SANTA CLARA UNIVERSITY
DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Tate Sakai
Kunal Pandey
Jose Perez

ENTITLED

WayPoint

BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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Department Chair

Department Chair

WayPoint

by

Tate Sakai
Kunal Pandey
Jose Perez

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Tate Sakai
Kunal Pandey
Jose Perez

Department of Computer Science and Engineering
Santa Clara University
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ABSTRACT

Paper maps and stationary maps such as directories are used in various places such as malls and amusement parks. Paper maps are used temporarily for those who are not familiar with the area, causing unnecessary waste. On the other hand, directories are a form of stationary maps that require visitors to find the directory first to figure out where their desired location even is. Determining one's own location on a map, finding the desired destination, and mentally mapping the pathway to the location can be a challenge for many people. WayPoint aims to create a platform for users to overlay the path on top of the sidewalks and paths that are already defined within the organization.

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Chapter 1

Introduction

Navigating through the SCU campus can be a headache and especially stressful when you are an incoming student or staff member. Our senior design project aims to solve this issue and in the process make everyone's life on campus easier. Students, faculty, staff, and their family and friends will no longer have to rely on campus map kiosks or bothering others to reach their destination. With our handy WayPoint app, one will only have to enter the destination and the path will be "illuminated" by a visible line that will appear on the phone as it is held up.

The current system consists of campus kiosks and online maps. These methods are somewhat helpful, but a person must remember the directions relative to the kiosk's location. Students who have familiarized themselves to the campus can easily use the map—as it provides relational knowledge to other key buildings—but incoming students and visitors who are unfamiliar with campus will still be confused as to which direction to go. Google Maps is unable to provide a detailed description of Santa Clara University, especially with the recent construction near the library. As neither Google Maps nor campus map kiosks are capable of providing visitors with proper directions on campus, our system aims to provide visitors and incoming students to be directed to their desired building by the highlighted pathway.

Our project aims to bring campus navigation into the 21st century and away from the current system—which seems almost obsolete. The WayPoint application is an augmented reality mobile app that aims to provide a sleek solution to navigating Santa Clara University campus. It will use the compass and camera feature of a smartphone and provide a highlighted path for the user. Our design will eliminate the need for new students and visitors to crowd around campus kiosks and memorize their destinations. Instead, students can simply download our application, which will provide dynamic real-time navigation. One could think of our application as a real-timed and location-tied Google Street View. Our application will not work only within Santa Clara University. Instead, we aim to develop a system that is flexible and scalable to other campus environments such as amusement parks and malls, where directories and Google Maps will encounter the same issues found at Santa Clara University.

Our proposed solution will drastically reduce the hassle of navigating campus for visitors as well as new students, faculty, and staff, and is much more efficient on their end. Once implemented, our design will drastically reduce the newcomers' confusion and effort needed to navigate through campus. Our design is scalable as well and upon completion will be the best way to navigate through Santa Clara University—and hopefully other locales as well.

Chapter 2

Requirements

Requirements enable us to define the system at a high-level and outline's the expectations of our systems responsiveness and functionality. These requirements will also limit the scope of out project and ensures the requirements will be reached. The following figures in this chapter outlines the project's functional and non-functional requirements, as well as the constraints. The requirements for our system can be seen in the tables below.

Functional Requirements
Use camera functionality on phone
Determine the location of user via GPS functionality on phone
Determine the cardinal direction of user
Provide a form to input destination
Display the distance and path towards the destination
Highlight white/gray ground

Non-Functional Requirements
Reliability — The system reliably gets the location of the user, making sure not to miscalculate the path
Usability — The system should be easy to navigate
Availability — The database should be readily and highly available at all times of the day

Constraints
Accessible via Mobile device
iOS is the only mobile OS supported

Chapter 3

Use Cases

In the following figure (Figure 3.1), one can see the various ways in which a user can interact with our WayPoint application. A user will first need to authorize location and camera services. Following the authorization of the aforementioned two features, users can enter a destination and the application will either illuminate a path or determine that the destination cannot be found.

