed. To preserve the current conditions of the historical furniture,

each individual piece was scanned and documented, and will eventually be available in the physical model display located inside the hotel.

1.1. Majestic Yosemite Hotel Background

Completed in 1927, the Majestic Yosemite Hotel, formerly known as the Ahwahnee, has a rich and significant history coinciding with the formation of the National Park System and National Park Service (Figure 2) (Yosemite Hospitality 2017b). The idea behind having a luxury hotel in Yosemite National Park came from the National Park Service's first director Steven T. Mather. Steven T. Mather wanted a luxury hotel in Yosemite to attract wealthy park visitors in order to acquire more interest and generate Congressional funding for the National Park System (Sargent 1990).

The hotel's stonework mimics the natural surroundings to support the goal of an environmental architecture, as these designs fit in with the national park idea (Walklet 2004; Sargent 1990). When the hotel was built, the developers did not use the park's natural resources, but instead, all the granite, stone, and other various materials were shipped in using railroads and mules (Sargent 1990). Preserving and protecting the park's resources set a precedent for other National Parks for natural resources management and development.

Fire is a natural process in Yosemite's ecosystem, and with fire suppression in combination with the seven-year drought in California, there is a high fuel load in Yosemite National Park. During the course of this thesis project, there were three separate fires within and just outside of Yosemite National Park in July and August of 2017. As of August 15th, 2017, one of the fires is currently threatening the Historic Wawona Hotel along Highway 41 in the park (Rocha 2017).



Figure 2 View from the south side of the Majestic Yosemite Hotel

Since fire is common in Yosemite, the hotel needed to be fireproof. Sugar pine trees were hollowed out and used as a mold for the concrete to appear as if it were made of wood, but closer examination shows the same grain and appearance throughout the hotel. A combination of concrete, granite, and steel were used in the construction of the hotel, making it completely fireproof in its structure (Walklet 2004). At the time, the hotel not only stood out because of its unique exterior design but was truly defined by the interior decorations and world-class amenities (McComb 2017; Walklet 2004; and Sargent 1990).

Over the last ninety years, the Majestic Yosemite Hotel has provided luxury accommodations to Yosemite National Park visitors including President John F. Kennedy, and more recently, President Obama (Sargent 1990). It is one of the most famous National Park

Service's lodging units, known for its elegance and significant history in helping shape protected lands across the United States. A closed-door dinner by Stephen Mather in 1927 in the hotel's dining room inspired some of the wealthy guests to write and share their experiences in Yosemite, further spreading the National Park Service idea and protecting these wild places into what it is today (Walklet 2004; Sargent 1990). This project focused on developing an educational mobile application to discuss the history and significance of the Majestic Yosemite Hotel.

1.2. Project Scope

The Majestic Yosemite Hotel is located in Yosemite National Park, as shown in Figure 3. The hotel has 97 hotel rooms, a large dining hall, a bar, a sweet shop, and is home to many different kinds of historical artifacts and objects. These objects represent cultures from all around the world, but also more local influences from the seven different Native American tribes in the greater Yosemite area (Farneth et al. 2011a, 2011b; Kollath McCann Creative Services 2011; Walklet 2004; Sargent 1990).

Location of Majestic Yosemite Hotel in Yosemite National Park, CA

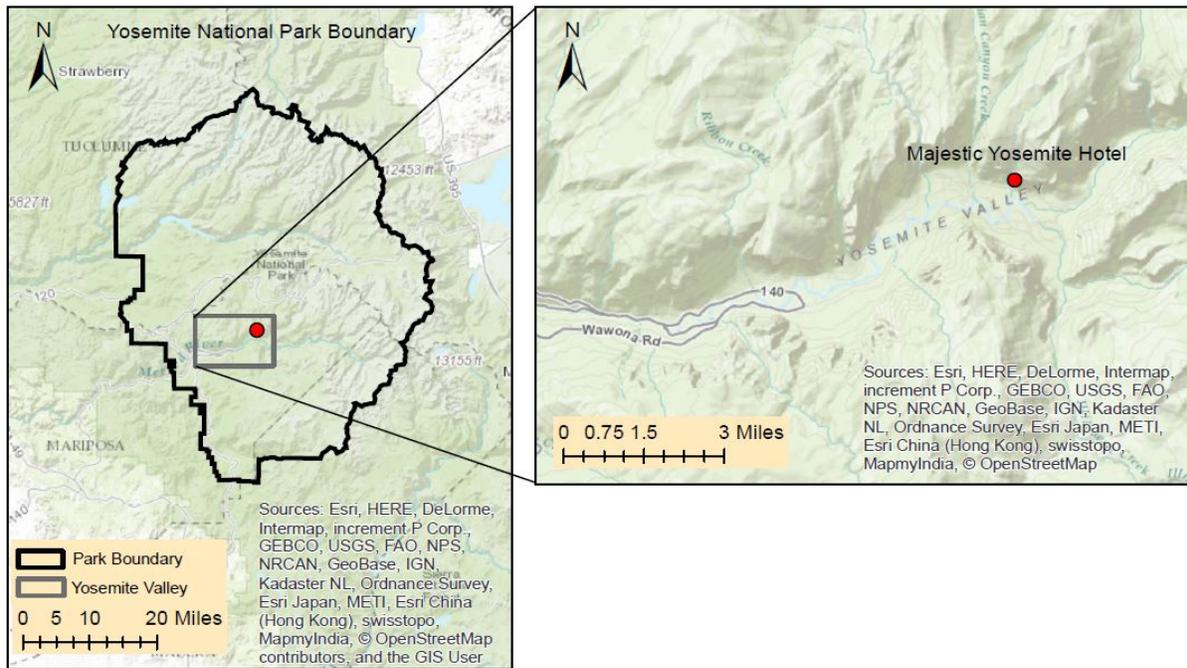


Figure 3 Location of the Majestic Yosemite Hotel in Yosemite National Park

The educational content included in the application is separated into different sections based on geographic location. To establish a flow, several chapters were created to guide users into a certain order based on content, but each point of interest (POI) has stand-alone information to allow flexibility for the end user to choose where they want to go and what topic they would like to learn about. The content of the project focuses on topics including furniture, historical rugs, American Indian baskets, architecture, gothic chandeliers, and the Firefall event that occurred until 1968.

Much of the furniture pieces inside the hotel are original but have undergone several restoration processes. When the Navy occupied the hotel during World War II, much of the original furniture was taken out of the hotel to make room for the hospital beds. Several train cars went into the Merced River, and some of the original chairs and tables were lost (Sargent 2000). In 2011, McCann Creative Services renovated the Great Lounge to help restore and

preserve the furniture and interior design based on design forensics (McCann Creative Services 2011). They looked at historical images, records, and documentation to try and replicate the original conditions that were present when the hotel first opened. The model for this project focused on the restored furniture in the south wing, consisting of the Mural Room, Lounge, Solarium, and Winter Club Room of the hotel. The scans were completed to preserve a snapshot as to what the original furniture looks like in the present day (Figure 4).

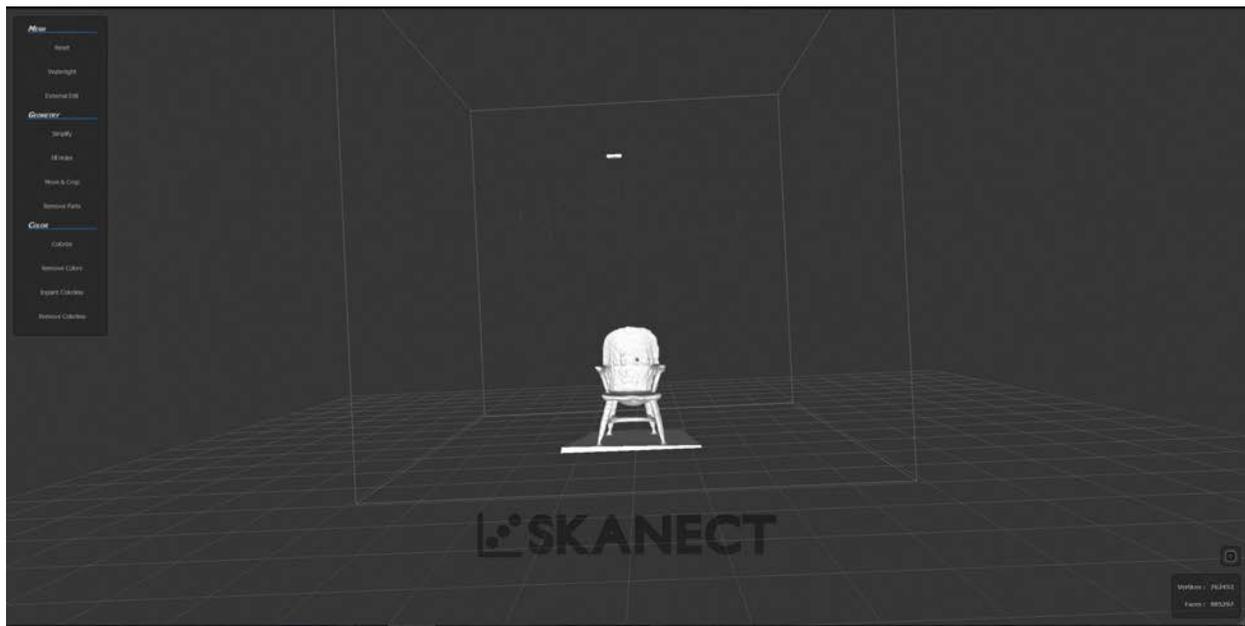


Figure 4 Scanned Winter Club Room chair processed in the scanning software Skanect

The rugs that can be seen hanging from the walls are known as “Kelim” carpets and were originally used to protect furniture when shipped across overseas (McComb 2017). Now deemed priceless and rare, the hotel now has the largest collection of Kelim carpets in the United States (McComb 2017; Walklet 2004; Sargent 1990). The decorative and utilitarian American Indian baskets that can be seen in the hotel’s Great Lounge have been restored or replaced over the course of the hotel’s history (McCann Creative Services 2011). The current baskets have been

cataloged by National Park Service historians and are now on display in the glass cases inside the great lounge (Figure 5).



Figure 5 Catalogued Great Lounge American Indian Baskets

The MVTA provides tour services for the first floor of the hotel only. The other five floors of the hotel contain guest rooms and guest only facilities thus were not included within the scope of this project. Many of the relics inside the hotel are kept on the first floor and are most easily accessible to guests and park visitors. The floorplan and map that was used in this project (Figure 6) show the extent of the MVTA and the MVTA's educational stops or POIs as peach colored dots. The hotel's grounds include the back lawn at the south entrance and the grass patch to the northeast.



Figure 6 Majestic Yosemite Hotel ground floor with locations of educational content (POIs are indicated by peach colored dots)

1.3. Motivation and General Objective

First and foremost, the purpose of this project was to meet the desired user experience for the Yosemite Hospitality. The desired user experience is defined as creating an overall engaging

mobile tour application through relevant information with the ability to select or receive information based on where the MVTA user is inside the hotel, an audio component where the user can choose to listen to the content or access a complete audio tour, a clean user interface layout and design, and incorporating historical and present-day photographs to establish relevancy to the educational content for each POI. All MVTA application design decisions were based on client application specifications regarding functionality. Working with the client closely facilitated achievement of those expectations.

To help meet the requirements of the thesis project, a second goal was set to test the utility of an IPS with mobile integration for the indoor and outdoor transition. A third goal included testing the applicability of different software architecture approaches for coding the application to determine the system best suited to meet the client's long-term needs and in-house maintenance expertise. The fourth goal of this project was to build a historical furnishings 3D model of the hotel for visual purposes to provide a current snapshot of the hotel and provide a current inventory of the relics, artifacts, and furniture on the hotel's first floor as part of the Long Range Interpretive Plan.

From a spatial and technological standpoint, the motivation stemmed from facilitating the indoor to outdoor transition using indoor positioning services. The natural outgrowth of Geographic Information Systems (GIS) came from location storage, defense, and utilities (Worboys 2011). The indoor to outdoor transition holds enormous potential (Goodchild 2011). Using both an indoor and outdoor space to deliver educational content through proximity-based location services can create an interactive and highly engaging virtual tour and help achieve the desired user experience. This thesis looks at several technological approaches to achieve the desired user experience for the client using different types of spatial technologies.

The intended users of the mobile application are guests and visitors of the Majestic Yosemite Hotel in Yosemite National Park. Currently, there is only one historical in-person tour available each day at the Majestic Yosemite Hotel. There is no limit as to how many guests can attend this interpretive and historical tour to learn about the hotel's history. The application was designed to complement and provide an additional source of information for park visitors who are curious to learn about the hotel.

The proposed methodologies of the application are focused on AR and the use of an indoor positioning system (IPS). The AR feature employs object recognition services to identify what the camera is looking at, and information about that POI will be displayed on the tablet device. An advantage to this is if the object is eventually moved, it is not dependent on a place-based information set, and the user can still use the camera function for object recognition and to learn about the object.

Using an IPS is meant to inform users on where the POIs are located, what rooms are restricted in the application, and help determine the current location of the user. The IndoorAtlas indoor positioning service tested allows for geofences to be created. Geofences are virtual zones that can be programmed into the application. When the user physically enters or exits these zones by walking, the application can react to that specific action, whether it is based on if they entered or exit, and display relevant information or take it away. Although this method was not ultimately used due to final financial and logistical considerations, the client did like the functionality of geofencing and the IndoorAtlas platform.

Over thirty POIs are available in the MVTA. From an educational standpoint based on the client's needs, the MVTA required high-quality content. The research was conducted at the National Park Service Research Library, and the information was vigorously edited based on

content, flow, and clarity by the Interpretive Services Department and National Park Service Interpretive staff.

1.4. Thesis Organization

This thesis outlines the processes and decisions made in the development of the MVTA that demonstrate several positioning system utilities. The MVTA is intended to provide an educational experience for visitors to learn about the park's cultural and historical resources in the Majestic Yosemite Hotel. Chapter 2 of this document provides a literature review of IPSs, comparable mobile tour applications currently in use, and indoor modeling techniques. Chapter 3 describes the methodologies developed for this project, including an analysis of two low-cost IPS services used in this project, testing BlueCats beacon services, Vuforia AR services, and building an application in Unity (Anyplace Architect n.d.; IndoorAtlas n.d.; BlueCats n.d.; Vuforia n.d.; Unity n.d). Chapter 4 outlines developing the model for the project. Chapter 5 describes the results of the project and its applicability to the client. Chapter 6 includes a discussion and closing thoughts on the project.

Chapter 2 Related Work

To understand the rationale for this project, it is important to understand the utility of an IPS. Positioning technologies have always favored the outdoors, but the development of IPS technologies have given established companies and start-ups a unique opportunity to fill the market and define the space (Dodge 2013; Goodchild 2011). For example, companies can use IPS data to better serve their customers by providing direct navigation to a specific POI, an IPS can deliver content based on the user's location within a specific location, or it can identify shopping trends tailored towards a shopper's experience. This attracted Yosemite Hospitality's desire for a unique user experience and overall engagement for place based interaction.

To achieve the desired user experience for the client, several approaches for content delivery were tested, including object recognition services and IPSs. This chapter highlights several positioning services available on the market at the time of this writing, and comparable self-guided tour mobile applications and web applications. A movement in the GIS field focuses on the indoor capacity and 3D indoor modeling, specifically in emergency and evacuation plans (Xiong et al. 2017). This chapter also highlights indoor model development.

The first section of this chapter provides an overview of positioning technologies and capabilities. The second section describes different applications for tour purposes, including those that use Virtual Reality (VR) or AR tools. The third section focuses on indoor modeling techniques and indoor scanning techniques.

2.1. Types of Positioning Systems and Technologies

There are many different types of positioning systems currently available including Global Positioning Systems (GPS) and IPS. This section provides a brief overview of different

types of positioning systems available at the time of this writing and their respective technologies.

2.1.1. Global Positioning System

GPS is a commonly used positioning technology that relies on satellites. GPS was originally developed for military purposes in the United States and consists of twenty-four satellites in six orbital planes to determine coordinates points that represent a location on the Earth's surface (Bahl and Padmanabhan 2000). The coordinate values are calculated by comparing the timing of satellite signals in the line of sight of the user (Goodchild n.d). Trees, clouds, and buildings are examples of obstacles that can disrupt the line of sight and the GPS signal. Since GPS is not as effective indoors, it was not used for this project.

One utility GPS does provide though is a location-based service (LBS) in the form of coordinates. LBS progressed in the late 1990s and early 2000s with pressure from the Federal Communications Commission (FCC) to improve emergency positioning technologies (Rao and Minakakis 2003). In an emergency, cellular carriers are required to identify an individual's location within a certain level of accuracy in order to identify and alert the correct entity. An LBS usually involves the user, a positioning technology provider, and a service provider (Gruteser and Liu 2004). Consumers continue to benefit from LBS with smartphone integration for navigation or finding local goods and services, applications dependent on the context and location of the device (Jiang and Yao 2006).

In an indoor space, the level of accuracy and precision performance is crucial to delivering accurate information and services. In the Majestic Yosemite Hotel, there are very narrow, roughly ~1m in width, paths of travel (POT). This could create potential issues when entering and exiting the proposed geofences that may be in proximity to another POI in the hotel.

One solution, which will be explained in further detail later in this chapter, was to use object recognition and AR services.

GPS in its pure form is generally not used in smartphone technology, but rather a combination of technologies called A-GPS or Assisted GPS. Assisted GPS combines network-based and handset-based technologies in an attempt to overcome the drawbacks of GPS (Fouskas et al. 2002). These drawbacks include power consumption, speed, line-of-sight, and cost, as well as keeping an estimated location based on the last recorded position (Fouskas et al. 2002). Assisted GPS is a hybrid because it uses a combination of network services with available wireless technologies (Wi-Fi). This combination of technologies gives LBS to the indoor/outdoor transition, an integration that holds enormous potential according to Goodchild, but does not necessarily provide location-based solutions for every situation (2011).

Giudice et al. mention that one fundamental research issue is the integration of an outdoor to indoor space framework (2010). It is important to note that an ontology is specific to a domain, and permits formal reasoning while using a computer (Zouggar et al. 2008). In order to address this research integration, a generic ontology *should* be developed where O-space and I-space are considered special cases for an OI- integration tool (Giudice et al. 2010). An OI-ontology would provide seamless integration at the fundamental level. This project intended to use an IPS for managing this outdoor to indoor integration on a small scale to demonstrate the utility of an IPS, but more importantly to treat indoor and outdoor space as a single type of space for smooth transitioning.

Although GPS and A-GPS are more commonly available positioning technologies, they do not support or have the capabilities in a remote area such as Yosemite National Park. The high amount of tree cover and granite cliffs in Yosemite Valley create obstacles for GPS to

acquire a signal and factored into the decision for which technology to use for an indoor/outdoor virtual tour. GPS does offer fundamental characteristics of positioning technologies and is a common technology available in most smart devices.

2.1.1.1. GPS Accuracy

An important thing to note about GPS is that its success depends on unit accuracy. Separate from mobile devices, GPS units offer positioning solutions in outdoor settings. Outdoor GPS technology has improved in covered areas or areas with some level of interference, but these types of units can be very expensive to the average consumer. Lower cost GPS units may be more sensitive to interference and obstacles (Abraham et al. 2012). The quality of the unit and level of object interference can directly affect the position accuracy. Readings can range from a few meters to below centimeter accuracy, depending on the quality of the GPS unit (Goodchild n.d.).

Having a system that has sub-centimeter accuracy provides higher quality data, but can also lead to security concerns and issues. An individual may approve certain smart phone applications to track their location, whether it's for navigation or emergency services, but may not want their location revealed or tracked in every situation. This is known as situation-dependent LBS (Gruteser and Liu 2004). Many phones now can turn off LBS for applications, but it may be considered tedious to turn this setting on and off (Gruteser and Liu 2004).