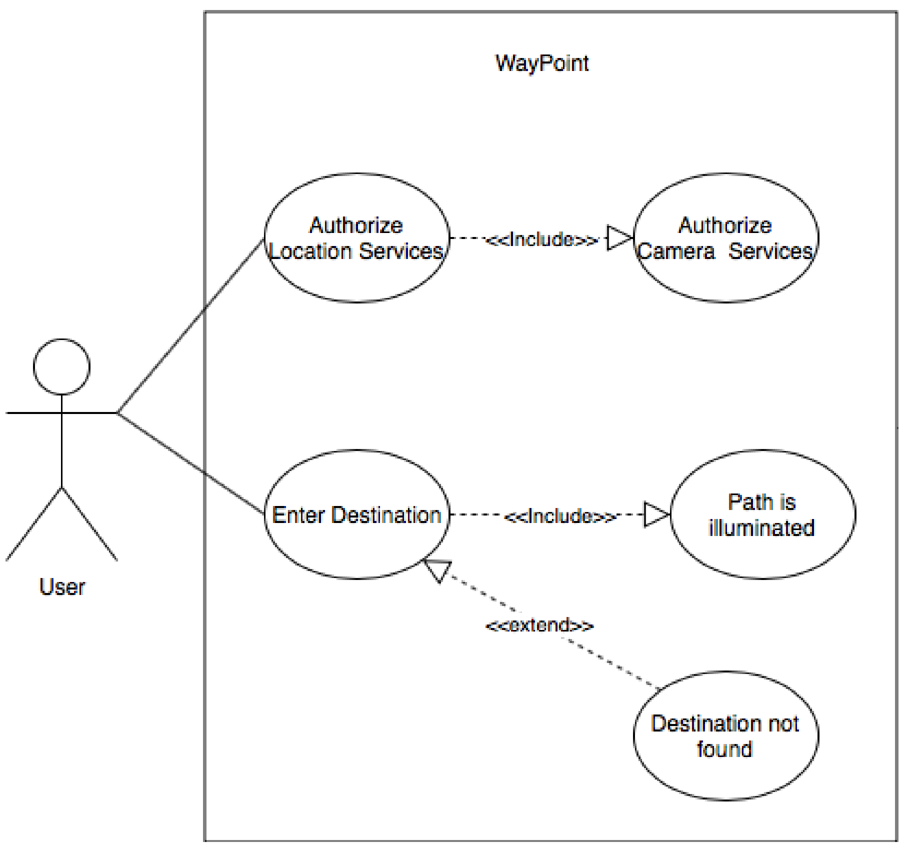

Figure 3.1: WayPoint Use Case

Chapter 4

Activity Diagram

In the following figure (Figure 4.1), one can see the activity diagram for our WayPoint application. First the application will require users to authorize location and camera services. If the user is on campus, the application will prompt the user to enter a destination. If the user is not on campus, the application will prompt the user to go to campus before entering a destination. After the destination is entered the application will return found or not found. If not found an error appears and the user can restart the process. If found, a path is calculated and illuminated via directional arrows.