One alternative for inherent privacy issues in an LBS can be found in the Empire State Building in New York City, New York (The Travel Magazine 2017). Visitors can rent out iPads with a preloaded application for a virtual tour of the New York skyline. Based on that example, it was determined that the first 12-months would provide only rented tablets available with MVT

preloaded from the concierge to address security concerns. This will also control the number of people that can participate in the virtual tour simultaneously.

2.1.2. Wide-area Cellular Networks

Wide-area cellular networks provide another form of user location and tracking. This form of tracking relies heavily on cellular network infrastructure and technologies (Moberg et al. 2009). Examples of a wide-area cellular network are long-term evolution (LTE) and 4G-LTE. These provide the necessary infrastructure for GPS, navigation, and other LBS, common applications in today's mobile technologies, as previously stated.

Ideally, a wide-area cellular network would be the preferred method for a mobile application. Wide-area cellular networks provide a commonly-used form of user location and tracking. In 2015, an estimated 92% of adults owned a cell-phone, and 68% owned a smart phone (Anderson 2015). Although accessibility to mobile technologies is high in the general populous, lack of dedicated cellular service in Yosemite National Park contributed towards using the proposed network-dependent IPS. In more developed areas, this could be a better fit solution for a virtual tour if high-level indoor accuracy could be achieved.

2.1.3. In-building Positioning Networks

Although there are many emerging technologies for IPSs, there is no accepted standard for their implementation (Davis et al. 2015). This project does not aim to define standards for implementing an IPS. The project does provide a methodology of implementing a low-cost IPS as an alternative to other positioning systems that may not have the optimal cellular network infrastructure or environmental conditions to support GPS signal acquisition to demonstrate an IPSs' utility. Another approach considered was using an In-building Positioning Network. Examples of these are Bluetooth, Wi-Fi, ultrasound, IR, or radio-frequency identification (RFID)

(Fouskas et al. 2002). A system requiring Bluetooth beacons, ultrasound and IR sensors, or RFID sensing capabilities would increase initial costs but may be cheaper for long-term maintenance. The following sections cover a brief description of Bluetooth, ultrasound, and RFID location services.

2.1.3.1. Bluetooth

Some services offered such as BlueCats Bluetooth beacons offer location services at the cost of the technology itself, but also have the option to charge for their SDK for user tracking and characteristics for a monthly fee or site license. For indoor positioning services, two of the five states of Bluetooth technology, advertising, and scanning, help determine the location of the devices (Conteras et al. 2017). In order to protect the privacy of the individuals in a Bluetooth IPS, BlueCats uses the advertising ID instead of any personal information to reduce the risk of information being leaked (BlueCats 2017).

Location errors have been known to occur, as with many different types of positioning systems, but there are ways to reduce or eliminate errors in some cases. Smoothing algorithms can be adapted to a specific space and is a key component to location accuracy in the proposed methodologies for the MVTA. Each room required one or more smoothing algorithms to determine the boundaries of each room. Conteras et al. (2017) recommend reducing cross-correlation issues, for example, by removing stronger signals so that the weaker signals can be favored. For BlueCats beacon services, the midrange beacons callback method available in their software developer kit (SDK) can provide a list of beacons objects in the range where the property “accuracy” is called (Dundee 2017). The beacons with the lowest accuracy represent the closest in proximity and based on that number the scale can be set based on the needs of the

application (i.e., 1-2 meters). This allowed for the beacons to deliver content based on the proximity of each beacon once the distance was set.

The beacons from BlueCats ranges between \$15 USD for a coin beacon and \$29 USD for their second-generation BC 313 (Figure 7). Some projects require hundreds of beacons to be deployed, but on this scale and methodology, it was determined that only thirty were required. This was one of the costlier purchases for the MVTA, but it provides an easy and reliable IPS service for the application.



Figure 7 BlueCats BC 313 beacon (76mm x 27.80mm) on left, and coin beacon (52mm x 27mm x 7mm) on right used in project

2.1.3.2. Infrared Radiation IPS

One type of indoor positioning technology uses IR sensors. IR sensors use computing devices for current location and allow the use of transmitters to automatically display information about the POI within that proximity (Tseng et al. 2001). This technology is appealing because it increases location-based interaction based on proximity to a POI, but requires more technology investment up front. The National Park Service had concerns about several hundred sensors installed near each POI as they would be noticeably visible inside the hotel. From the client's perspective, the cost was a large factor looking at IR IPS systems. Some sensors can cost up to several hundred United States dollars (USD) apiece, so to reduce costs an IR Radiation-based IPS was excluded.

2.1.3.3. Wireless Systems

Using a system that relies on already in-place infrastructure such as Wi-Fi is a simple way to reduce costs. One of the main objectives of this project was to reduce the ultimate cost to the client. Finding a low-cost IPS system with high performance and accuracy to demonstrate the utility for virtual tour purposes in a small environment was vital. Two hardware components for these types of systems are signal transmitters and measuring units (Liu et al. 2007). Many mobile smart phones come with standardized Wi-Fi and can be used with these types of systems. Table 1 describes several Wireless-based IPSs, their specific technologies, and accuracies. Cost ranges in the table represent the combination of money, time, space, weight, and energy for the technologies. One disclaimer for Anyplace is that there is not an already-in-placed wireless network in which the IPS could use.

Table 1 Wireless-Based Indoor Positioning System and Solutions (Adapted from Liu et al. 2007; Georgiou et al. 2015)

System/ Solution	Wireless Technologies	Positioning Algorithms	Accuracy	Precision	Scalability	Cost
Microsoft Radar	WLAN, Received Signal Strength (RSS)	K NN, Viterbi-like algorithm	3-5m	50% within around 2.5m and 90% within 5.9m	Good/2D, 3D	Low
Horus	WLAN RSS	Probabilistic method	2m	90% within 2.1m	Good/2D	Low
DIT	WLAN RSS	MLP, SVM, etc.	3m	90% within 5.12 m for SVM; 90% within 5.40m for MLP	Good/2D, 3D	Low
Ekahau	WLAN Received Signal Strength Indicator (RSSI)	Probabilistic method (Tracking- assistant)	1m	50% within 2m	Good/2D	Low
SnapTrack	Assisted GPS, time difference of arrival (TDOA)		5m – 50m	50% within 25m	Good/2D, 3D	Med
Anyplace	RSS	Local IMU and Wi-Fi	1.96m		Good/2D	Free
WhereNet	Ultra-High Frequency (UHF) TDOA	Least Square/ RWGH	2-3m	50% within 3m	Very good/ 2D,3D	Low

The Anyplace indoor information service is one example of a Wi-Fi IPS that was considered for this project. Anyplace is an indoor information service that combines network-based service accuracies with a terminal-based service (Georgious et al. 2015). The five components that comprise the Anyplace application are Server, Architect, Viewer, NoSQL data store, and Logger/Navigator. This creates a full-service, scalable, open, modular, and extensible architecture (Georgious et al. 2015). Anyplace stores buildings, floorplan data and POIs, and uses Couchbase for database information retrieval (Petrou et al. 2014; Couchbase n.d.).

Information is continuously updated through crowdsourced information and data input for location services, providing built-in long-term maintenance capabilities (Petrou et al. 2014).

The Anyplace Architect is a website feature service that allows the user to edit and upload floorplans for each respective floor for any building (Anyplace Architect n.d.). Floorplans are placed on a built-in Google Maps Application Programming Interface (API) for scaling and resizing. Additional POIs inside the building can be uploaded, and feasible paths for indoor navigation services, also known as POT, are created directly in the Anyplace Architect. The Anyplace Logger uses Wi-Fi access points (APs) to track and record current locations and contributes to the overall radio map (Petrou et al. 2014). The Anyplace Navigator gives users their current location within the building based on exchanges from smartphone or device sensors with Wi-Fi APs to obtain navigation direction from their current location to different POIs (Petrou et al. 2014).

Researchers from the University of Cyprus in Greece developed the Anyplace technology and implemented this type of IPS on the university campus (Zeinalipour-Yazti et al. 2017). The Anyplace mobile application is currently available on Android for free, and the entire application is available on their Github (Anyplace Github 2017a). The main functions of the Anyplace application are for navigation purposes to different POIs and indoor positioning but could be used for virtual tour purposes. Navigation using defined POT were considered for the user to find the next POI.

Wireless technologies provide an easy solution for IPS services, and many public buildings and outdoor areas offer Wi-Fi hotspots that customers can use. The Majestic Yosemite Hotel already offers Wi-Fi access for hotel guests and park staff, but does not have a public network available for non-guests. This proposed a fundamental problem as a separate network

would need to be provided for guests to use the MVTA, adding on additional infrastructure costs to the client.

Another main issue with Anyplace is that there have been documented issues on the Anyplace website with native mobile application integration (Anyplace Github 2017b). Since the code is freely available, a developer can recreate the code to fit into their own application, but other researchers have also had no success in implementation. Such efforts, including in this thesis, have reported experiencing critical functionality errors and locational display errors. This was considered a major drawback in using this type of system.

2.1.3.4. Geomagnetic Systems

Another type of IPS considered for this project that uses already in-place infrastructure is based on the Earth's magnetic field and is called a geomagnetic system. One example of a geomagnetic platform-as-a-service (PaaS) leader is IndoorAtlas, an IPS service that provides indoor location services using built-in magnetic sensors in mobile devices (IndoorAtlas 2016). IndoorAtlas uses a similar web API to upload floorplans and building data, and the user downloads a mobile application (Figure 8) to record the geomagnetic pulses inside the building for POT and room information (IndoorAtlas 2016). One contingency is that IndoorAtlas requires steel in the buildings because the interaction between the steel and the geomagnetic pulses determines users' locations within the building. The farther the user is from the building, the less accurate the positioning is. Since the Majestic Yosemite Hotel is completely fireproof and made out of only concrete and steel, it was deemed a suitable location for testing the IndoorAtlas service.

Ground Floor

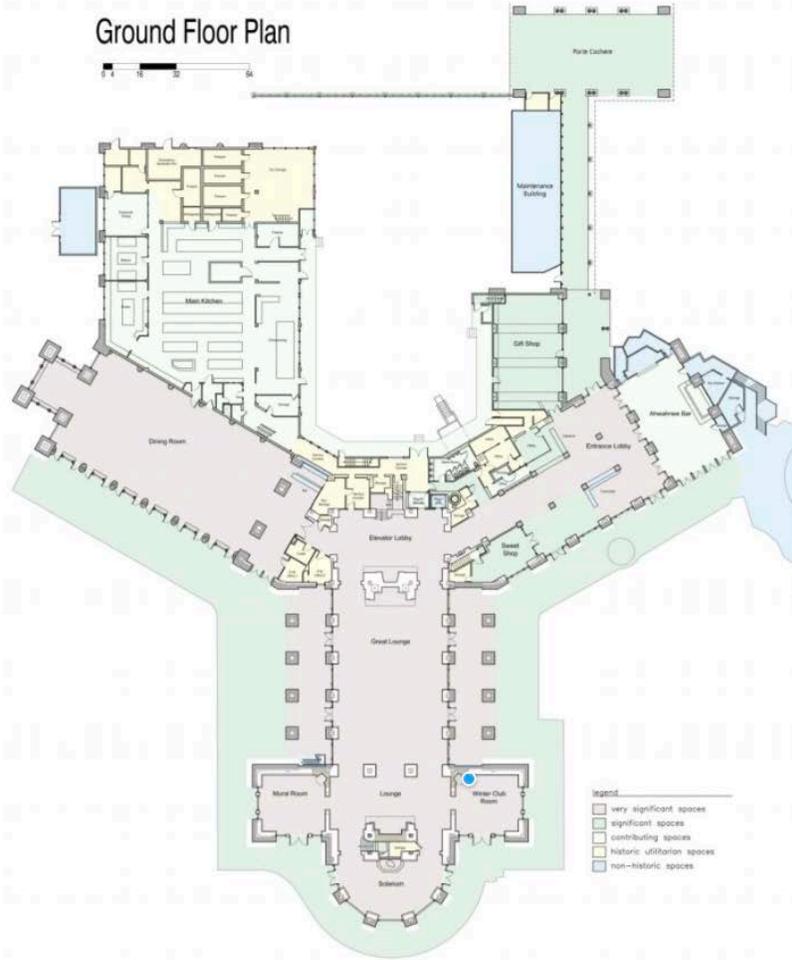


Figure 8 IndoorAtlas mobile application showing current location of user inside the hotel

The IndoorAtlas services are available to developers using a “Freemium” rate, so the initial costs are free, then increase based on the amount of average monthly users. IndoorAtlas services are provided in an SDK, which offers developers easy application integration. IndoorAtlas’s patented technologies provide location accuracies around 2-3 meters, comparable to other high-end IPS systems (IndoorAtlas 2017a). IndoorAtlas provides one of the only geomagnetic positioning systems currently available and was the IPS that produced the most successful prototype while testing in this project.

Since the application is only available on a set number of devices, knowingly using IndoorAtlas’ services under 100 users in the “freemium” model in perpetuity would raise terms of service concerns. IndoorAtlas does offer a flat rate service fee based on specific project needs, but the estimated costs for the service would be around \$100 a month. Although IndoorAtlas provided the most user-friendly experience when implementing an IPS, it does require a data signal of some sort, and therefore could not be guaranteed throughout the tour for guests should the application launch for public devices.

2.2. Existing Tour Applications

The field of interpretation forges connections between the audience and the inherent meanings in the resource (NAI n.d.). Non-personal interpretation fosters the connection between the visitor and the resource using signs or mobile applications, instances where an interpreter is not presenting the message or theme directly. Understanding why protected areas exist through interpretation can reduce negative impacts of tourism and improves visitor enjoyment (Danwadee et al. 2015).

New technologies have made progress in the virtual tour industry, including more technological approaches to deliver information in new and exciting ways. Traditionally,

museum tours may have pointed to objects with signage placed in front as the main communication method. In this setting, the user looks at only text and the actual image or object, with limited engagement and interaction. The communication only flows one direction, and the information presented is limited to the text provided. This section explores tour and virtual tour technology progression using the web and mobile applications.

2.2.1. Virtual Tour Web Applications

In the early 2000s, web application technologies represented a major focus point for virtual tours. Users could connect to the World Wide Web (www) on their personal computers and devices to explore different museums that had this technology available. Visitors could learn about the artifacts and objects in the particular location even though they were not physically present. One web application example is the Virtual Tour of the National Museum of the American Indian (Figure 9).

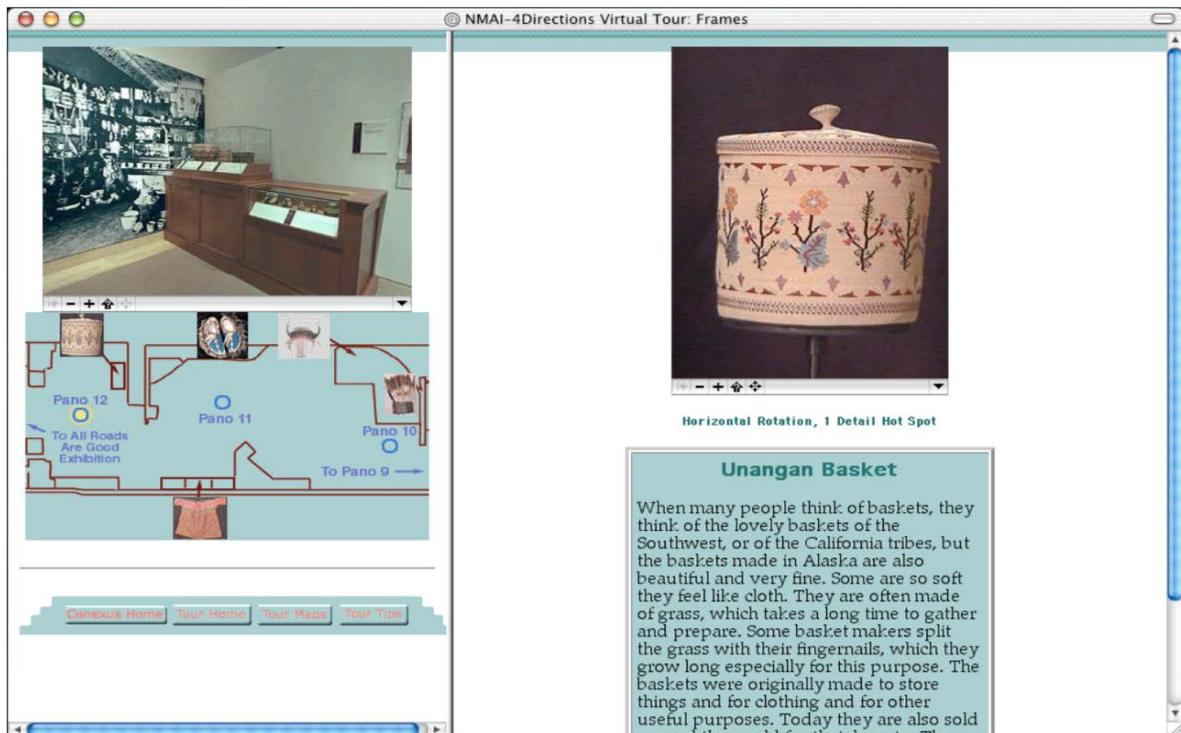


Figure 9 Virtual Tour of the National Museum of the American Indian (Jones and Christal 2002)

The National Museum of the American Indian virtual tour provides an interactive map, object images, and a text description. Created as a collaboration project between the National Museum of the American Indian, the Four Directions project, and the Bureau of Indian Affairs, this tour includes web links to other resources where the “virtual visitors” can learn more about the items in the museum and the Native American cultures represented, without being physically present in the museum.

The MVTA contains several common elements used in the National Museum of the American Indian virtual tour. These include text, photos, and a map of the hotel and grounds, which are all basic components for a tour. Another common element between the MVTA and the National Museum of the American Indian virtual tour is the goal behind it. The Four Directions project and the National Museum of the American Indian shared the desire to offer meaningful learning experiences in museums and schools (NMAI n.d.). These meaningful learning

experiences are similar as to what Yosemite Hospitality wanted to achieve with the desired user experience for the MVTA.

Another early 2000's web-based tour application was developed for the fourteen Smithsonian Museums. Users were not required to be physically present to learn about the 360 artifacts highlighted in the Virtual Smithsonian web application. This tour included high-resolution images, videos, audio clips, and 3D rendered artifacts featured throughout the museums (Jones and Christal 2002). The limitations of having 3D rendered artifacts in a web application required the end user to have a faster internet connection speed. In the early 2000's, a faster internet connection was much more expensive and less accessible to the average consumer. This resulted in end user access issues and did not necessarily provide the best user experience.

In 2013, a more updated web application featuring the Smithsonian National Museum of Natural History was developed and released by Loren Ybarrondo (Smithsonian Institution n.d.). Here, the user can select a virtual tour of past exhibits, virtual tours of permanent exhibits, and other Smithsonian exhibits that may be added in the future. The user has the freedom to access the virtual tour using either a desktop computer or on a mobile device. In addition, using the high-resolution panoramic photos taken for each room can help navigate the user through the virtual exhibit, providing educational information and content anywhere there is an internet connection.

An even more recent update to these virtual tours includes Google Cardboard VR capabilities. Users can download the Google Cardboard VR application plugin to view the Smithsonian presentation in VR (SNMNH n.d.). To navigate from room to room, the user focuses on the navigation arrows within the application. The user can also zoom in and out, as

well as move around the scene, regardless of where they are. This is a potential direction that the MVTA could eventually reach using similar VR technologies.

One example of a place-based web application is the National Central University Tour Guide system (Tseng et al. 2001). Researchers at the National Central University in Taiwan prototyped a location-aware and context-aware tour guide system. The prototype included a 2D map, showing the current position of the user, a 3D virtual world where users can track their movements and find different POIs, and a web feature that provided additional information through a web browser (Tseng et al. 2001). This system has both an educational feature and an IO- location feature. These represent two major components of this project. Figure 10 displays the National Central University tour interface.



Figure 10 Integrated interface of National Central University tour guide system (Tseng et al. 2001)

Tour participants used a laptop that was connected to a GPS receiver to determine the current location. Participants were also able to communicate with other users (Tseng et al. 2001). An advantage of this type of system is that the system is location-aware and context-aware, meaning if the user is inside or outside, it can determine location based on either the GPS signal for outdoor use and indoor based on contextual information (Tseng et al. 2001). This type of system can provide users with directions and information on how to get to specific locations and information about each area.