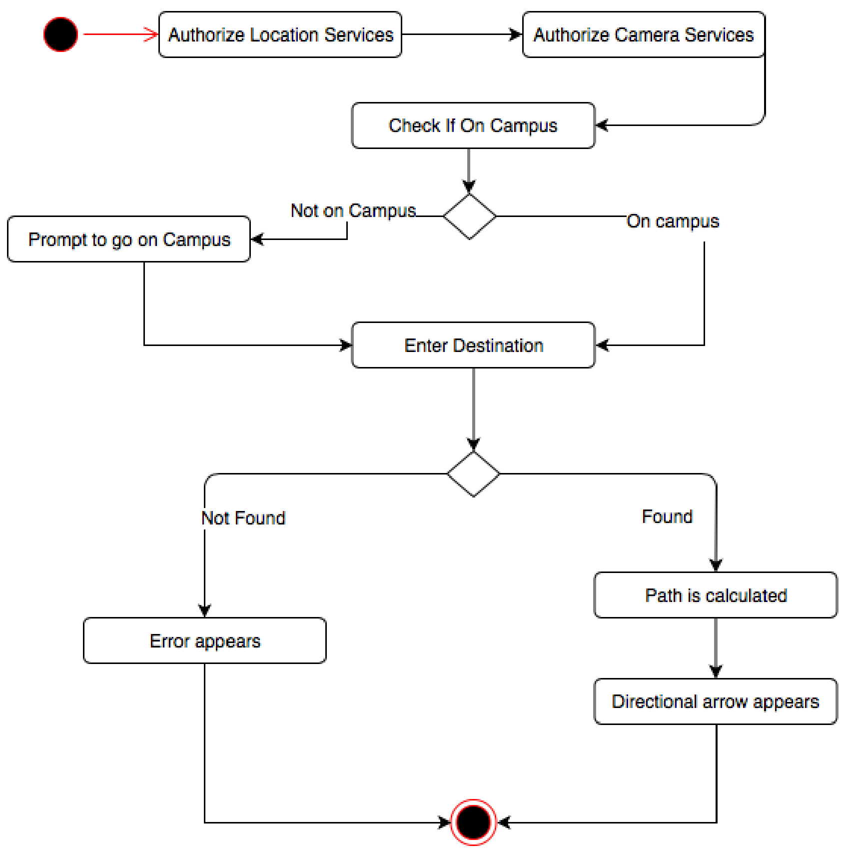

Figure 4.1: WayPoint Activity Diagram

Chapter 5

Technologies Used and Architectural Diagram

5.1 Back-end Software

- Swift - ARkit
  - ARkit is Apple's in-house augmented reality development package. Other augmented reality API's such as OpenCV can be used in iPhone development but require various wrappers and may cause complications in development. OpenCV development on iOS is not as well documented as ARkit. As we are new to augmented reality development, further complications with OpenCV is likely to elongate development time.
- Swift - CoreLocation
  - Apple's CoreLocation service provides a device's location, altitude and orientation which is borderline essential when creating a navigation application with Swift.
- Framework – ARCL
  - ARCL is a framework that combines CoreLocation and ARKit to utilize GPS data and camera motion to map out the world around you. It combines the high accuracy of AR with the scalability of GPS. https://github.com/ProjectDent/ARKit-CoreLocation

5.2 Front-end Software

- Swift - UIkit
  - As Swift is the main platform for iOS development, UIkit will be used to develop an easy to navigate user interface.
- Swift - SceneKit
  - SceneKit allows us to generate 3D objects to generate in the foreground of the AR scene
- Swift - MapKit
  - MapKit allows us to embed maps directly into our application that help the user to navigate the world around them.tg