2.2.2. Mobile Tour Applications

Mobile capabilities and technologies have proven to be more capable than ever before. Mobile application utility and pervasiveness continues to increase as more services become available (New Media Consortium 2012). Recent mobile application tours provide users with navigation, IPS integration, and LBSs indoors. These technologies increase place-based interaction with the resource or objects of interest in places such as universities, museums, hospitals, and conferences. The flexibility and utility of a mobile tour application using IPS services gave Yosemite Hospitality different options to achieve the desired user experience, which was a major driving factor for this mobile application. This section explores virtual tour mobile applications, including those available in National Parks.

An example of an IPS project includes the one used by the Smithsonian museum and National Zoo located in Washington D.C. A collaborative project with Google, the Smithsonian mapped out over 2.7 million square feet for indoor navigation purposes (Smithsonian 2012). The IPS was built right into Google Maps for Android and allowed users to navigate to specific exhibits at the museum and National Zoo. An advantage of building an application right into Google Maps is that it is more widely available and accessible for users. Users do not have to

download any additional applications or plugins to use it, and can directly access the content based on their location.

2.2.2.1. Mobile Interpretive Tour Applications in National Parks

The National Park Service works with partners, universities, non-profits, and third-party developers to develop mobile applications for several national parks. The MVTA was developed to educate park visitors about the hotel. According to the National Park Service, most of the apps previously developed have focused less on education and interpretation aspects, and more on directions and planning (National Park Service n.d.b). Blaser (2015) looked at several mobile interpretive applications that varied in geographic area, content, capabilities, and level of engagement. The Chesapeake Explorer Application provides a basic informational mobile application but does not provide any map services. It offers textual directions to the sites and visitor fee information.

The National Park Service National Mall and Memorial Parks application are more similar to a virtual tour. It provides self-guided trail capabilities and audio tour services for park visitors, as well as Google Maps integration and web integration where users can learn about each of the 70 cultural sites through an interactive map (Blaser 2015). National Park Service Independence National Historical Park also includes self-guided tours, program information, and general site information. The “Park Lens” feature uses AR services and a mobile device’s camera to find out what is around the user (National Park Service n.d.c). This includes labels of buildings, memorials, and other POIs at the National Park Service National Mall and Memorial Parks.

The Boston National Historic Park and Boston African American National Historic Site has a joint mobile application that visitors can download ahead of time to learn about the “Trails

to Freedom” (iTunes 2017). In addition to providing map and location services, the application comes equipped with navigation features, audio tours about different POIs, and a general overview of the area (National Park Service n.d.d).

There are currently a few available applications for Yosemite National Park. Many focus on the climbing community and mapping over 2,000 of the routes in the park. A lot of these applications are developed by third-party creators, and those entities are explicitly stated in the respective app stores. The National Park Service Yosemite application provides simple information about the park, focusing on the amenities, including the Majestic Yosemite Hotel. Table 2 lists the currently active mobile applications relevant to the National Parks.

Table 2 Mobile Interpretive Applications in National Parks (Blaser 2015)

Application	Description
Chesapeake Explorer	Contains directions for finding park entrances, fees, and program information for over 400 National Park Service sites in the Chesapeake region.
National Park Service National Mall and Memorial Parks	Contains map tours, site information, and the ability to create digital postcards that visitors can customize while on their trip. Application covers over 70 cultural sites and provides interpretive information for each.
National Park Service Independence National Historical Park	Provides a park map, interpretive information about the site, current events and program information, and self-guided tours.
National Park Service Yosemite	Features 50 landmarks in the park and amenity information. Park programs and event schedules can also be found.

2.2.2.2. Yosemite Hospitality and Aramark Applications

There are currently no other applications owned and operated by Yosemite Hospitality. Yosemite Hospitality is a subsidiary of Aramark. Aramark owns a few applications in the hospitality business. The CampusDish mobile application allows college students to look up

nutritional information for food choices on their respective campuses (Food-Management 2012). Aramark also partnered with Major League Baseball to provide food delivery service directly to your seat at MLB games (MLB 2010). The MVTA is a first of its kind application for Yosemite Hospitality, creating an engaging and educational mobile application for one of its biggest assets.

2.3. Indoor Modeling Techniques

There are several Mobile scanning technologies that are currently available and were considered for this project. The more expensive mobile mapping units generally provided a faster scanning and customizable output formats compared to cheaper solutions, but some units can cost as much as \$15,000 USD (Viametris n.d.; Applanix 2015; Geoslam n.d.). Rental services are available for some units and can help reduce the cost to the client.

The lower cost Structure Sensor unit used in this project required more upfront scanning time but processing time was reduced by their paid “Scan to CAD” service (Structure sensor n.d.). This service converted the point-cloud scans to a CAD file. The goal with mobile mapping and scanning for this project was to incorporate newer spatial technologies for the indoor area to preserve the architecture and furniture in the hotel. Many of these units allow for easy GIS integration and spatial modeling and would meet this project’s requirements, but costs and resources heavily influenced the decision to go with a cheaper scanning unit.

Several high powered mobile scanning units are offered by Viametris, GeoSlam, and Trimble. Although there are many others, these units all offer customization, user-friendly framework, and high-level of accuracy (Viametris n.d.; Applanix 2015; GeoSlam n.d.). Viametris is a continuous indoor mobile mapping scanner and includes full building environments including furniture. This unit can be used in the outdoor capacity to scan exterior building conditions, and produces average accuracies of ± 30 mm (Viametris n.d.).

Geoslam is a 100Hz handheld mobile laser scanner with a simple interface and operating system (Geoslam n.d.). This scanning solution is time-efficient, it takes roughly 30 minutes to scan a 3-story building, and an accuracy of around 15mm (Geoslam n.d.). Geoslam offers the high accuracy and efficiency desired for this project, but the costs for the unit exceeded the budget for this project and were not used.

The Trimble Indoor Mobile Mapping System (TIMMS) by Applanix can produce highly accurate scans and models. Several case studies documented their accuracies, processing time, and results. One case study reported over 1.8 million square feet of the Los Angeles International Airport (LAX) in under 30 hours (Applanix 2015). In comparison, a traditional LiDAR method would have taken over 3 weeks to complete the same amount of space (Applanix 2015). All interior components were included in the model, and the post-processing time took around 100 hours for this project (Applanix 2015).

Another case study featuring TIMMS was coordinated with the mapping and survey company Pictometry. The Pictometry project merged both aerial and indoor georeferenced data to create Critical360, a technology used for querying building resources and structural details (Applanix 2016). This type of unit was the preferred method for Pictometry because of the time it took to scan 91 separate buildings and the level of accuracy the unit produced.

Since the project's scope focused only on the first floor of the hotel due to time constraints and money, a more realistic and hands-on approach was used to complete the indoor model of the hotel. The Structure Sensor built by Occipital is an iPad attachment for scanning and measuring environments (O'Kane 2016). Each room was scanned individually and uploaded to the "Scan to CAD" feature in the Canvas.io mobile application. This scanning technique reduced processing time and overall costs to the client and produced the desired CAD files.

The Canvas iOS application with the Structure Sensor allows digitization for any room instantly, including measurements of the scanned space. This modeling technology is cost effective at \$399, besides the cost of the iPad. The Structure Sensor also works for Skanect, a scanning environment and software used to create 3D printed objects and rooms. This system offered the necessary means to scan and produce the furniture models for this project.

Chapter 3 Methods

This project compared four different approaches to deliver educational content for MVTA users to determine the technology best suited to fulfill the client's project requirements. Each methodology was chosen based on customer review and product functionality capabilities. This chapter explains the rationale for each approach and the chosen methodology based on Yosemite Hospitality's needs. The initial approach to complete this project was based on testing two separate IPSs for the indoor and outdoor spaces, one based on Wi-Fi provided by Anyplace, and the second based on IndoorAtlas. The second approach to this project relied on the BlueCats beacon and SDK services, which can deliver content based on proximity to the beacons. A third approach tested for this project focused on the use of object recognition and beacons in Unity. This methodology resulted in a shift from Android to iOS platform development, based on the client's requirements. The fourth methodology tested, and the most basic approach deployed Unity without any additional software or infrastructure and provides services for both iOS and Android devices. Long term maintenance, user-friendly application architecture, and costs to the client ultimately decided the direction that was chosen for this project. This chapter provides an outline to technologies that were ultimately used.

3.1. Choosing an Appropriate Indoor Positioning System Technology

Cost, time for implementation, accuracy, and long-term maintenance were determining factors when selecting the appropriate IPS for this project. Chapter 2 explored different types of IPSs. As previously stated, two low-cost IPSs that were tested as part of this project were Anyplace and IndoorAtlas.

3.1.1. Cost Analysis

When looking at different factors that influence cost, infrastructure stood out as one determining factor. Using an already in-place infrastructure such as a Wireless system is one cost-effective approach for an IPS (Ott et al. 2011). Microsoft Radar, Horus, DIT, Ekahau, and WhereNet are wireless IPSs with lower cost infrastructure (Liu et al. 2007; Georgiou et al. 2015). The differences between these systems occur with the algorithms, and each has a different price point based on the particular technologies used. Under normal circumstances, the availability of a wireless IPS is higher because it is a common technology. However, there is limited internet access only available for Majestic Yosemite Hotel guests, and an additional installation of a wireless system dedicated to this project application was not in the budget. It was also determined that all of the application information would be stored locally on the device since dedicated wireless access would not be available for the tablets.

Another low-cost system that was analyzed for this project was IndoorAtlas. IndoorAtlas provides a “freemium” service based on the monthly active users (MAUs). IPS services would be available through IndoorAtlas’s Android and iOS SDKs. Initial tests do not require any commitment up front which allowed for the service to be tested during this project. No financial loss was suffered to the client during the testing of these IPS systems.

3.1.2. Time for Implementation

The initial start-up time for IPS implementation in a native application heavily favored IndoorAtlas. Anyplace required the building to be “added” to a Google Map, and once the floorplans were uploaded and resized, an indoor model was required for the POI components that could be exported to JSON format. IndoorAtlas had a similar web API where floorplans were uploaded, but this required the developer to go immediately into the physical space using

IndoorAtlas' MapCreator application and collect measurement points for the geomagnetic readings. The collection of these geomagnetic signals instantly gave the user a location on a map. These readings were also available through the IndoorAtlas Cloud server, and the locations could be added into a native app in either Google Maps for Android or Apple's MapKit for iOS.

With regards to Anyplace, several factors prevented it from working in a native application. Android source code was readily available through the Anyplace application and was originally considered for use as a guidance tool for implementation of the project as a native Android application (Anyplace Github 2017a). At the time of this writing, it was also possible to develop an Anyplace implementation as a native iOS application.

3.1.3. Long-Term Maintenance

Another key factor for this project was to have a system with ease of long-term maintenance capabilities. Anyplace uses an algorithm to identify data outliers from crowdsourced heat maps and removes them to maintain accurate positions. In this case, the user is responsible for maintaining accurate indoor positioning since it is crowdsourced data. Compared to IndoorAtlas, Anyplace did not offer sufficient guides or technical support for implementing and maintaining the services. When updates were implemented for Anyplace, maintenance went well-beyond a single update to an SDK, but rather required an update to each of the Anyplace Server, Anyplace Architect, Anyplace Viewer, NoSQL data store, Logger/Navigator, and the model.

IndoorAtlas uses updates in the SDK to reduce overall updates to application code if the errors or updates occur on the server side. If positioning needs to be corrected, a quality report can be generated on the IndoorAtlas website where it outlines several reasons for inaccurate information (Peltola 2015). These quality reports let the client know where the problem areas

are. If there is a need to go back into the field to collect data, the report can be automatically updated using the IndoorAtlas application and uploaded directly to the cloud service (Figure 11).

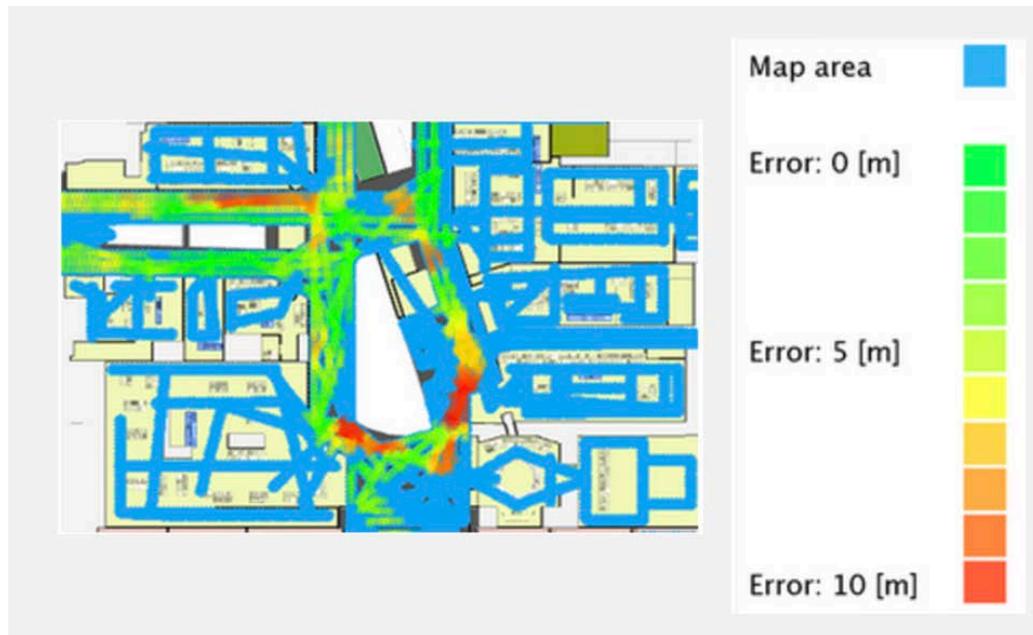


Figure 11 Quality report from IndoorAtlas guide (Peltola 2015)

Table 3 lists several reasons why the errors may have occurred in the IndoorAtlas mapping service. The table also provides solutions to fixing the different types of errors. Other errors can occur caused by uneven walking speed and misplacement of landmarks (Petola 2015). Nevertheless, the solutions for long-term maintenance, consistent server updates on both the cloud and SDK side, and overall technical support and guides initially heavily favored IndoorAtlas for use in this project.

Table 3 Possible mapping errors in IndoorAtlas (Peltola 2015)

Problem	Way to fix
Lack of nearby test paths: red/blue	Record a test path through the affected area
Lack of nearby mapping paths: “hole” in the coverage	Record a mapping path through the affected area
Problem in recorded test path data: red through the test path	Delete the affected test path and re-record the test path
Problem in recorded mapping data: red through the test path	Delete the mapping path passing the area and re-map
Problem persists after remapping	You may have a problem with the mapping device. Check that your device meets the mapping device requirements, reboot the device to make sure any sensor errors are cleared

3.2. Testing the Indoor Positioning System Methodology

Since both services provided no up-front costs and long-term maintenance solutions, both were considered for use in the final MVTA. A digital indoor model was created using Floorplanner as both a model and a map within the application (Figure 12) (Floorplanner n.d.). This map was overlaid on both the Anyplace API and IndoorAtlas’s API. Specifically, the model was created to define the spatial scale and extent of the hotel’s immediate grounds.



Figure 12 3D Floorplanner model of the Majestic Yosemite Hotel and immediate outside grounds

Floorplanner was used to develop one of the 3D models of the hotel. The 2D version of the model was used as a Floorplan and map in the final version of the MVTA. An overlay feature was used in Floorplanner to maintain an accurate scale from historical maps provided by the maintenance staff at the Majestic Yosemite Hotel (Figure 13). During the course of the thesis, construction on a set of stairs on the Northeastern side of the bar was completed, and the floorplan needed to be updated to include the area highlighted in Figure 13.

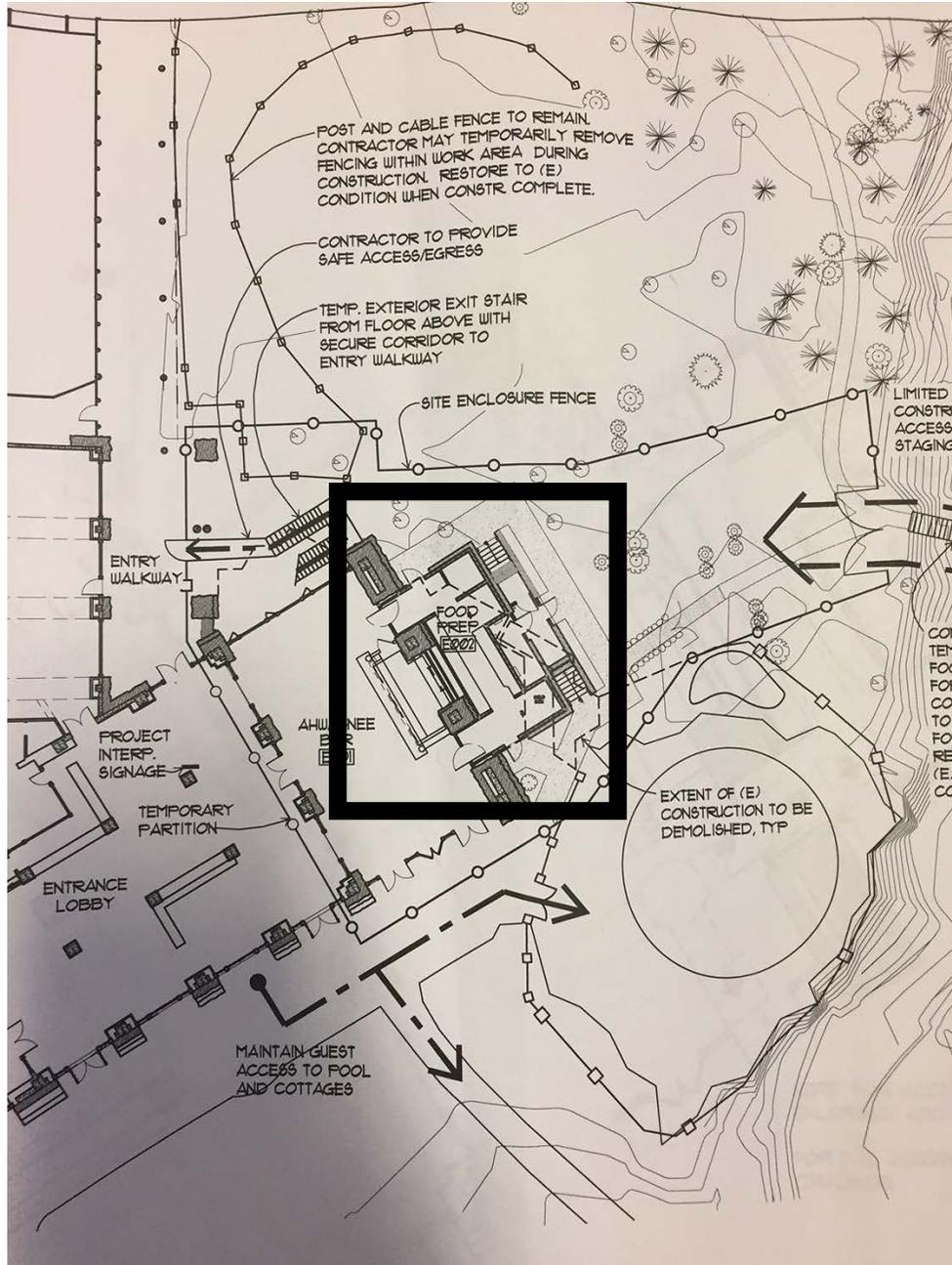


Figure 13 Update to back side of the bar area in 2017 (Ahwahnee Rehab Plan Component 2014)

The tour of the Majestic Yosemite Hotel takes place on the first floor, in addition to the hotel's immediate grounds because these locations are where the relics and artifacts are kept. It was important to have the "Architecture" POI on the hotel's back lawn because it was originally going to be the front of the hotel (Sargent 1990). Floors two, three, four, five, and six have only

guest rooms and as previously mentioned were not a focus of this project. The methodology supported the capability of producing an indoor model for the entire hotel but was not necessary because of the application's tour objective for the first floor only.

3.2.1. Anyplace

Anyplace Architect was the first tool tested to develop the Majestic Yosemite Hotel's indoor model including the location of wireless routers and location of POIs. Anyplace Architect uses a Gmail associated email account to store building information data on the Anyplace Cloud Storage. This allows the developer to access, modify, edit, or delete building data created in Anyplace Architect. The user can also set buildings to private mode so only specific individuals can have access to its contents, floorplans, and POIs.

Developers search for a building in the search bar where they want to "add" a building. When an app developer "adds" a building, an icon appears where the user inputs specific information such as the building's name, and the user marks on the map the building's position on Earth. Once the building is added to the map, building information such as floorplans can be uploaded to the Anyplace Architect server (Figure 14). Figure 14 shows the floorplan as an image accurately georeferenced and scaled to the map interface integrated into the Anyplace Architect API.

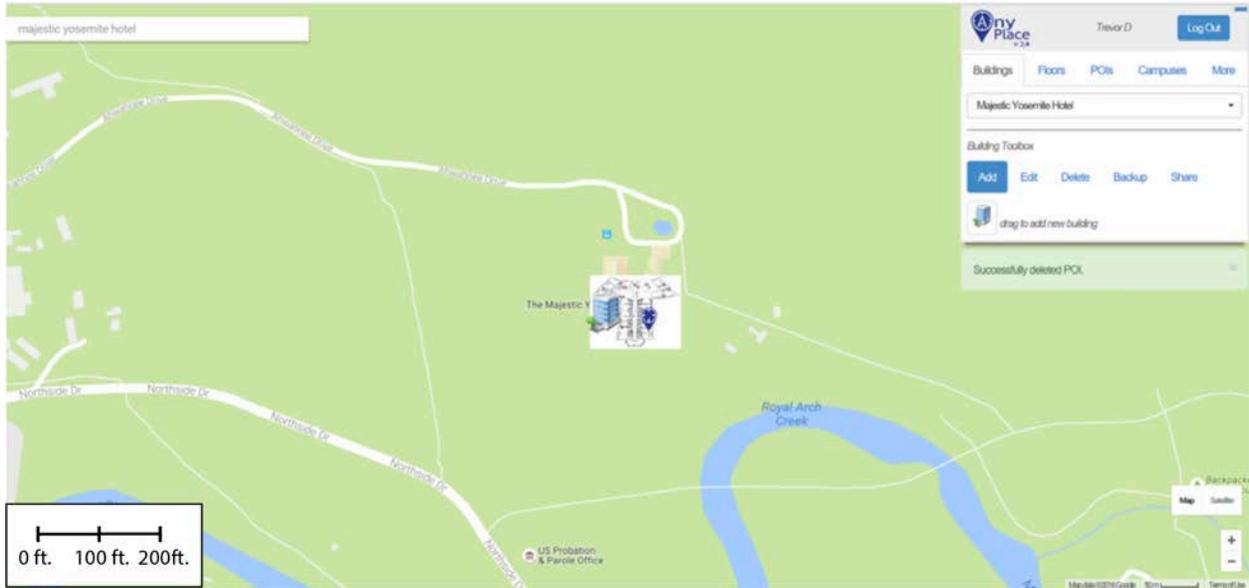


Figure 14 Anyplace Architect screenshot adding a building to Google Maps

3.2.1.1. POIs Toolbox

The POI toolbox in Anyplace Architect consisted of adding a POI, adding a new connector for navigation purposes, and toggling the edge mode. The “Add POI” tool allowed the user to click and drag a POI icon to a specific location within the hotel. The “Add Connector” tool was used for adding connection points for POT. The toggling edge tool created links between connection points and POIs.

The add POI feature in Anyplace Architect allowed the user to define the location of each POI within the hotel, the name of the object, and a small description. Each POI was selected based on its historical or cultural significance, if it was protected in a display case, or if it offered a good view of a particular design feature. The majority of the POIs were rugs, hand-woven baskets, murals, stained-glass windows, desks, old winter apparel, and notable architectural designs of the hotel. The type of POI was also noted in the description.

Anyplace Architect has many different types of POIs that can be added to the map, depending on the type of building and its contents. Predetermined types of POIs provided by Anyplace were categorized into Disabled Toilets, Elevator, Entrance, First Aid, Office, Ramp, Room, Stair, Telephone, and Toilets. Each POI added for the MVTA based on the educational significance was categorized into a POI type, and were confirmed by ground truthing.

The Add Connector tool in the POI toolbox was used for creating connection points of travel. These connection points were strategically placed to avoid furniture, pianos, and other obstacles within the hotel. Occasionally, the furniture is moved for events such as the Chef's holiday and weddings, so navigation was ultimately excluded in MVTA. The add connector tool was complemented with the toggle edge mode tool.

The toggle edge mode provided the direct route between the connection points and the POIs in the hotel. When a user selects a POI in the mobile application, the route is automatically generated using the created toggle edge lines. The toggle edge mode was also used to connect to different floors within the hotel through stair cases or elevators.

3.2.1.2. Anyplace Logger

The Anyplace mobile application that is available on Apple's App store and Google Play store has Anyplace Logger built in. Anyplace Logger was downloaded and installed on a Nexus 5 Tablet to record the positioning and readings around each room on the hotel's grounds. The readings were based off a "heading" signal, similar to an x, y coordinate system, and represented a calculated location in the hotel. The boundary of each room was "traced" using Anyplace Logger, and each reading was collected and stored on the Anyplace Cloud server. Once all the rooms were recorded, a database was created to store the locations of the wireless routers.

The database was stored on the Anyplace Cloud server for the locations of POIs, routers, and navigation routes. This, coupled with Couchbase SQL, allowed for fast POI information retrieval. The Anyplace Cloud service stores much of the backend information for retrieval. At this point in time during testing, only nine POIs were approved for their educational content and were included during testing phase.

3.2.2. *IndoorAtlas and BlueCats Beacon Services*

IndoorAtlas was the second IPS tested in this thesis project. During this testing phase, a large-scale shift in programming from Android to iOS development occurred due to client requirements based on device reliability. The programming shift used Swift 3.0 and XCode 8 to program the application from scratch for IndoorAtlas. Beacon integration was also tested during this phase of the project. A beacon was purchased for the original nine POIs to calibrate and help correct positioning in the IndoorAtlas IPS. Additional beacons were purchased for the thirty POIs in the final version of the MVTA as the educational content was approved. The beacon integration capabilities were heavily favored by Yosemite Hospitality for improved accuracy.

3.2.2.1. Creating the Mapping Area on IndoorAtlas API

The first step for using IndoorAtlas was to create an account on their website. Using their web API, a location was created for the Majestic Yosemite Hotel in Yosemite National Park (Figure 15). In Figure 15, the building is shown as a green polygon and marked with a classic Google marker. A floorplan was uploaded and scaled to overlay on to the Google Maps tool on the web API. Once the map was uploaded to the API, the mobile map tool was used to record the geomagnetic signals used for determining on-site location.

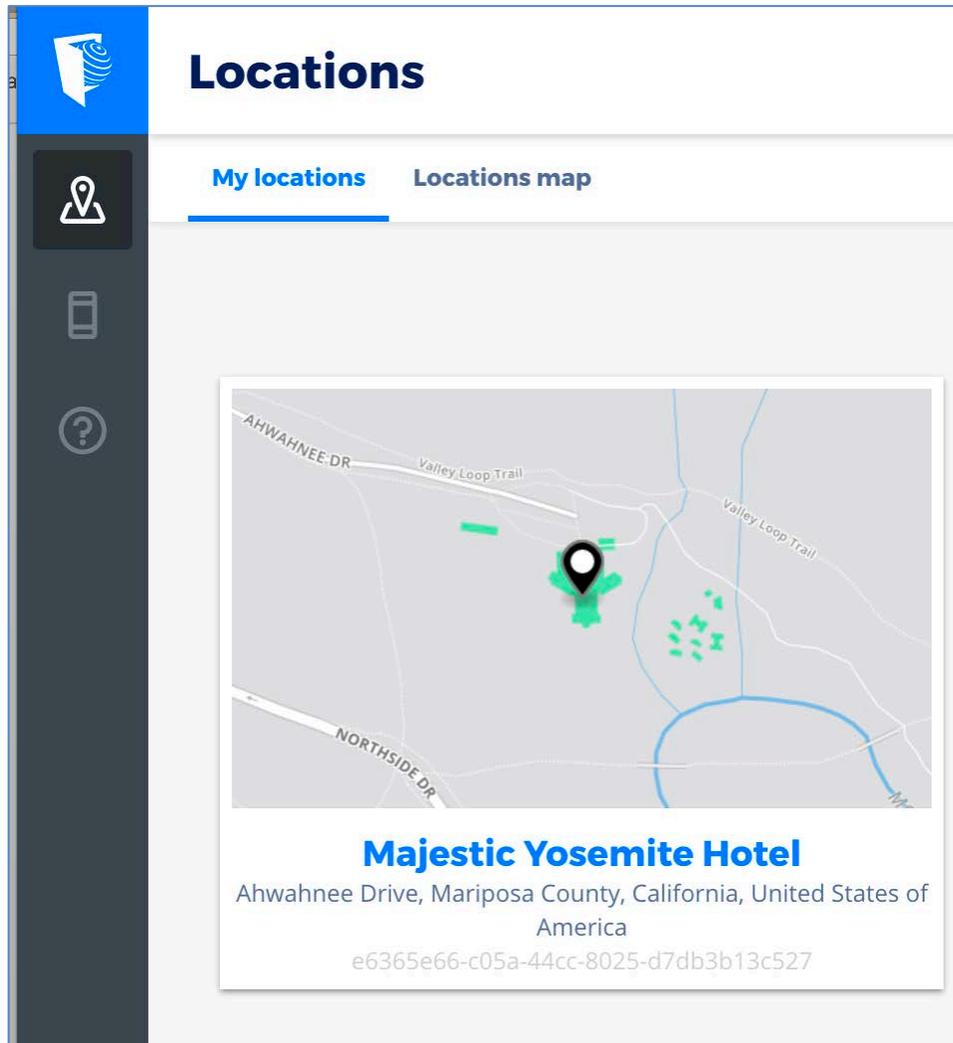


Figure 15 Example of creating a location using the IndoorAtlas web API

3.2.2.2. Recording Geomagnetic Signals

For best practices, the “Mapping Quick Start Guide with MapCreator2” was consulted to map the first floor of the Majestic Yosemite Hotel. Once the MapCreator2 Application was installed on an iPhone 6, the device was calibrated by moving the device in all directions and orientations to set the magnetometer, accelerometer, and gyroscope sensors in the device. It was noted in the Quick Start Guide that some Samsung Devices have sensor filtering and may impact

mapping, so the original Samsung tablet purchased for testing phases in the project was not used (IndoorAtlas 2017b).

The first floor of the hotel was mapped over the course of several days between 11 P.M. and 2 A.M. to avoid disturbing the guests inside the hotel. Once the first-floor map was complete, the hotel's immediate grounds were recorded, focusing mainly on the hotel's back lawn and near the entrance to the hotel. Figure 16 shows the two different types of paths that were recorded during the mapping phase, the test paths and the mapped paths. The test paths provide a summary analysis in the map's quality report (Peltola 2015). The mapped paths feature is the final output for the geomagnetic recording that is used to generate locations in the app.

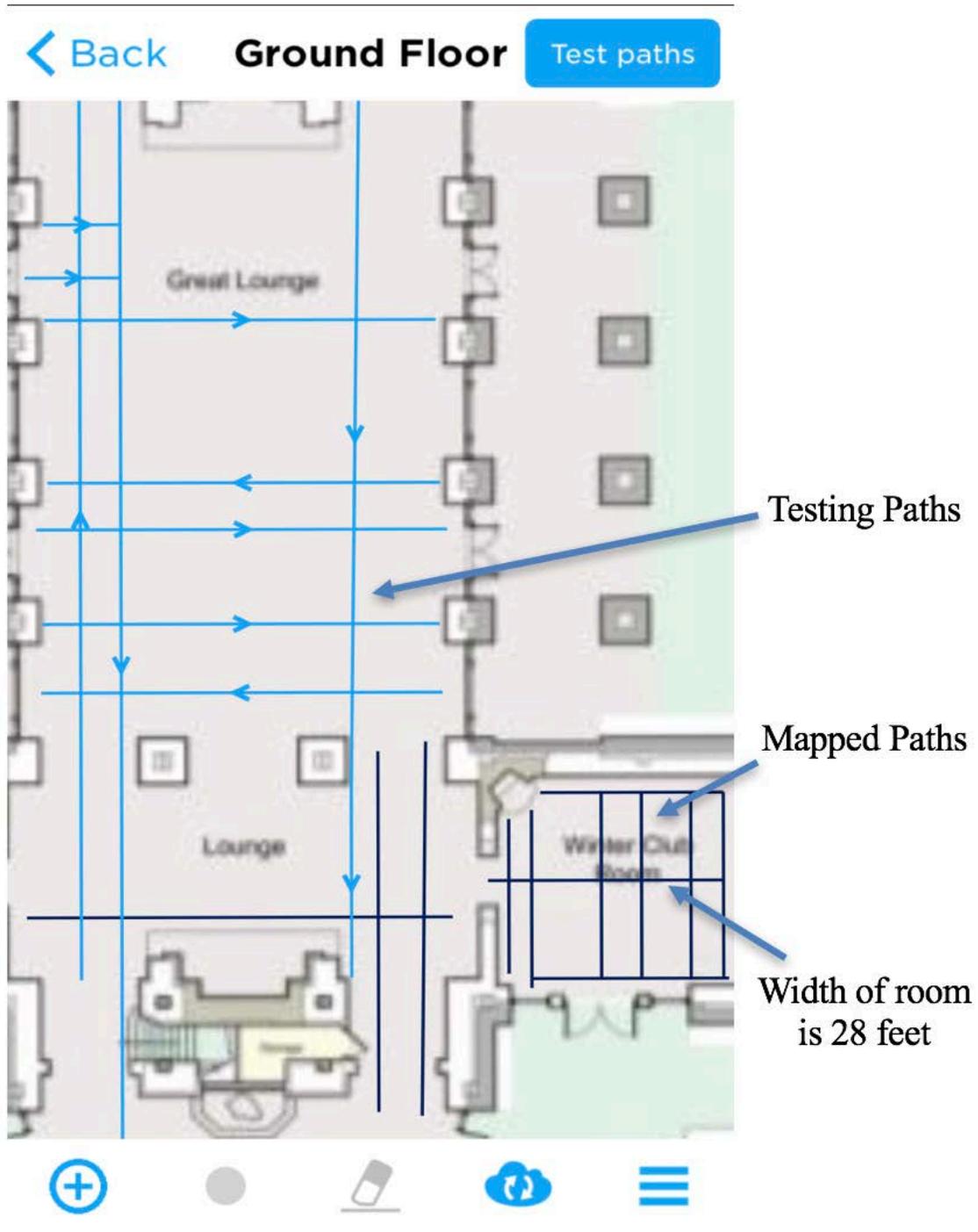


Figure 16 Zoomed in location of mapped paths (dark blue lines) and testing paths (light blue) in IndoorAtlas MapCreator

3.2.2.3. Generating and Saving the Map

The map was saved when all the recordings were completed and uploaded to the cloud server. Immediate indoor positioning testing began using the IndoorAtlas Service. The map data was managed on the IndoorAtlas web API once the map was generated on the MapCreator mobile application.

3.2.2.4. XCode and MVTA Structure

The structure of iOS applications relies on the Model-View-Controller. The model represents what the application is, the controller is how the model is presented, and the view is what sends the action when things happen in the UI (Hegarty 2017). In XCode 8, the design for the application can be either done in the Main.Storyboard (Figure 17) or programmatically in each individual class or Cocoatouch file that makes up the app.

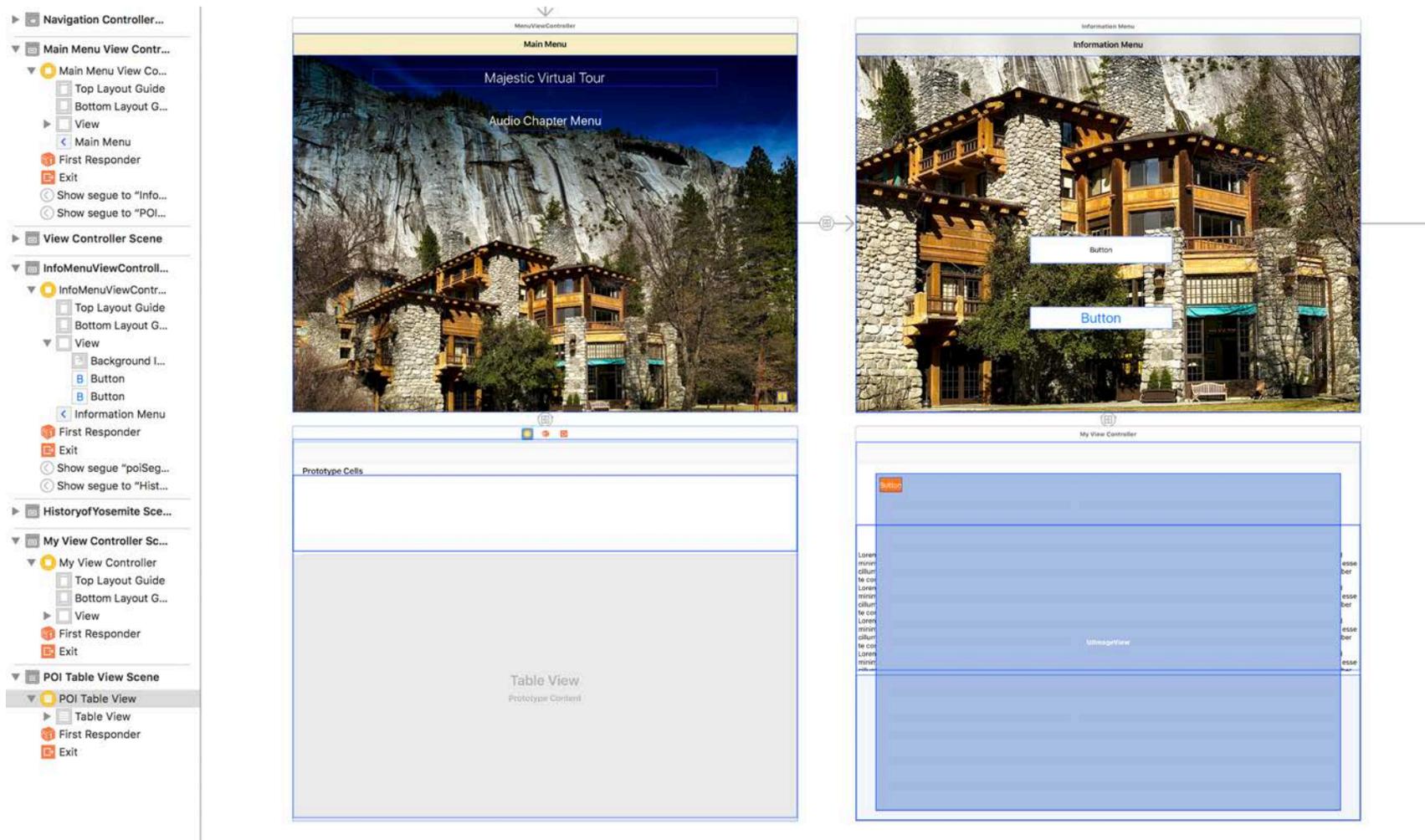


Figure 17 Portion of the Main.Storyboard for the IndoorAtlas version of MVTA

The screenshot (Figure 17) shows several of the View Controllers used in this testing phase for the MVTA. When the user selects a button, the segue transitions to another View Controller based on the user's input. The bottom left view controller is a table view controller which houses the list of POIs that the user can access the information without having to move around the hotel. This was a requirement of the project to create a backup methodology should the positioning service no longer work, and to provide accessibility to users who may not be able to walk or navigate through the hotel (National Park Service 2017b).