5.3 Architectural Diagram

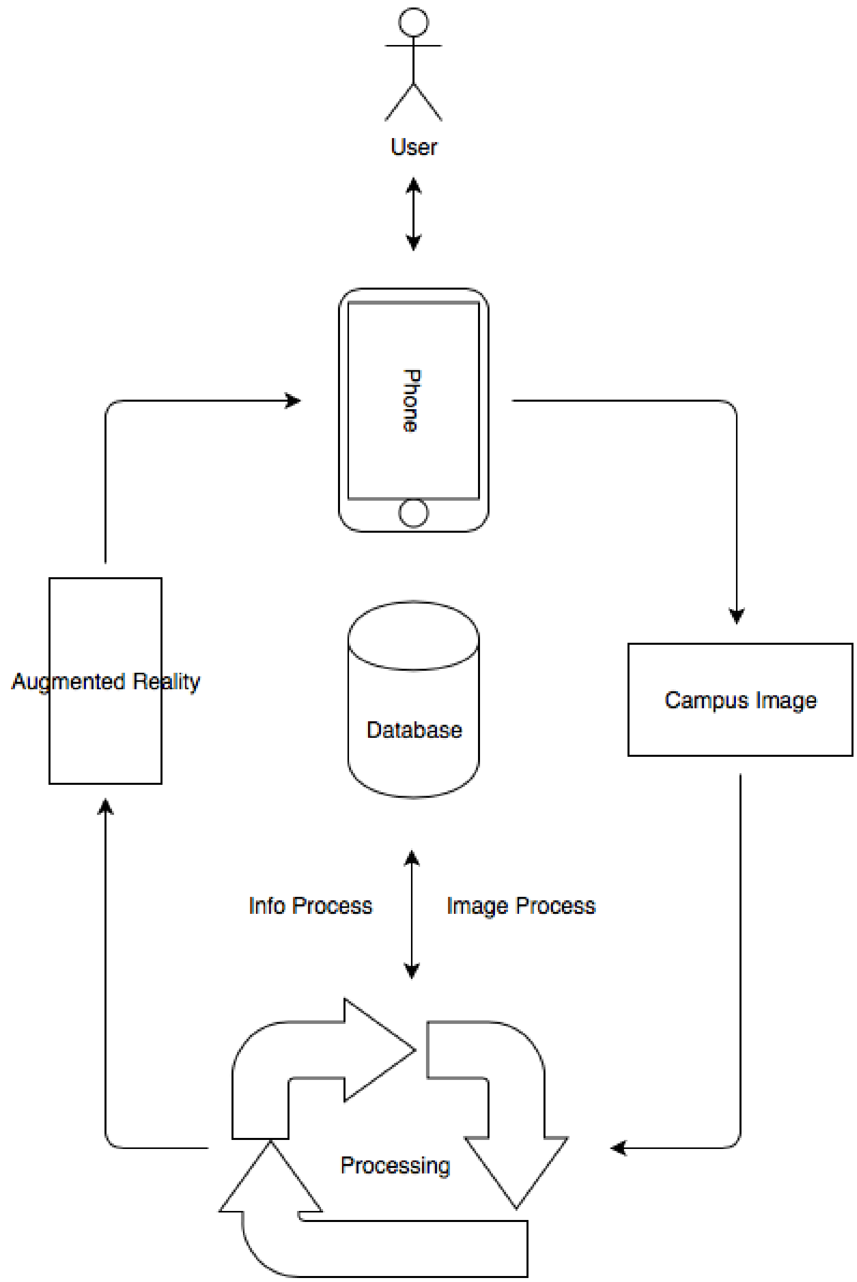

Figure 5.1: Technical Architecture Diagram

Chapter 6

Design Rationale

The UI for WayPoint is simple and straightforward for users to interact with. Once a user allows the WayPoint application to access camera and location services when in use, users can simply choose a desired location that is pinned on the map shown. If valid routes are found to the location, a path is illuminated for the user on the application using both GPS and cardinal directions. A small map is also shown on the top left-hand corner of the iPhone screen to help the user orient themselves correctly. Upon arriving to the destination, the user is prompted vocally that the destination has been reached.

The development environment of WayPoint is on iOS because iPhone GPS development tools are much more accurate and easier to work with. Additionally, iOS development is faster so it is easier to bootstrap a working application within the year. We used the ARCL framework — which combines aspects of ARKit and CoreLocation–for the AR navigation because many of the library applications make designing an application like WayPoint less time consuming and more convenient. Additionally, iOS allows the use of MapKit, a framework that enables the use of Apple Maps API, which helps create the initial user interface that allows the user to determine which location to get directions for.

Chapter 7

Test plan

For this design process our team will primarily use unit testing. Unit testing is done to isolate each component of the system to ensure that each function works independently. Unit testing will be used to find problems early on in the development cycle, rather than later. Once a unit has proven to work independently, it will be added to the rest of the system for integration testing. Integration testing ensures that the system works as a whole. Finally we will conduct acceptance testing with our faculty advisor to determine acceptability of our design. Finally, we will conduct white-box testing by having classmates use the application in order to ensure our system is easy to navigate and intuitive.

During the design process of WayPoint, the team primarily used unit testing. Unit testing is done to isolate each component of the system to ensure that each function works independently. Initially, the MapKit functionality was tested to ensure the user was able to select the desired location correctly. Afterwards, the ARKit functionality was rigorously tested in order to detect horizontal planes and continue to hold the MapKit information in the new ARKit scene. The smaller map along with the highlighted line on the smaller map was tested from initial location to destination to ensure that the line was correctly placed throughout the use of the application. Finally, the line placement on the AR view was tested for it's accuracy to the mini-map view.

Due to being away from campus because of the COVID-19 situation, we could only conduct limited integration testing. One of our group members would go to campus and test that the application worked as a whole and checked different functions. We had also planned to conduct acceptance testing with our advisor and black box testing with various students and faculty (preferably newer ones) around the campus to see how our application could be improved for consumers, but once again, we could not, due to the COVID-19 situation.

Chapter 8

Risk Analysis

This section analyzes the potential risks and pitfalls that our group could encounter over the course of this design process. The table below describes the risks, their consequences, probability (P), severity (S), Impact (I), and possible mitigation strategies. The risks have been ordered in descending order in terms of impact.

Some of the less severe risks we anticipated were communication issues and time. However, we did not foresee the COVID-19 debacle that has occurred over the past few months and as a result were ill-prepared to both communicate effectively and efficiently and manage workloads and time spent together on the project. As a result, the risks ultimately had a much larger impact than we had foreseen. Additionally, the impacts of all the risks as a whole were slightly exacerbated due to the virus and its effects on our society.

Risk	Consequences	P	S	I	Mitigation Strategies
Unfamiliar technologies	Time spent to learn new info	.9	4	3.6	• Research ahead of time • Simpler implementation
Unsatisfactory UI/aesthetics	End users unhappy	.5	5	2.5	• Gather user feedback throughout implementation
Conflicting schedules	Unable to communicate and make decisions	.5	1	.5	• Designate meeting times • Project leader can make decisions
Unreliable GPS location	The user will be placed at incorrect location	.5	.8	.4	• Use cardinal direction w/ a picture of direction to assist user placement
Not enough time to finish	Incomplete project	.5	5	.25	• Prioritize features • Simpler implementation
Data loss	Restart project	.01	10	.1	• Backup frequently • Utilize GitHub

Risk Analysis Table

Chapter 9

Ethical Analysis

The WayPoint application changes the way people will navigate through campuses. Ethical issues arise due to the inability of the application to detect walls, fountains, and other obstructions that may fall within the path. Users who choose to follow the application directions to the tee may encounter such obstructions that can potentially harm the user. To avoid this, an alert after choosing the desired detection was added to the application that warns the user to exercise user discretion as the application may lead you into walls, fountains, ditches, construction zones, etc. Although we cannot determine whether a path is obstructed, warning the user relieves the application of liability if the user does get harmed while following the directions. Another ethical issue that arises with the use of this application is due to the reliance of GPS capabilities throughout it's use. Tracking the user's location Senses the phone battery quickly and can inhibit the use of the phone for long periods of time. In order to avoid constantly tracking the user's location, the application only gets user location and provides directions when the application is actively in use. When in the background, the application no longer asks for the user location. This limits battery usage and ensures the user will be able to use the application throughout their day within campus grounds.

While this application encounters and addresses multiple ethical issues, some existing problems are resolved with the development of WayPoint. At times, first-time visitors to campuses will have large maps that they are carrying. Some visitors walk as they are trying to read the map. This can result in the visitor walking into a pole or into another person. WayPoint alleviates the need for the user to constantly be looking at a map by providing a mini-map at the top of the phone screen along with the camera highlighting the direction in which the user needs to go. This way, the user is always aware of what is in front of him. Furthermore, these paper maps given out to visitors on large campuses contribute to environmental issues. WayPoint eliminates the use of a paper map, thus reducing the amount of paper waste found on campus. Visitors instead could download the application and remove it once they leave the campus.

Chapter 10

Conclusion

10.1 Summary

We created an accessible navigational augmented reality application for the iPhone by utilizing the phone's camera and location services. Alongside the augmented reality navigation, audible directions was also provided. The user interface of the initial destination selection section of the application provides the ability to choose many buildings on the Santa Clara University campus. While the initial map and user interface was easy to work with, the location detection accuracy was limited and created many jitters and movement of the directional line on the augmented reality section.

10.2 Lessons Learned

Throughout our design process we did basic research on technologies and documentation available to us at the time. This, in combination with our unfamiliarity with every technology used in the design, became a larger issue during the development of the application. The lack of prior knowledge slowed down development time greatly and pushed deadlines back. Further delays were caused due to current public safety events.

The Covid-19 situation put stress on the development of the application. All team members were not comfortable with remote work. As such, communication between team members and progress slowed down. We created a schedule along with weekly progress review meetings to push through the latter portion of the project. We learned that remote work requires more communication and a good understanding of source control. Ensuring that we were working on the most updated version of the application became an issue a few times during our remote work sessions.

10.3 Future Improvements

While our application provides a good proof of concept, many improvements can be made on the application. The location detection and placement of the directional line was up to five meters inaccurate. While navigational assistance was still possible, the aesthetics of the application was drastically affected. Ensuring the placement of the directional line is correct would be a key improvemnt to be made in future iterations. Further accuracy changes could also help create other portions of the application that improve the overal user experience. With improved location accuracy, providing annotations above the building on the augmented reality view would allow the user to know the direction in which the building is by looking at the correct cardinal direction.

Furthernmore, improvements to the initial map interface could hasten the user's experience. A search bar for finding the correct building by name would enable newcomers to instantly get directions to a certain building without having to look for it on the initial destination screen. Our application also did not show the directions to the building in text. Showing the directions in text, along with visually through the directional line and aurally provide directions in three different sensory channels.

Appendices

Code Repository

All code for WayPoint is available at this open repository: https://github.com/jperez08/WayPoint/tree/jpBranch2.0