The top right ViewController shows two separate buttons, one of which that segues into the bottom right View Controller. This view controller is called the POIViewController and was the most important one in the project because depending on the user's location; an array was used to identify which zone, and later which beacon was closest in proximity to the user (Figure 18). The "struct" model was created in Swift and was used to rotate through the text, images, and descriptions used in each POI based on where they were. All thirty POIs were included in the struct and were assigned a reference id in the form of a beacon String value.

```

2
3 struct POIModel {
4
5     let name: String
6     let images: [String]
7     let description: String
8     let beaconID: String
9
10    // have an array here of all the pois
11
12
13    static func all() -> [POIModel] {
14        return [
15            POIModel(name: "National Historic Landmark", images:
16                ["bareentrance","image2"], description: "This building became a National
17                Historic Landmark on May 28, 1987. Its rustic architecture along with the
18                role it played in interpreting the heritage of our National Parks made it
19                a historic icon. From the moment the cornerstone was laid on August 1,
20                1926 to opening day on July 14, 1927 and on, this building has fostered a
21                rich and provocative history. This virtual tour will open your eyes to
22                the architectural design, interior design elements, history and quirky
23                stories behind this phenomenal building.", beaconID: "0123"),
24            POIModel(name: "Cornerstone", images: ["cornerstone"], description: "Stephen
25                Tyng Mather, the first Director of the National Park Service, once
26                stated, "Scenery is a hollow enjoyment to the tourist who sets out in the
27                morning after an indigestible breakfast and a fitful night's sleep on an
28                impossible bed." From that the idea for a luxury hotel in Yosemite
29                National Park was born.An architect was selected in July of 1925 and
30                plans for the hotel quickly started to take shape. From the start the

```

Figure 18 POIModel used in IndoorAtlas testing phase

Additional beacons were purchased for each individual POI for this project to deliver content based on proximity to each POI. These beacons were provided by BlueCats and were mentioned in Chapter 2. An update to the BlueCats web API required remapping beacon locations if an object needed to be moved (Figure 19). The peach colored dots shown in Figure 19 represent the POI locations, and the white dots represent the locations of the beacons. Once all the beacons were purchased, a beacon table was created using Serial Numbers and POI location. These were used to monitor and manage each individual beacon, and make sure they were placed in the correct location.

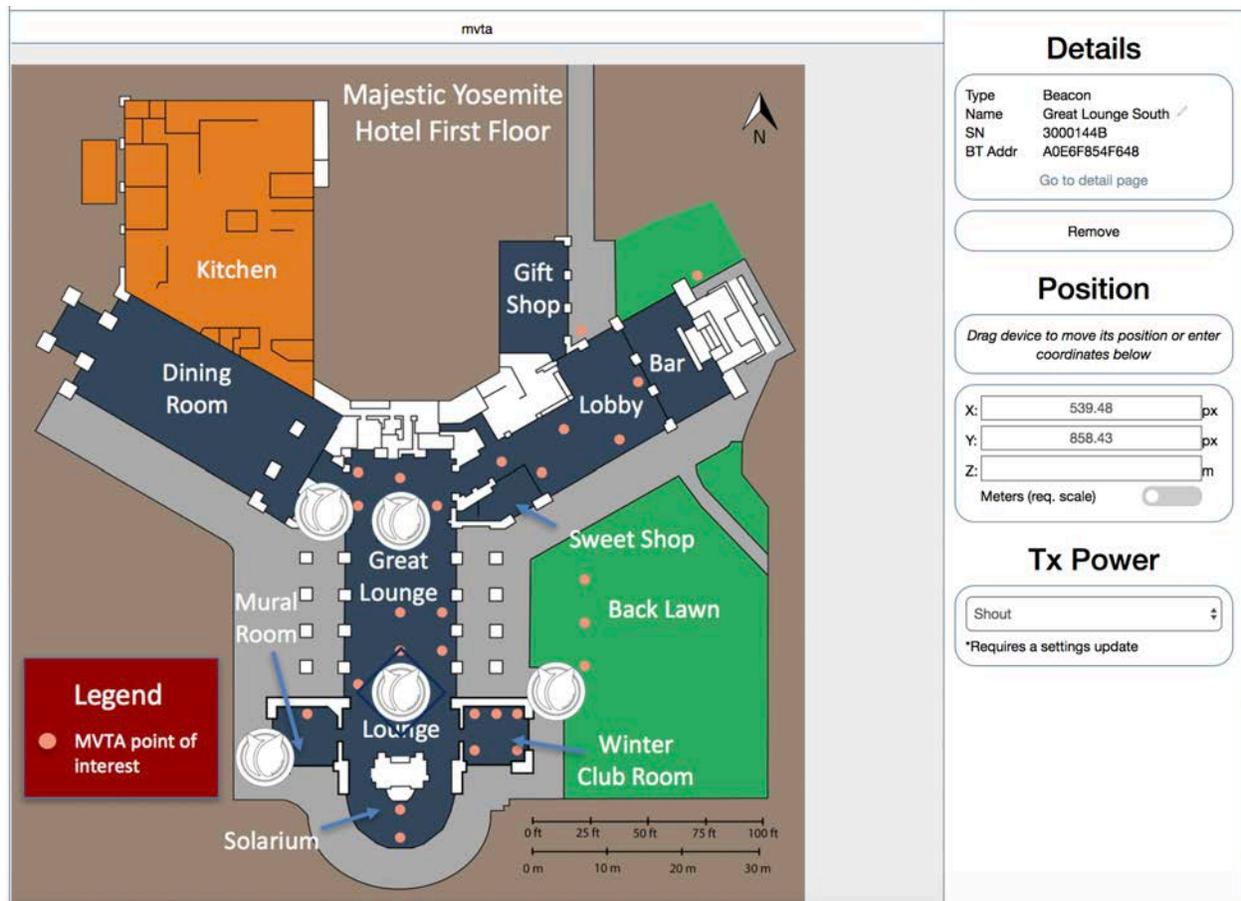


Figure 19 BlueCats web API used for mapping individual beacons and scaling

3.2.2.5. Adding the IndoorAtlas and BlueCats SDK to an XCode Project

Cocoapods was used to install both the IndoorAtlas SDK and the BlueCats SDK (Cocoapods n.d.). This was the preferred method to install the SDKs because of its user-friendly update methods and the ability to control the project files from a terminal program. Cocoapods was installed using iTerm, and the directory was changed to the local file of the MVTA application. A podfile was created and both SDKs were installed (Figure 20).

```

Last login: Thu Aug 17 10:37:53 on console
Trevors-MacBook-Pro:~ trevordenson$ cd /Desktop/
-bash: cd: /Desktop/: No such file or directory
Trevors-MacBook-Pro:~ trevordenson$ cd Desktop
Trevors-MacBook-Pro:Desktop trevordenson$ cd MVTATests
Trevors-MacBook-Pro:MVTATests trevordenson$ touch pod
Trevors-MacBook-Pro:MVTATests trevordenson$ pod install
[!] No 'Podfile' found in the project directory.
Trevors-MacBook-Pro:MVTATests trevordenson$ pod install
Analyzing dependencies
Pre-downloading: `BlueCatsSDK` from `https://github.com/bluecats/bluecats-ios-sdk.git`
Downloading dependencies
Installing BlueCatsSDK (2.0.2)
Generating Pods project
Integrating client project

[!] Please close any current Xcode sessions and use `MVTATests.xcworkspace` for this project from
now on.
Sending stats
Pod installation complete! There is 1 dependency from the Podfile and 1 total pod installed.

[!] Smart quotes were detected and ignored in your Podfile. To avoid issues in the future, you sh
ould not use TextEdit for editing it. If you are not using TextEdit, you should turn off smart q
otes in your editor of choice.
Trevors-MacBook-Pro:MVTATests trevordenson$ █

```

Figure 20 Cocoapods installation of BlueCats SDK

The podfile created was directed to the source files for both the SDKs for installation on their respective Github pages. This established the connection required to access the IndoorAtlas web API and the BlueCats web API services in the MVTATests application. In June 2017, an additional Geofence Beta API was released to trigger callbacks based on entering or exiting the geofenced borders (IndoorAtlas 2017c). The SDK could also be installed to the MVTATests project workspace using the Cocoapods dependency manager.

The podfile created an .xcworkspace file and was used from that moment on instead of the original .xcodeproj created (Figure 21). Since the application testing was done using Swift, a bridging header between the BlueCats Objective C files and the Swift files needed to be created

in order to access the BlueCats beacons. To test the interaction between the application and the beacons, a print statement was used for beacons that were in the range of the iPhone 6 device used during testing. Successful interaction confirmed that the BlueCats beacons were working in the application, then the struct file used was set up in the MapViewController.swift file.

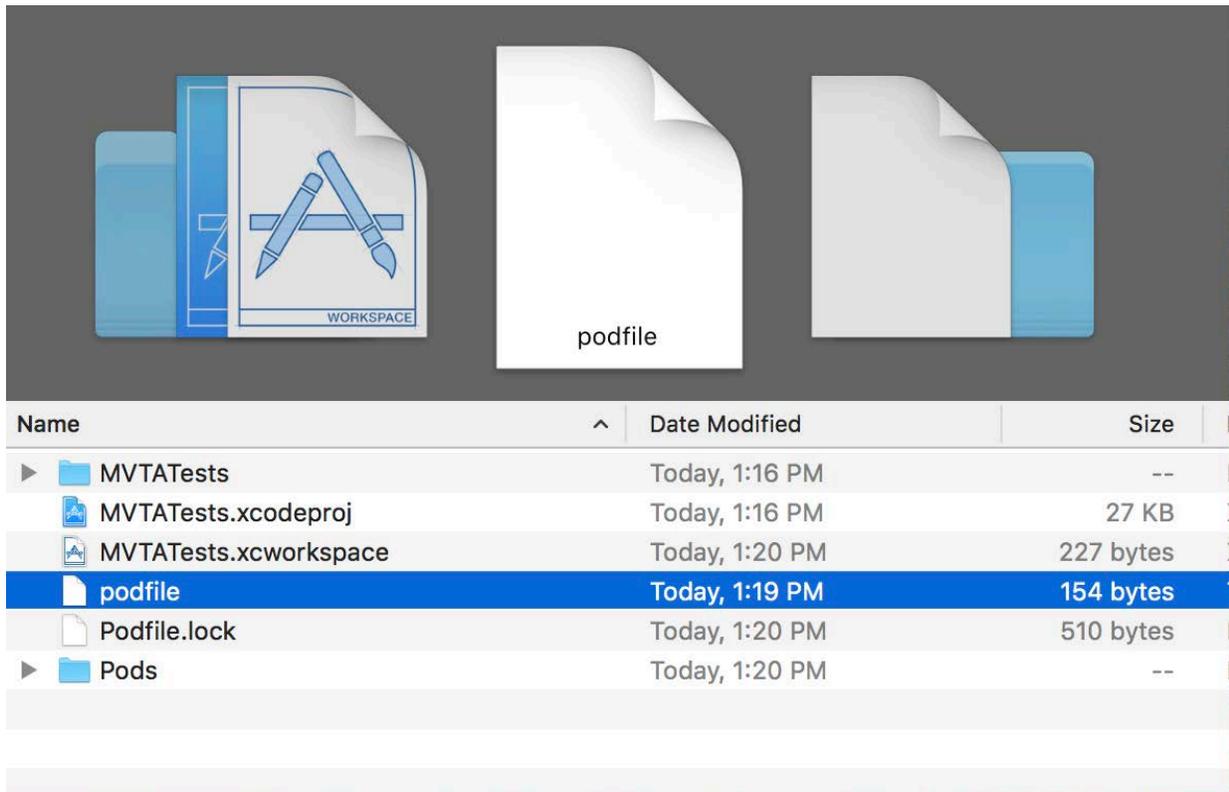


Figure 21 Initial BlueCats testing and application structure

A separate test was conducted using sample code for the IndoorAtlas SDK. Both the Quick Start Guide and iOS SDK guide were used to add the indoor positioning services to the MapViewController in MVTATests. The spatial components were then accessible in the application, and the callbacks needed to be managed using the POIModel for the TableViewController.Swift and MapViewController.Swift files. This methodology was the most spatially relevant used in the project. However key issues were encountered in testing with Swift programming, described in Chapter 5.1.2 and 5.1.3.

3.2.2.6. Programming and Testing IPS Services and BlueCats in XCode

The POIViewController needed to have a high level of customization and reliability to be capable of managing all of the hotel model data. Each POI had a different set of texts, number of images, and a video. In addition, the views for each POI needed to be adjusted individually based. The POIViewController was set up to handle either one or two paragraphs and one photograph (Figure 22). Other customizations were included in separate view controllers for longer POIs with more content and more photographs. Storing POI content in separate ViewControllers made the programming interface confusing, and risked a higher chance of user device memory failure. An array in a single ViewController.Swift file was the preferred solution for this project, set up to rotate based on the location ID or AudioChapter ID. The high level of customization for the ViewController.Swift file required this to be done programmatically.



National Historic Landmark



This building became a National Historic Landmark on May 28, 1987. Its rustic architecture, along with the role it played in interpreting the heritage of our National Parks made it a historic icon. From the moment the cornerstone was laid on August 1, 1926 to opening day on July 14, 1927 and on, this building has fostered a rich and provocative history. This virtual tour will open your eyes to the architectural design, interior design elements, history and quirky stories behind this phenomenal building.

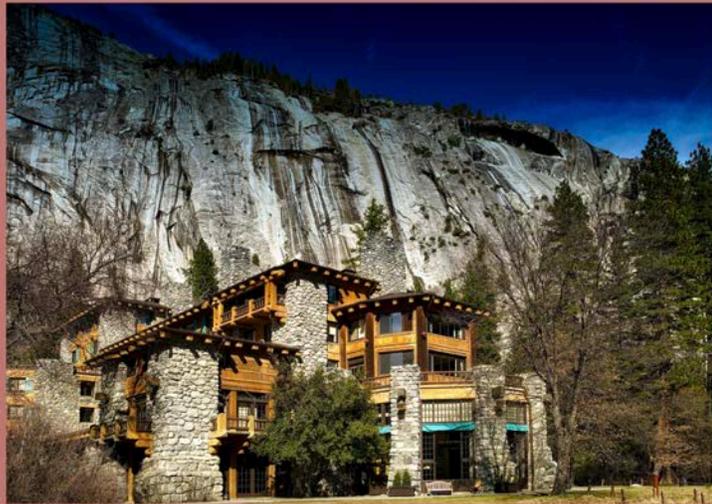


Figure 22 A sample view for a National Historic Landmark POI

In initial testing, a separate ViewController was created for the Stephen Mather and History of Yosemite POI which is the longest POI in the MVTA (Figure 23). This tested the scroll feature and an alternative approach to triggering the beacon interaction. The high level of customization for the scroll menus built in the Main.Storyboard file met the requirements of the project, but issues for scaling across all the devices were encountered which was one of the client's requirements.

Each user interface (UI) element needed to be “pinned” and anchored for scaling on alternative devices (i.e., iPhone or other iPads). This divided the screen into different sections based on points. Since different devices have different resolutions, points are used to set distances based on the percent of space from surrounding elements. For example, in Figure 23,

the content box was set 20 points from the “History of Yosemite and Stephen Mather” title. The results for this section are described in Chapter 5.1.3.

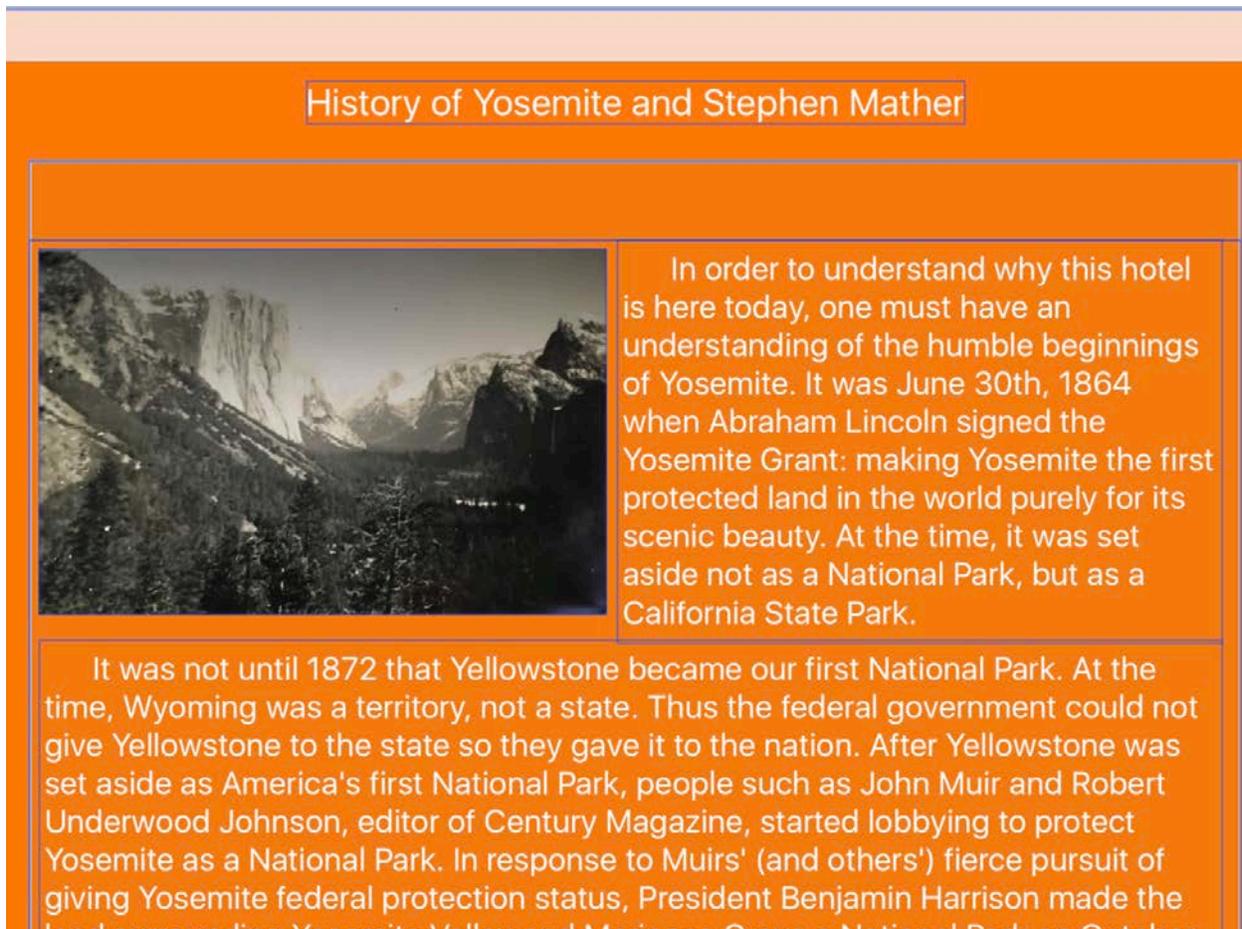


Figure 23 A sample POI View Controller about the History of Yosemite and Stephen Mather developed in Xcode

3.3. Developing with Unity

After the testing of the applications described above was completed, it was determined by the client there would need to be an iOS version of the application because of the reliability of Apple products and the device’s capabilities for camera initialization using Vuforia Object Recognition (Vuforia AR Discussion, February 7th, 2017, Forum post communication). The iOS devices currently available offer fewer differences in resolutions compared to Android devices,

which is anticipated to reduce the number of updates to the application required over the long-term. Thus, an iPad pro was selected as the base screen resolution that would be used for developing the application and the ideal device for guests to check out in the hotel to go on the tour.

Since many of the POIs were close to one another, an attempt was made to use both the beacons and object recognition/AR services was made. The idea behind this methodology was to use the user's position in reference to the object to deliver educational content based on what the camera was seeing. This was made available using both Unity 5.5.2f1 and Vuforia.

3.3.1. Introduction to Unity Development

Unity is available on both iOS and Android, Mac and PC. Since the target device was an iPad pro with a resolution of 2056x1536, this was set as the default screen size for the Unity project, as a game scene. Unity is highly flexible in its design elements and functionality and would meet the user design requirements of the client. Overall maintenance for the MVTA in Unity was also preferred based on Unity's functionality and components. Figure 24 shows a sample introduction menu of the MVTA developed as part of this thesis project in the Unity Game Scene.

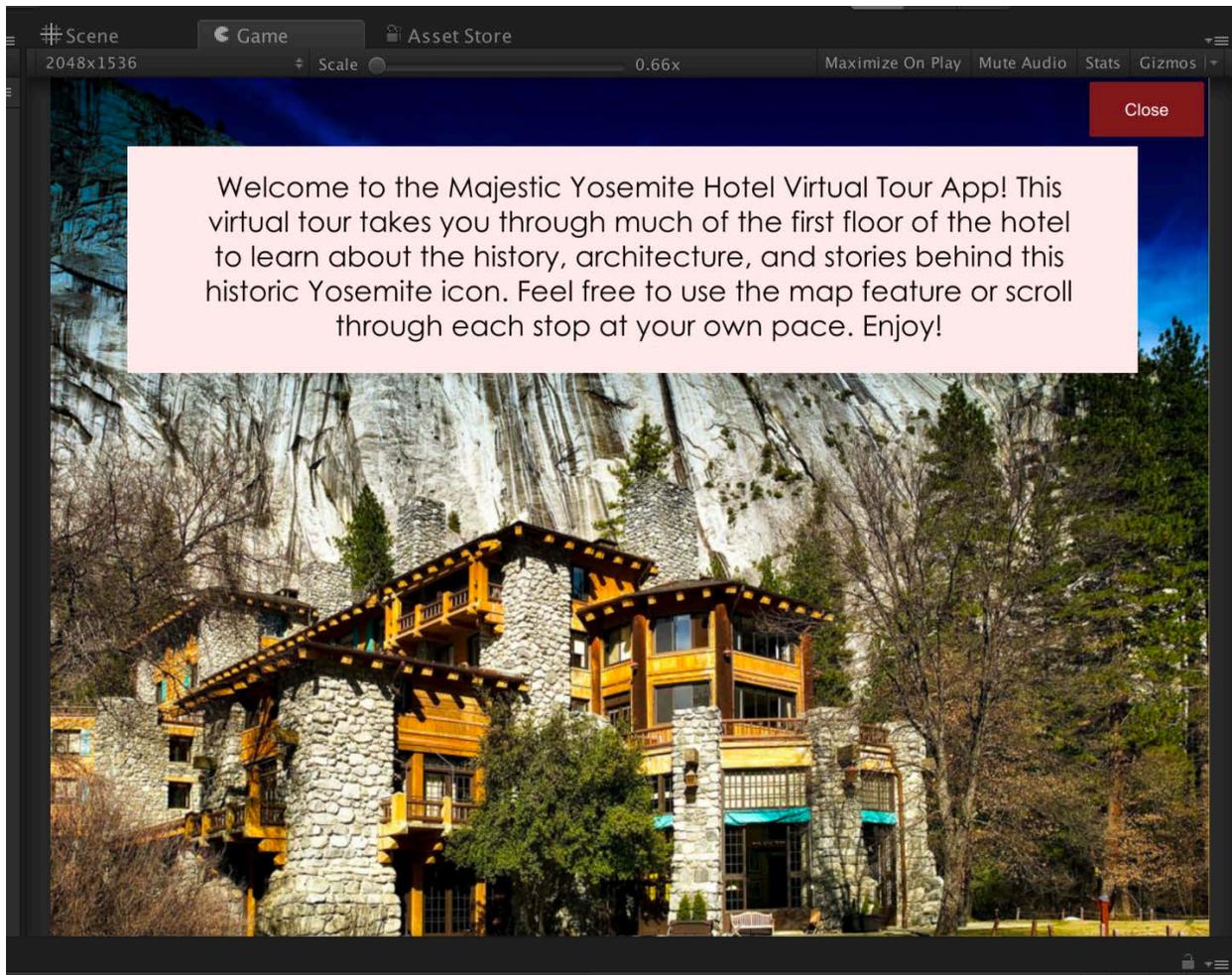


Figure 24 Unity MVTA Game Scene on iPad resolution

Once the target resolution was set, the camera in Unity was set to display what was on the canvas, or within the frame of the application. Since this application is rendered in 2D based on specifications of the client, the 3D components that Unity provide were not required. The first step was to design each of the POI panels, as in XCode. Each POI was required by the client to have at least one image of an object in the hotel and one text description, along with an audio file that would satisfy the requirements of the American Disability Act (ADA) and National Park Service accessibility guidelines (National Park Service 2017b).

3.3.2. Unity and Vuforia Object Recognition Service

The Vuforia asset package was downloaded from their developer website and was used to test out the object recognition features in the MVTA. The scripts used for object recognition features were written in C# and were modified for use in the MVTA based on target images. Once the Vuforia assets were downloaded and added to the Unity project, a Vuforia web API key was created to initialize the camera services in Unity. Object target photos were taken of each individual POI to be included in the object recognition database created on Vuforia's size and in gray scale per Vuforia's database requirements. Once all of the POIs had a target image, the target image database was uploaded into the Unity application.

Next, each POI was assigned an id number for reference. In case the client required more POIs, sixty-five additional potential POIs were documented and processed for object recognition services. With the timeframe of this project, the final amount was reduced to thirty. Each target image was rated on a 0 – 5-star scale based on “augmentability.” This calculation is based on Vuforia's algorithm where geometric points are defined within each photo (Figure 25). The more geometric points used, the higher the augmentability rating and the greater chance for success in object recognition.

[Edit Name](#) [Remove](#)



Type: Single Image

Status: Active

Target ID: d9f781631b8943a39cedcfe4818f6108

Augmentable: ★★★★★

Added: Mar 3, 2017 18:49

Modified: Mar 3, 2017 18:49

Figure 25 Women's Restroom sign augmentability sample points and geometry

Multiple image databases were included in this project for different times of day and from different angles to reduce user error for object recognition. Ninety-three target images were used in the Vuforia and Unity application for the thirty final POIs. The images ranged on augmentability, but the “0”, “1”, and “2” star-rated photographs were removed because of lack of a reliable detection. The higher augmentability-rated target images for specific POIs detected objects 100% of the time and the “backup” photographs were removed to reduce application space.

3.3.3. Object Recognition Scripts

Each individual POI had its own scripts built into the application based on image target recognition. Each script would SetActive each appropriate GameObject based on what the camera device was looking at. The GameObject was the main component used in the project.

Each individual POI had its own GameObject appropriately named based on the POI and would activate whenever triggered or identified in the application. For consistency, each GameObject consisted of all the photos, videos, text, titles, and buttons in the application. An advantage to using the camera was when the RestorationStencilWork GameObject was identified, information about the object would display on the screen. The GameObject would be loaded during the application startup but would start in a “false” or inactive state (Figure 26).

```
void Start()
{
    mTrackableBehaviour = GetComponent<TrackableBehaviour>();
    if (mTrackableBehaviour)
    {
        mTrackableBehaviour.RegisterTrackableEventHandler(this);
    }

    RestorationStencilWork.gameObject.SetActive (false);
}

#endregion // UNITY_MONOBEHAVIOUR_METHODS
```

Figure 26 Restoration Stencil Work POI GameObject loading state

In the OnTrackableFound method, this is where the GameObject would be set to true and would display each GameObject in the application. In the OnTrackableLost method, the GameObject would disappear when the camera no longer recognized the object and the device had moved away. Setting the GameObject to “false” when the object was lost created a problem of the GameObject from deactivating and reactivating numerous times. This was later adjusted by creating a close button within each GameObject to set the GameObject back to false.

3.3.4. Testing Unity and Vuforia

The initial object recognition tests and layouts were designed to wrap around each individual object present to orient itself in virtual space (Figure 27). The example shown in

Figure 27 shows the text floating in mid-air, but the content is not easily read on the device. Depending on the background, the text would augment itself around the object. The first test for augmented services was successful. The test produced an application that could recognize objects in the real-world environment, and augment the content based on where the user's device was oriented. It also challenged the current interface design and its ability to clearly provide the user's information.



Figure 27 Example of an initial Vuforia object recognition tests using Unity

3.3.5. *Unity and Bluetooth*

Assets provide code packages to help developers run certain tasks or provide assistance in application development for Unity projects. There is an Asset Store where developers can read and test out different types of assets based on their project's needs. For this project, a Bluetooth asset would be required in order to communicate between the beacons provided by BlueCats and the Unity project. The following discussion highlights two separate approaches that were considered.

3.3.5.1. Unity and Bluetooth Assets

There are several scripts to establish a connection from the Unity gaming engine to Bluetooth technologies in Unity's Asset Store. These scripts, in the form of assets, were written by Unity developers, and provide their services for sale on the market that other developers can use. Most of the Bluetooth Assets on the Unity Store at the time of this writing were Android only. There was one Bluetooth Asset that was taken into consideration, but because of its high cost and lack of reviews, it was ultimately not used.

3.3.5.2. Unity as an XCode Project

The final attempt to incorporate Bluetooth technology into the Unity application occurred when exporting the Unity application as an XCode Project. The idea behind this tested the ability to manipulate the Unity project to incorporate the BlueCats SDK, but in fear of going against the terms of service for the Unity project and failure to manipulate game objects based on Bluetooth proximity, it did not work out.

Manipulating the Unity XCode project did not have much documentation on forums or YouTube. Much of the code was converted from C# into Objective C using Unity's scripts, and

the structure of the Unity application in XCode did not allow for easy manipulation of sample code within the given time frame. The experience in Objective C projects was also limiting.

3.3.6. Educational Content

The educational content in the application was developed specifically for this project. The information was co-authored by Yosemite Hospitality's Interpretive Services Department, and final revisions were completed in August 2017 after approval by the National Park Service. All of the POIs were determined during the first few walkthroughs of the hotel based on questions asked by park visitors and common information already discussed during the Historic Hotel tour. The educational content was designed to go into further detail about each POI and cover more about the rooms that aren't frequented during the Historic Hotel tour. The rooms in which the content went into greater detail included the Solarium and Winter Club Room as these rooms aren't frequented as much during the historic hotel tour. Each POI was designed to have varying amounts of information based on the subject matter and was broken up accordingly.

Each set of text was recorded by Cory Goehring of Yosemite Hospitality's Interpretive Services and was edited to fit into the application to meet ADA standards. Each audio recording was recording using a Yeti Stereo Microphone and GarageBand. The audio recordings were exported as a low-quality MP3 to save space in the final app. An Audio Tour menu was also included where the user could click one button and learn about all thirty POIs to meet ADA requirements. This did not require the use of navigating between different menus in case of vision impairments. Table 4 lists all of the Audio Chapter Titles and POI topics in the MVTA.

Most of the information used in the application was based on historical documents, books by Shirley Sargent, Keith Walklet, Yosemite Nature Notes, and historical newspaper clippings from the Yosemite National Park Research Library (National Archives 2017; National Park

Service 2017a, 2017b, 2017c; Lund 2014; National Park Service 2012; National Park Service 2009a, 2009b; Walklet 2004; Sargent 1990; National Park Service 1986; Century Magazine 1890; Sierra Club n.d.a, n.d.b, n.d.c). All photographs used in the application required Copyright permissions and one-time use agreements for Commercial Use should the client end up selling the application in the future. Copyright was provided by the Huntington Library, Alan Petersen and the Gunnar Widforss Raisonne' Project, the John Muir Trust, Holly Cannan, Ansel Adams, Dakota Snider, and Breanne McNitt.

3.3.7. Designing the User Interface

Four menus were proposed and tested in the MVTA. The first and introductory menu is a welcome screen where it explains how the application works to the user. Once the user closes the introduction menu, the POI Scroll Menu is displayed, and the user can navigate between the Map feature or select a POI in which they want to learn about. The final menu proposed consisted of an Audio Only menu with a play and pause button.

Each user interface object such as buttons, photographs, or text needed to be able to scale across different screen resolutions. Unity allows anchor points to be set on each object for scaling across all resolutions and devices. To avoid distortion in portrait mode, a landscape only orientation was tested. The font proposed in the MVTA was Century Gothic for ADA standards, and the size minimum was equivalent to a size 16. The final User Interface is shown in Chapter 5.2.

Chapter 4 Model Development

A historical model of the south wing of the hotel (Figure 28) was created as part of this project for the purposes of preserving the architectural components, and with the intent to preserve conditions of the historic furniture within the south wing of the hotel. The model is comprised of two separate components, a digital and physical model. Each room was digitally scanned using the Canvas.io application and Structure Sensor device previously mentioned. The scans were converted using the “Scan to CAD” feature in the Structure application and uploaded to a SketchUp file (SketchUp n.d.). A SketchUp Pro license was purchased in case the client wanted to use it for commercial purposes.

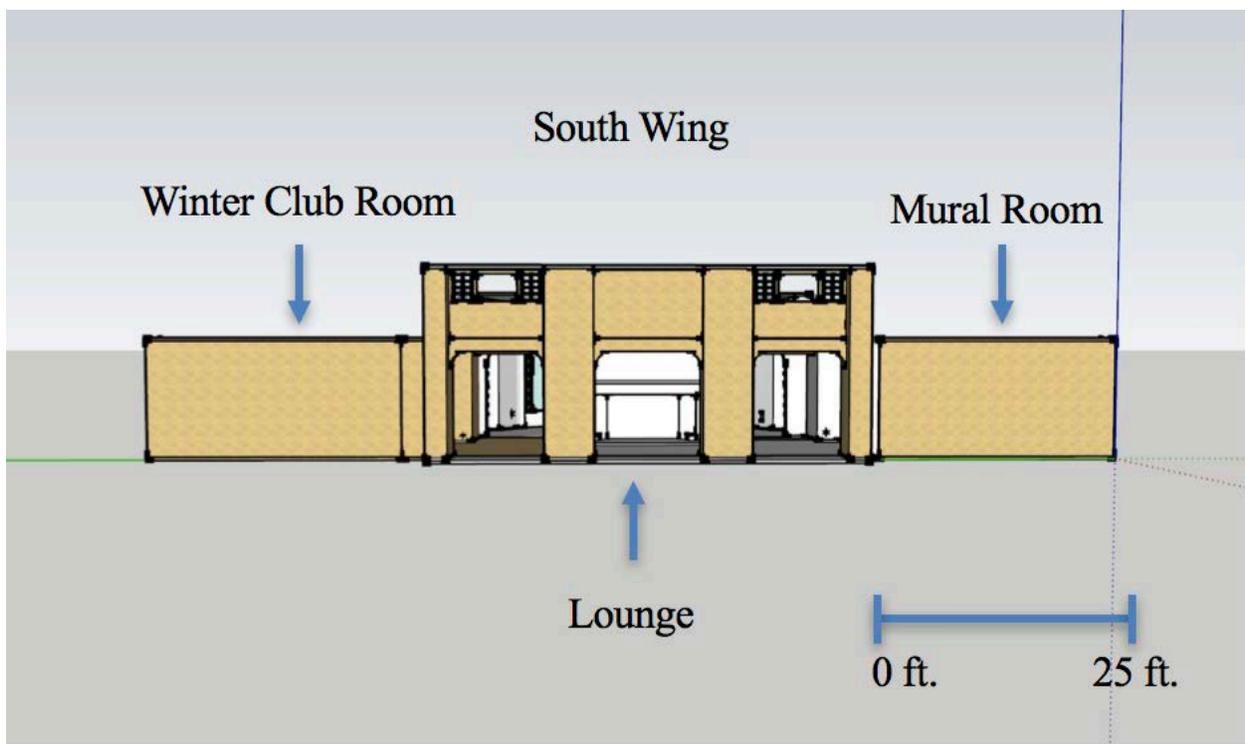


Figure 28 Combined model view from north side of the hotel’s south wing

The furniture scans used the same Structure Sensor iPad connection with Skanect.

Skanect is a scanning environment that uses a wireless network to transmit the Structure sensor

signals and creates a virtual scan of an object, room, or space (Skanect n.d.). Each piece of furniture was scanned and documented based on its location and assigned an ID number. Figure 29 shows one of the furniture pieces in the Winter Club Room being scanned. This chapter highlights the processes to create both the digital and physical model of the Majestic Yosemite Hotel's south wing.

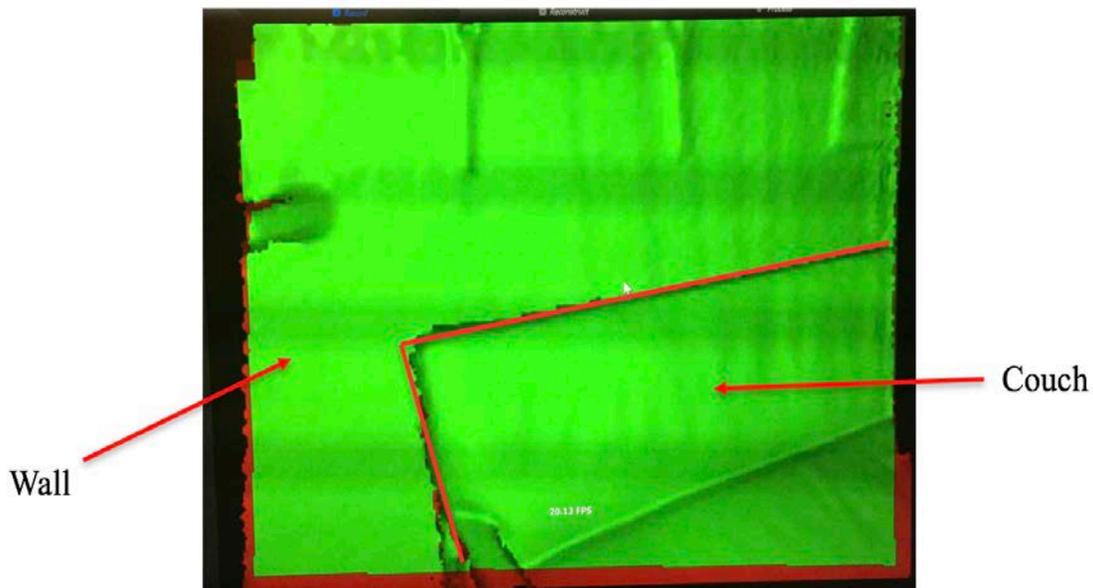


Figure 29 Scanned front side of the couch and adjacent wall in Winter Club Room

4.1. Scanning the Hotel's South Wing

Each room was scanned individually up until the 2GB ram capacity on the iPad Pro 9.7-inch model. The optimal scanning environment required a well-lit area and a lack of moving objects. Scans were completed between 10 P.M. and 2 A.M. in the hotel when many of the guests were asleep to avoid conflicts. The goal was to scan the whole first floor of the hotel, but due to limitations experienced while scanning, specifically the time frame and the range of the scanner, this goal was ultimately not met. Several of the rooms on the first floor have very high

ceilings, and the range of the Structure Scanner could not reach the tops of the Solarium, Great Lounge, and the Dining Room. A number of rooms on the first floor are not publicly accessible and were not scanned because of privacy concerns. In addition, most rooms required two or more scans, and each scan needed to be stitched together using the Scan to CAD feature. A scanned portion of the Winter Club Room can be seen in Figure 30.

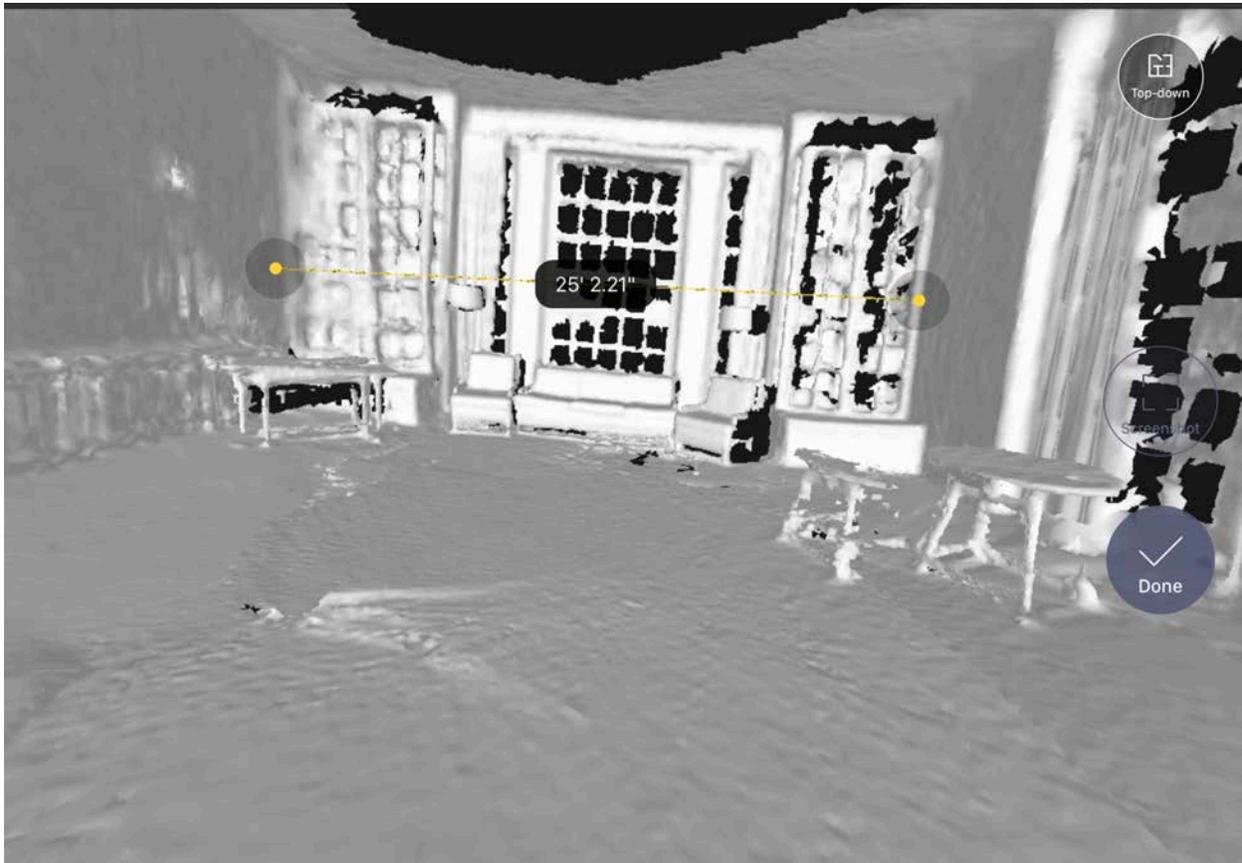


Figure 30 Scanned portion of Winter Club Room

Both models focus on the south wing of the Majestic Yosemite Hotel, which includes the Lounge, the Solarium, the Winter Club Room, and the Mural Room (Figure 31). The peach colored dots in Figure 31 represent the POIs in the hotel's south wing. Additional measurements for each of these rooms were taken using a Bosch GLM 35 laser measurement tool and a measuring tape. The measurements were taken to compare the accuracy of the Structure Sensor

scans to more classical measuring and surveying techniques. After the scans were complete, they were uploaded on the Structure App and processed into a CAD file.

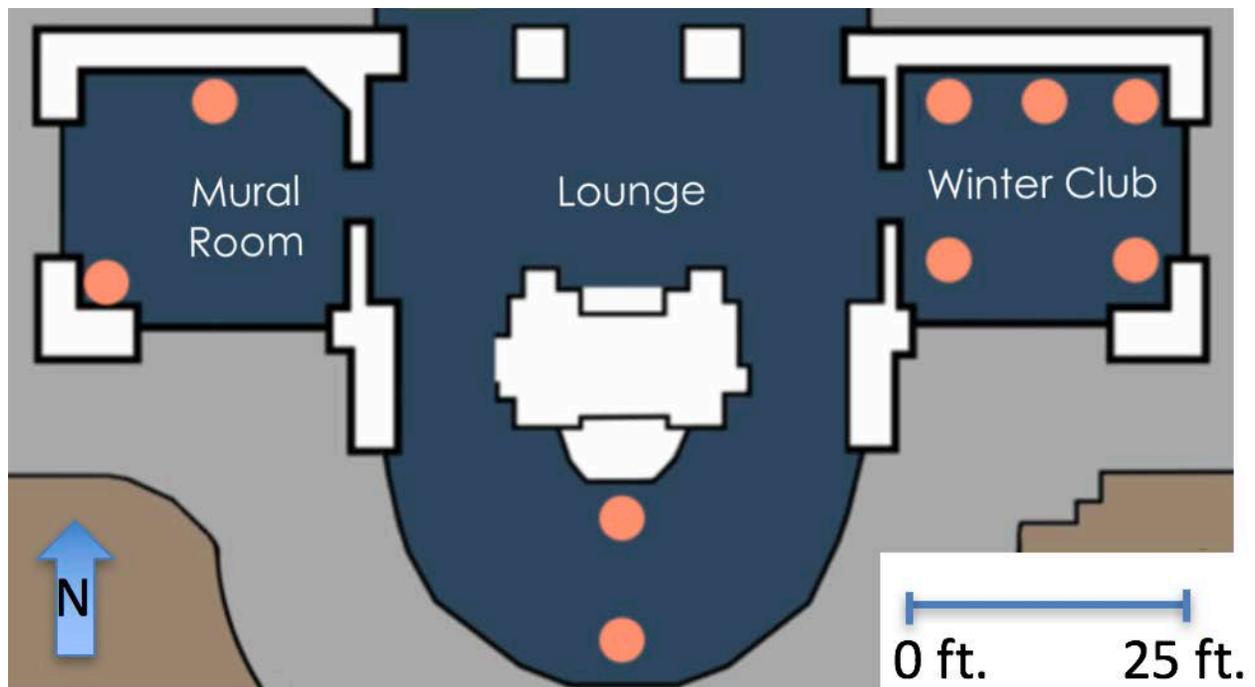


Figure 31 Majestic Yosemite Hotel South Wing

4.2. Scanning the Hotel's Furniture

The hotel's original furniture in the Lounge, Solarium, Winter Club Room, and Mural Room were all scanned as part of this project. Due to time constraints, one piece of each furniture was scanned and labeled. Types of furniture included tables, chairs, the Solarium fountain, and desks. The American Indian baskets on the fireplace's mantle were not scanned to avoid possible damage from IR sensors. The lights in the hotel were not scanned because of their narrow structure and the inability to get a complete scan from all angles, from above each lighting fixture.

Each piece was scanned using Skanect. Skanect can use either the Structure Sensor or the Kinect by Microsoft as its input source and transmits data streamed from the iPad sensor to the

computer. The scan on the iPad is also displayed on the computer in Scanect after the scanning environment is set up on the computer. If there was not enough “geometry” or reference objects detected in the sensor’s view, the scan would need to be reset to the last known location.

Raw data recorded in Scanect for one of the Mural Room tables is shown in Figure 32. The width of the scanning environment was recorded at 6 feet. Each scan took several attempts to make sure each angle and side were completed for each piece. This scan shows the initial data from one angle previously scanned. The scans were then processed in Scanect using the crop and fill holes tool to complete each object.

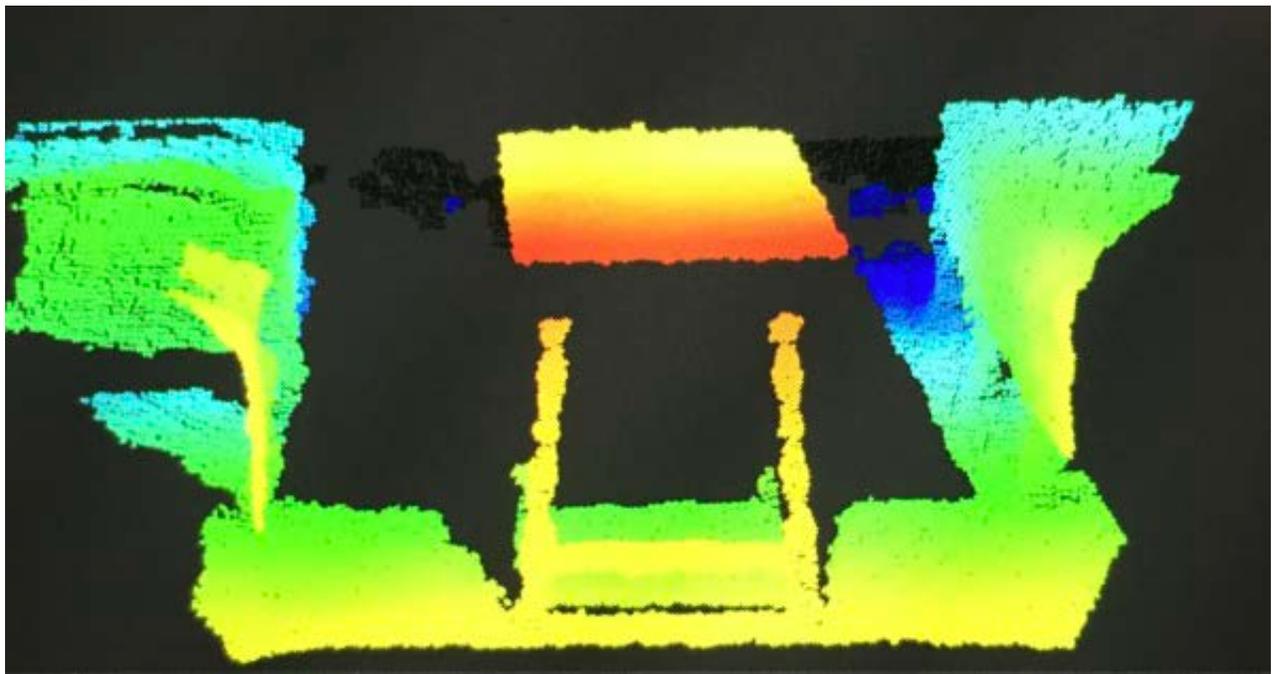


Figure 32 Raw scanned data in Skanect of a Mural Room table (middle)

4.3. Building the Physical Model

The physical version of the CAD model was built using 1/8th-inch birch wood and a laser cutter. Every panel in the CAD model was exported as a PDF and scaled down using calculations derived from the SketchUp model. Every inch in the model represents 3 feet in the hotel (Figure

33). Initial testing of the laser engraver used a higher setting for each individual face to confirm that it would cut through the 1/8th-inch piece of wood. There were forty sheets of 8in x 10in birch wood used in the making of the physical model. Several panels such as the model's doors required a "cut" file and a "draw" file. The cut file used the higher laser setting to remove excess wood, and the draw file used to burn a thinner line into the wood for accent. Once each face was cut out, the model was assembled on top of a 48in x 36in wooden base, glued, and laser aligned. Figure 33 shows the assembled model.



Figure 33 Birchwood model of south wing in Majestic Yosemite Hotel

The next chapter details the results of the MVTA and the physical and digital south wing model.

Chapter 5 Results

Although several of the methodologies tested in the development of the application architecture were rejected upon consideration by the client, these tests contributed to the overall design of the final project. The first section of this chapter highlights the decisions based on testing results and working with the client to determine the final product. This chapter also highlights the final version of the application submitted to and accepted by the client and the current version of the indoor model at the time of this writing. The final section of this chapter discusses the lessons learned while working on this project.

5.1. Alternative Application Methodologies and Results

This thesis documented several approaches for developing the MVTA, including use of Anyplace, IndoorAtlas, BlueCats, Vuforia, and Unity. This section highlights the results of each application methodology.

5.1.1. *Anyplace*

Anyplace on the Android platform was the first IPS tested in this project because of its free and open-source code. It uses a wireless network and RSS values to determine the location within a given space. The Anyplace Architect was used to overlay the Majestic Yosemite Hotel's floorplan in Google Maps, and to attempt to create the initial location services. Since the guest wireless network was ultimately deemed not usable for this project and because there is no other accessible wireless infrastructure in the hotel, the Anyplace IPS was eliminated from consideration early on. Additional location display errors and critical errors when incorporating Anyplace into a native application would also require heavy debugging and complex application

updates as needed, both of which would not meet Yosemite Hospitality's goal in maintaining the application effectively in-house. In normal circumstances with readily available wireless systems, this IPS solution may be more applicable, but further development and improvements were required.

5.1.2. IndoorAtlas

The results from IndoorAtlas produced LBS inside the hotel in a native application on iOS with just a few lines of code. The cloud-based features relied heavily on a data source to initialize the location and to keep an accurate location. Testing was completed using a Verizon Wireless cellular mobile device, but reception could not be guaranteed across all devices because of the lack of cellular support infrastructure. During testing on the mobile device, location display errors occurred due to the lack of a dedicated service. The resulting errors, as well as the service's costs for the large venue, ultimately did not meet the goals of the client. This service may be considered in future versions of the application once more infrastructure is readily available and cellular service is more reliable in Yosemite National Park.

5.1.3. BlueCats

BlueCats beacon services was the third methodology tested during this project, also tested in combination with IndoorAtlas. Using the BlueCats SDK allowed for easy integration into the MVTA. Many of the costs were up-front on the technology side, and the BlueCats SDK long-term service costs would have been based on the client's use. Programming using the SDK allowed information to be displayed based on the categories set for each beacon or based on their proximity. These were the two methodologies tested in the MVTA. Issues programming the MVTA's interface challenged the backend structure of the application. The POIViewController required varying amounts of information such as multiple text boxes and photographs and

needed to be extremely adaptive in the live version of the application. Issues with the POIViewController excluded this methodology from consideration, and ultimately developing a native application in either XCode or Android Studio within the given time frame permitted for project completion.

5.1.4. Vuforia

Vuforia was tested using Unity, and although this component was not ultimately chosen, rejection was due to the particular conditions encountered within the physical space of the hotel and overloading the device's processing power. Each target POI generally needed to have a well-lit area that could be used for object recognition. Many of the POIs considered did provide well-lit areas, but at different times of day, the object recognition services would not work for certain POIs due to the amounts of light inside the hotel. In the evening, the chandeliers in the hotel do not provide adequate lighting for the POIs and led to object recognition issues. Even different weather patterns during the winter such as outside snow produced unreliable user experiences.

During Vuforia testing, 27 out of 30 POIs tested successfully. Testing with Interpretive Services staff, the department of Yosemite Hospitality that will maintain the MVTA, produced 22 out of 30 POIs tested successfully. Unsuccessful tests resulted because it wasn't clear how far away the user needed to stand from each POI in order for object recognition to be successful. As a workaround for this issue, additional target images were collected for those POIs but ended up requiring so much memory in the application that the MVTA crashed often and the power usage drained the battery in 45 minutes of use. Appendix D contains the POI image targets collected for the MVTA. These difficulties as well as the additional cost for the Vuforia software ultimately influenced the final decision of choosing Unity by itself.

5.2. The MVTA and Associated Project Requirements

This thesis outlined several methodologies that were tested in the context of this project for the development of the MVTA, both with successes and failures incorporating spatial technologies and object recognition technologies. IndoorAtlas and BlueCats produced favorable results for this project, but lack of programming experience using XCode and the Model-View-Controller scheme, as well as long term in-house maintenance considerations and associated costs eliminated these options. In a location with more Wi-Fi and cellular infrastructure, these systems may be more reliable and preferred. One lesson learned in regard to infrastructure was not to assume that these infrastructure resources are readily available in every context. Costs, long-term and short-term maintenance, and programming experience of in-house staff led to the final decision for using Unity.

Unity was the preferred architecture for building the application in the end because of the problems that occurred with the other technologies during testing phases. One of the biggest issues faced was during the upgrade to XCode 8 and iOS 10. Many of the iOS programming classes that were used became deprecated and needed to be modified for improved functionality. Updates to the SDKs were not readily available after the noted iOS update and provided a valuable lesson in long-term application maintenance. Relying on multiple software and web service companies for different services and updates requires time, and towards the end of this project, it was deemed most critical to the success of the project to complete the application in a timely manner.

Maintenance costs on the client side were heavily considered in the final MVTA implementation. In order to avoid having to hire a full-time developer, an application built from scratch was not preferred. A Unity Pro license was purchased for this project in exchange for the

vendor's services and support. Enhanced capabilities in Unity also provided the necessary tools for the Interpretive Services to maintain the application over the long-term.

Unity was proposed because it did not require a full-time developer to maintain the application since many of the components could be edited directly within the interface. Since part of the future work involves training Interpretive Services staff on maintenance, limiting development to only Objective C and C# in Unity was preferred, as opposed to implementing all four programming languages used and tested during development. Unity also allows each project to be exported to work on a variety of platforms including Mac, PC, Linux, iOS, and Android. These different platforms give the client flexibility as to which devices can be used with the application.

In addition, the ability to modify and create the user interface to the specifications of the client was ideal in Unity. The Unity structure allowed for a high level of customization without relying on any outside services. Many of the interface elements can be built directly into the view. This gives the client the ability to edit or create content directly into the interface, rather than doing everything programmatically in multiple languages. One additional requirement was to make the application commercial ready. Each photo used in the application was either in-house or required a one-time Copyright use form. Unity gives the client the ability to monitor sales and usage on their website as part of the Unity Pro license.

The Unity Pro license is \$1,500 per seat, per year. The costs for hiring a full-time developer to maintain the application would be significantly higher. The license gives Yosemite Hospitality the ability to make as many applications as they would like in the future, as well as maintain the MVTA. One of the original ideas was to have an application "game" in the Mural Room of the hotel. This could become its own application in the future and may incorporate

Vuforia's AR services that were tested during this project. It is for these reasons that Unity was the preferred methodology to go with for this project. The goals of reaching the desired user experience that meets ADA standards, an easy to use interface and map feature, and having an audio tour were all met on the client side. Although the costs were high in initial startup, the Unity solution provides services for long-term maintenance and gives the client flexibility for developing other applications.

Working with all of the architectures listed in this thesis produced unexpected results. Building a "commercially ready" application requires a more involved approach compared to a theoretical approach, especially while looking at the legal requirements of many of the terms of use of the software components involved. In addition, working with staff in a large company on a day-to-day basis requires a certain level of professionalism. One of the challenges was the amount of time that this project was to be completed in. Application development is deceptively long, and there needs to be adequate time allocated for application testing and debugging. The final product was completed 10 months after starting, almost double the proposed time. Nevertheless, the end result met the satisfaction and requirements of the client listed above.

As a result, both an Android and iOS version using Unity have been created for the MVTA and were submitted to the client. The final version of the application was tested on the iPad Pro 9.7 inch and Samsung Galaxy S2 Tab and is owned by the client Yosemite Hospitality. The Splash Image when the Application is first opened (Figure 34) contains the Yosemite Hospitality Logo and the Unity Logo. After the Splash Screen Menu, the Introduction menu is displayed. A large image of the hotel's south wing and granite backdrop immediately brings the user into the setting. Once the user closes out the introduction page, the audio chapter scroll

menu is displayed with all 30 POIs. The end user is able to select the POI based on topic or navigate to the map function in the application.



Figure 34 Splash Screen Image for MVTA

The map function contains buttons to each POI game object similar to the audio menu but is based on where the user is located. When the user selects the map function, a “You are here” box pops up at the location of the concierge desk in the Majestic Yosemite Hotel (Figure 35). The user can then dismiss this box and begin the tour. Each stop is in a publicly accessible area. The buttons were originally color coded by room and geographic section to suggest a flow for the application, but ADA standards required a single color since communication cannot only occur based on color. The user can walk out the doors and learn about National Historic Landmark POI which is listed as Chapter 1.1 in the MVTA, or the user can select any other location-based on where they want to go.



Figure 35 MVTA map starting point and POI's are shown as gold boxes

The map contains a scroll feature which allows users to readily access other POIs and information. The close button remains stationary so the user can exit and segue between different menus. Once the user selects a POI, they are able to learn about that specific location or object. An example of a POI is the Women's Restroom POI, or Chapter 5.1 within the MVTA (Figure 36).



Women's Restroom

Close

The women's restroom, located upstairs, was created so women could avoid the "uncivilized atmosphere." In the 1920's, a man was not supposed to watch a woman enter the restroom. The Mezzanine floor in the hotel's early years was also used as a powder room, popularly coined "the Ladies Lounge." This is where women would get all dolled up before making their grand entrance down the stairs to the hotel's first floor. This attracted many of the wealthy women at the time. Although the Mezzanine floor does not have the Ladies Lounge today, it still does house the women's restroom. Regardless of the day or age, women still make their grand entrances down these very stairs.



Figure 36 A sample POI in the MVTA

The client required at least one photograph for each POI, and an audio version of the content. Consistent formatting throughout the POIs was also required to keep the MVTA uniform in structure or user experience. Each title font was Century Gothic 80, and the body paragraphs were Century Gothic 50. The play and pause buttons were created in Adobe Illustrator, and the close buttons were created in Unity. Each menu in the MVTA contains an off-screen scroll-bar to avoid clutter. All images used in the MVTA were saved as a texture in order to overlay it onto the Unity user interface canvas.

There is one video in the application which was also saved as a texture. The video is from the 1950s, a recording of the historic Firefall event. The video required a separate C# script to be written to access it from the StreamingAssets in the project's files loaded onto each device.

The user-friendly navigation and options met the needs of the client. Although it did not incorporate the place-based interaction originally desired using an IPS, beacons, or object recognition, it does provide a consistent method for content delivery and a professional-grade application without draining the device's battery. The final version of the application also met the client's needs of providing content based on where the user is inside the hotel, while also providing access to each POI without the use of LBS for ADA standards.

5.2.1. Testing and Debugging

Initial tests involved checking memory and energy consumption on the iPad Pro device. Memory tests using XCode's debugging feature produced energy and memory consumption data. Based on those results, modifications were made to the Unity project. The amount of data in the application exceeded 500mb and consumed a high level of the device's energy. Each file included in the Unity project was compressed to reduce energy power and memory consumption. This lowered the initial MVTA loading time from thirty seconds to twenty-two seconds.

Interface elements during initial testing failed to produce intended results. Several buttons were not working because of missing scripts and functions. These were easily noted and fixed. Testing on an iPhone 7 resulted in a much smaller font compared to the iPad Pro. The "best fit" option for each text string was used and would scale the font based on screen size. Once all the interface elements were fixed, the application was ready for submission to the National Park Service.

The National Park Service and Yosemite Hospitality's Interpretive Services Department required staff testing of the final version of the MVTA before public release. The content was edited based on accuracy and clarity, and the audio components were analyzed for quality standards. After the final round of testing and revisions requested by both entities, the application was ready to submit to Yosemite Hospitality.

5.3. The Physical Model

This project's physical model will be on display in the Majestic Yosemite Hotel later this year. At the time of this writing, some of the paint needs to be redone, and the 3D printed furniture needs to be added. Initial furniture printing resulted in a morphed and inaccurate scaled chair which was eventually discarded. The physical model in its current form is shown in Figure 37. The purpose of the model was to display some of the architectural components and updates in a smaller form. The added furniture will provide the historical context originally envisaged for the project.

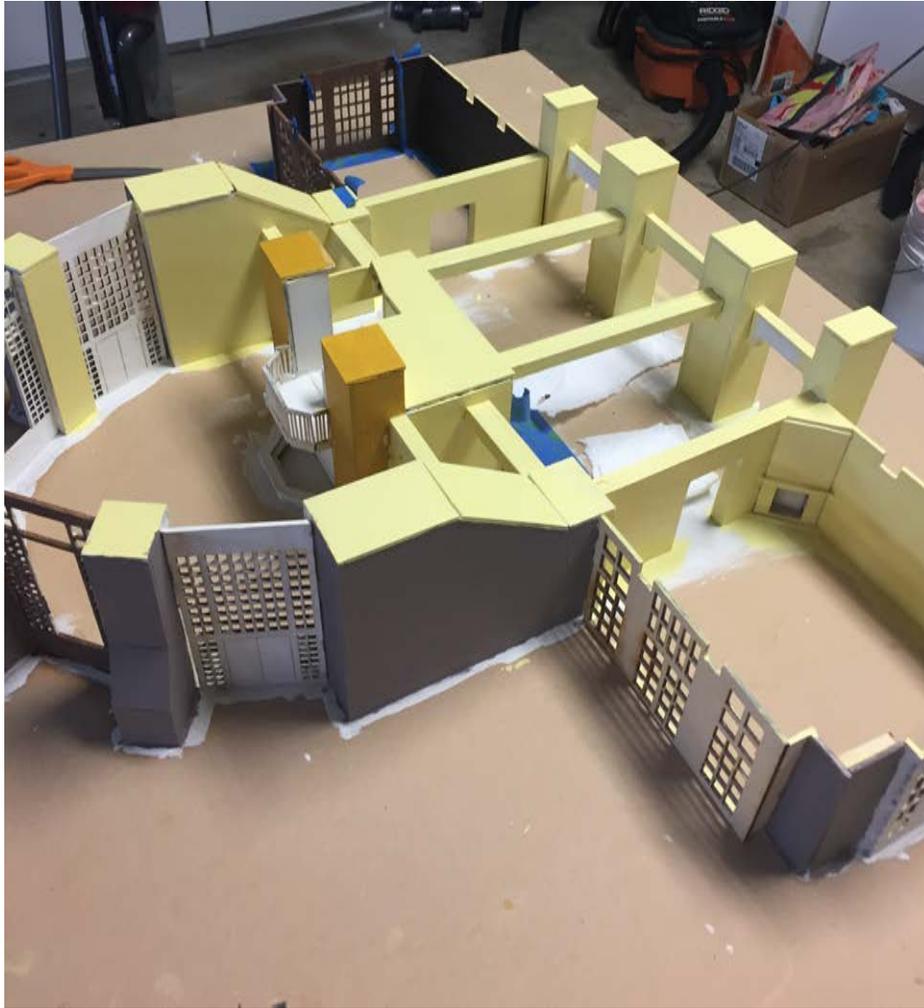


Figure 37 Majestic Yosemite Hotel Model

Chapter 6 Conclusions

The purpose of this project was to meet the desired user experience for the client. The desired user experience was defined as creating an overall engaging mobile tour application through relevant information about POIs within the hotel with the ability to select or receive information based on where the MVTA user is inside the hotel, an audio component where the user can choose to listen to the content or access a complete audio tour, a clean user interface layout and design, and incorporating historical and present-day photographs to establish relevancy to the educational content for each POI. All MVTA application design decisions were based on client application specifications regarding functionality. The main component of this project was the mobile application and much of the thesis project time was focused on its implementation. The end result of this thesis produced a “living” virtual tour application that can easily be modified and updated in the coming years by the client. The ability to reach more park visitors and increase the visitor experience supported the client’s desire for building such an application.

The testing of different kinds of positioning technologies such as several Indoor Positioning Services, Bluetooth beacon interaction, and AR services presented many challenges along the way. From programming a native Android application to making a switch to iOS for development, new technologies were experimented with and tested to try and meet the desired user experience. The limiting cellular infrastructure and wireless access in Yosemite National Park ultimately eliminated the applicability of some of the methodologies, whereas required programming experience prevented success with others.

There are however, many positive outcomes that came from this project. In terms of professional growth, the author was fortunate to work with many excellent colleagues across

disciplines in getting this application to the best state that it could be in the time frame required by the client. The author was part of a team to help write interpretive text, worked in a professional environment and in meetings with executives and managers, and coordinated with hotel staff on project updates and methodologies. Working on both the Android and iOS platforms, learning how to write applications in Swift and scripts in C#, working with dependency managers, working with outside developers, students, professional networking, and building an application to be proud of were all positive experiences and thus invaluable outcomes from this project.

6.1. Future Work

The MVTA is a living document, as many more POIs will be added in the future. Thirty were chosen for this project based on qualities previously noted. The Interpretive Services staff at Yosemite Hospitality will continue to improve and update the application for both iOS and Android devices. Future versions of the MVTA will include audio and text in multiple human languages to provide educational services to more international visitors who come to Yosemite. This was one of the main appeals for Yosemite Hospitality, and the type of system that is in place for the application's architecture will allow for this to happen.

With regards to the physical model, this will also continue to be a living document. The goal is to provide visual, tactile information about each piece of historic furniture, and further research will be required about each piece within the model. This is just the start of preserving the cultural and historical resources inside the hotel and will provide a snapshot into the hotel's interior design elements for future generations.

6.2. Technology Transfer

The final MTVA files will be transferred to Yosemite Hospitality's Interpretive Services Department in Yosemite National Park for Android and iOS release. Interpretive Services staff will be trained on how to update, debug, and maintain the application using Unity, XCode, and Android Studio. Training will involve designing the application's architecture and interface for consistency across all devices, scaling, photo processing, audio processing, script updates and resources, Unity resources, and a user guide manual.

The Unity Pro license seat will be transferred to one member of Yosemite Hospitality's staff for long-term maintenance of the MVTA. All of the tested applications created as part of this project will also be included should the client choose to go in another direction in the future. All model resources created will also be transferred to Yosemite Hospitality Interpretive Services staff. The technology transfer will be completed in September 2017.

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Appendix A User Guide

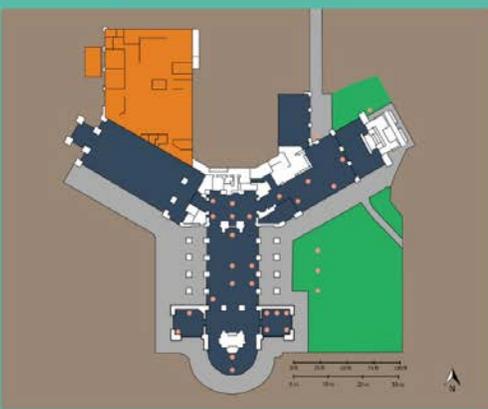
Majestic Virtual Tour Application User Guide 

The Majestic Virtual Tour Application (MVTA) is a self-guided tour inside the hotel. There are two main components in the application. The first one consists of an interactive map feature where you can learn about each of the icons based on where you are inside the hotel. The second component is a menu where you can scroll and select which topic you want to learn about, no matter where you are.



MVTA Map

Scroll Menu





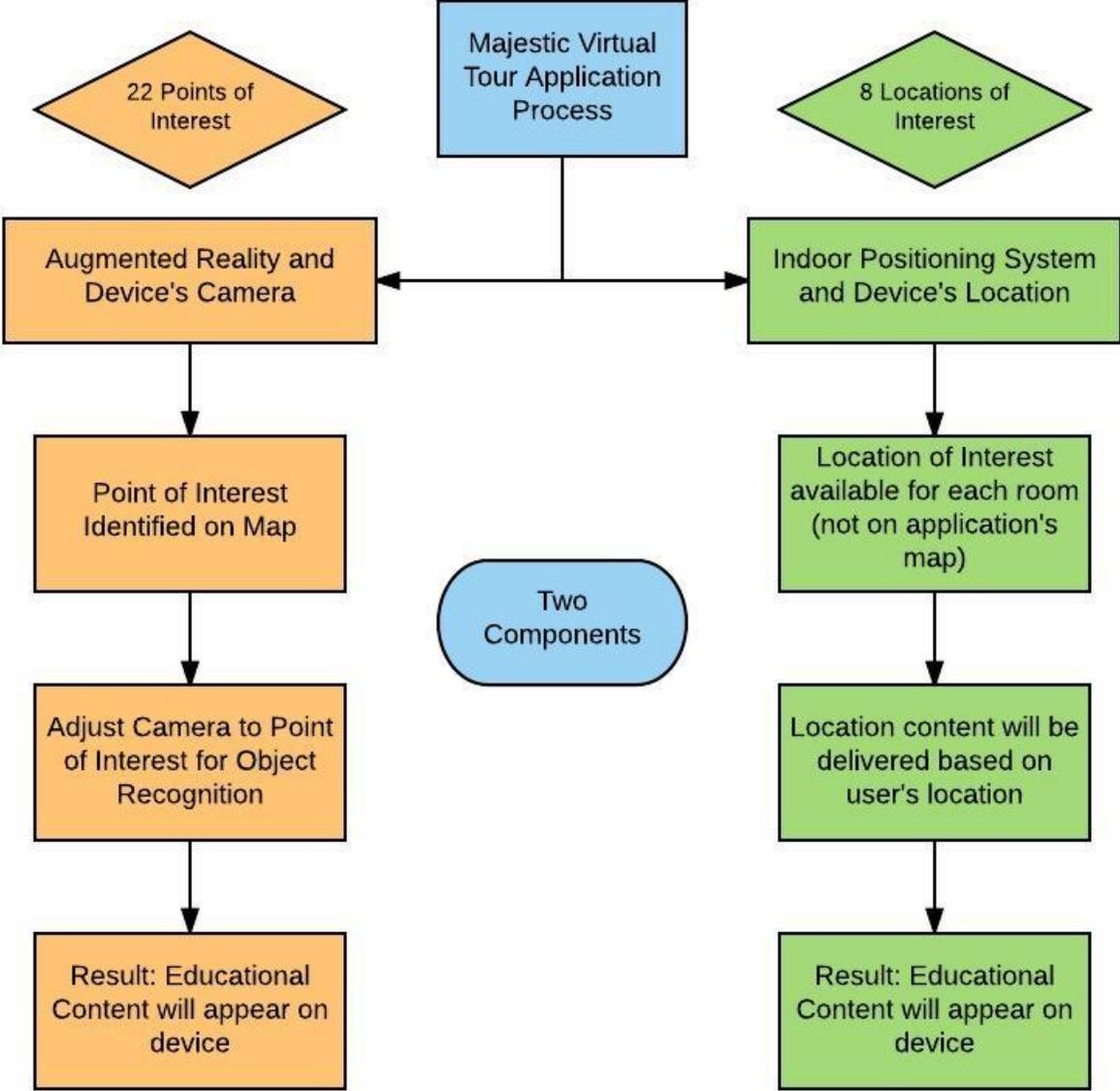
Each of the dots on the map represents the area in which you can learn about. Feel free to click along and explore throughout the hotel's ground floor!

The menu is broken up into different chapters. Feel free to click on each topic or specific ones to learn about the hotel!

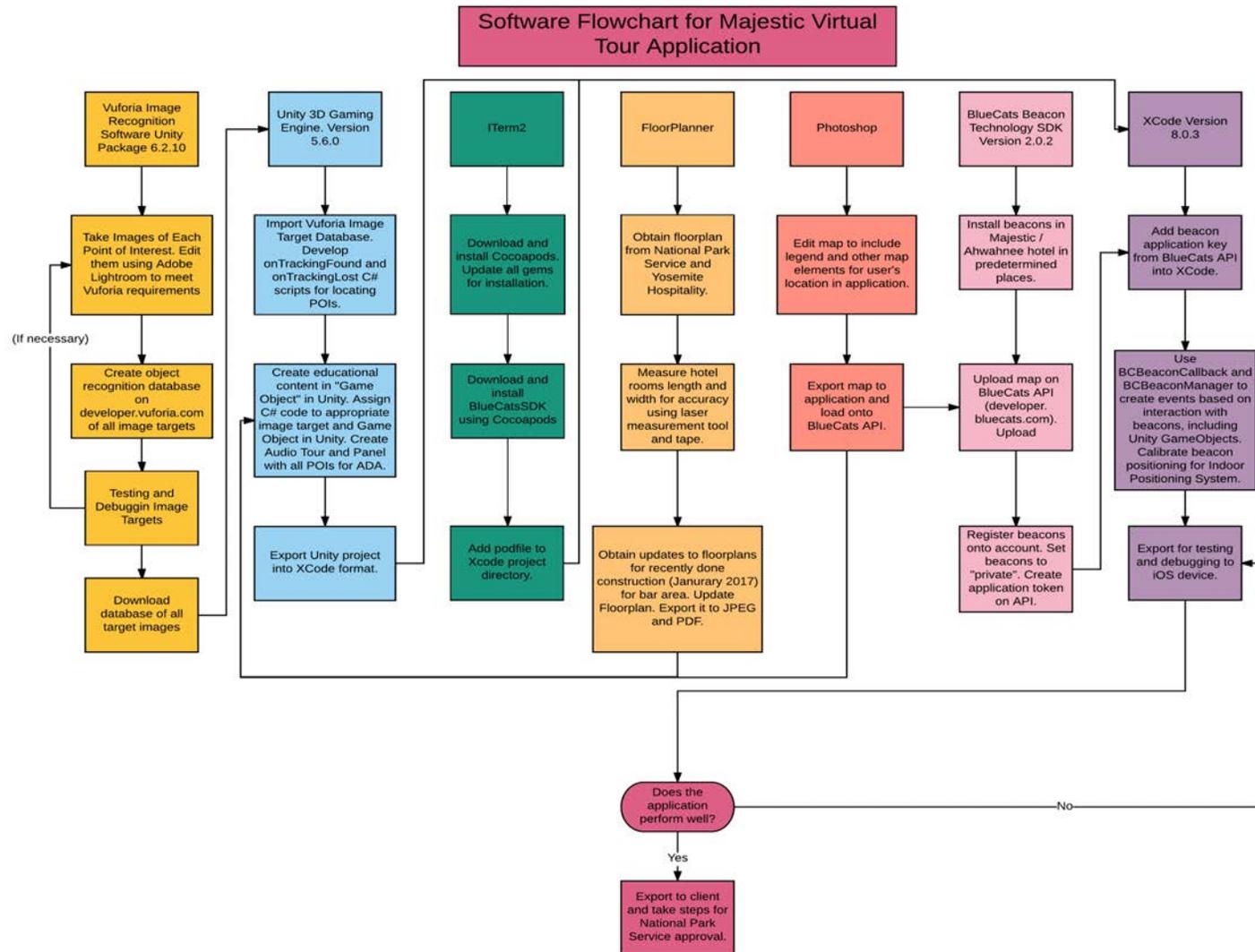
Thank you for checking out the MVTA!

MVTA Sample User Guide

Appendix B Draft Flowcharts



MVTA proposed flowchart using Unity and Vuforia with IPS services



MVTA proposed Architecture for Unity and BlueCats

Appendix C Audio Chapter List

Audio Chapter	Title
1.1	National Historic Landmark
1.2	Cornerstone
2.1	Bar
2.2	Floor Mosaics
3.1	History of Yosemite and Stephen Mather
3.2	Organic Act
3.3	Architecture
4.1	Sweet Shop
4.2	Gunnar Widforss
4.3	Gothic Chandeliers
5.1	Women's Restroom
5.2	Kelim Carpet
5.3	Basket Swirl Mural
5.4	Kitchen
5.5	Dining Room
6.1	Covered Up Mural Above Fireplace
6.2	Navy Occupied the Hotel
6.3	Baskets
6.4	Stained Glass
6.5	Interior Designers
6.6	Restoration Stencil Work
7.1	Winter Club Room
7.2	Donald Tresidder and Skier's Ten Commandments
7.3	Della Taylor Hoss and Peter Hoss
7.4	Frank Givens and Luggi Foeger
7.5	Leroy Rust and Hannes Schroll
8.1	Fountain
8.2	Firefall
9.1	Mural Room
9.2	Secretary Desks

Appendix D POI Photos



Dining Room



Solarium Fountain



Kelim Carpet



Winter Club Room Panel 1



Sweet Shop



Floor Mosaics



Old Mural in Great Lounge



Gothic Chandeliers



Organic Act



American Indian Baskets



Kitchen



Gunnar Widfors



National Historic Landmark



Women's Restroom



Secretary Desks



Cornerstone



Stained Glass



Winter Club Room Panel 3



History of Yosemite and Stephen Mather



Restoration Stencil Work



Mural



Firefall (film)



Great Lounge



Bar



Basket Swirl Mural and Jeanette Dyer Spencer



Navy Occupied the Hotel



Winter Club Room Panel 4



Winter Club Room