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Integration of Personnel Tracking in an Augmented Reality Environment

Project Plan

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List of Definitions

CSI/Channel State Information: Properties of a communication link, including information that describes how a signal propagates from the transmitter to the receiver and represents the combined effect of, for example, scattering, fading, and power decay with distance (Wikipedia)

1 Introductory Material

1.1 Acknowledgement

We would like to thank Daji Qiao for pointing us in the right direction when it comes to our wireless communications technologies and coming up with viable tracking solution.

We would also like to acknowledge Andrew, our client. He always believes in us and gives us hope whenever we would meet. He is the perfect client, giving the team concise requirements and being understand of our lives outside of senior design.

1.2 Problem Statement

Problem Statement: There are inherently a lot of problems with not knowing where people are located at. Whether they are in the location they say they are, or if they are missing and trying to find them. When workers can't be located, there are safety concerns if you are working with something dangerous that could harm somebody such as demolition on a building. It can also mean people can get hurt doing something they shouldn't be, and lie because you have no way of seeing where they were and what they were doing.

Solution Approach: The goal of the project is to create a Hololens application that shows a live map of where different people are at any given time. The personnel are tracked through a small token, which is attached to issued Personal Perspective Equipment (PPE), that communicates with a distributed tracking system that relays data to the Hololens that a supervisor will utilize for monitoring purposes. This will allow a supervisor to check the environment before doing something that could cause harm to someone in the vicinity. It will also allow them to make sure their workers are held responsible for where they were and what they were supposed to be doing.

1.3 Operating Environment

Our end product will have to work in an outside and inside environment. This means it will need to endure almost all types of weather conditions. With this in mind, it will have to be water resistant, or have a case that is water resistant. It will need to be able to work in dusty and dirty environments, and be able to withstand a reasonable amount of force applied to the token. It will also have to endure very cold temperatures, as well as hot summer temperatures. For the inside environment, it will also have to work well without being in the way of the typical indoor operations, as space will be limited.

1.4 Intended Users and Intended Uses

This project's outcome will be marketed towards companies in construction companies and the those who want to ensure that outdoor worksites are running efficiently and safely. The players in our proposed solution will be all personnel who enter the active construction site and the supervisors who will be monitoring the location of the personnel using the hololens either on site or the company's headquarters.

The areas that this product will prove useful is any outdoor environment where keeping track of personnel location will ensure their productivity and well being. The solution will be very versatile and will cater to the needs the clients we outfit it for. In the case of emergencies, it will be vital for responders to know the location of personnel on the worksite the facilitate the rescue process. Another intended use case is the improvement of low efficiency worksites. Using our system worksites will be able to improve their effectiveness by ensuring that workers are in their correct positions accomplishing their jobs in a timely manner.

1.5 Expected End Product and Other Deliverables

1. 491 Deliverables
    a. A proposed solution that include limitations, software and hardware choices, and a work plan (sprint backlog items) to complete by the 20th of December.
    b. Hardware with embedded software that act as tokens to send positioning data back to the server, which we will have to present to our client by the 20th of December.
    c. A backend service that allows for collection of data from tokens, and handles the information as well as sending it forward for the next piece of our project.
    d. Simple web interface to track accuracy of the tracking system, which will be up and running when we get the initial hardware component down.
    e. Access to the git repository that contains all the documents from the semester and code written for above systems, which is currently being delivered to the client on a regular basis, whenever something new is uploaded.
2. 492 Deliverables
    a. A work plan for the rest of the project that includes the exact schedule of all the tasks left to complete, as well as documenting who's responsible for each part of the product, deliverable by February 15th.
    b. A modular case for hardware that can fit in multiple areas on a construction worker, deliverable by March 15th.
    c. An application for the Hololens that gets information from backend service and displays a 3D map with personnel tracking, deliverable by May 1st.

2 Proposed Approach and Statement of Work

2.1 Functional Requirements

- Must track at least 6 people in playground-sized environment (20 x 20 m): the end goal is to be able to track our group successfully in a small coned-off simulated outside work environment.
- Must be accurate within 0.5 - 1 meter: the tracking must show the avatar as accurately as possible to track people in real time.
- Token relays info to Hololens: Create tokens that relay info to hololens in readable format
- If active sensor, battery life = 1 work day (10 hours): needs to be able to last an entire workday without being charged.
- Sensor communication range: 10 m: must have a minimum range of 10 m to limit the number of sensors needed.
- Real Time tracking: acceptable delay of 1 second: if there is too long of delay the positioning will not be accurate on a moving target.
- Store 1 day's worth of data: this will help to keep a heat map to show where the worker has been for the past day, allowing supervisors to keep workers honest about where they spend their time.
- Track people moving at maximum of 5 mph: this will allow the positioning to still be accurate on someone moving at a reasonable speed.

2.2 Non-Functional Requirements

- Realistically-sized token: wearable device (preferably attached to PPE)
- Token must be a water resistant, withstand external forces (durability): main use case is a construction site for our phase, so it must be durable and be able to withstand outside weather conditions.
- System secured so inaccessible to unauthorized users: must be secure so others cannot gain access and view positioning of workers, very negative consequences in future phases.
- Create a system that is scalable to larger projects: must be able to scale for projects that have a lot more than six workers.
- Maintainable for length of project: for construction site, must be able to be easily maintained for length of construction project, so months at a time.

2.3 Standards

IEEE 802 Standard

This standard is relevant to wireless local area networks. This is relevant to our project because we are working with wireless networks. Our practices will not be considered unethical by this IEEE standard.

http://www.ieee802.org/

Microsoft C# Coding Conventions:

There is not a standard created for the C# language according to Microsoft. However, there is a guide that includes naming conventions, layout conventions, commenting conventions, and Language Guidelines. These guidelines are not technically standards and they are not approved by standard organizations like IEEE or ABET. Since this is a coding standard, we will not be doing any unethical practices by standards. These conventions are important for our project and we will use them when we program in C# for the Microsoft Hololens application we will be building for our client to visualize the employees they are tracking.

https://docs.microsoft.com/en-us/dotnet/csharp/programming-guide/inside-a-program/coding-conventions

Python Style Guide:

Python provides a style guide for code layout, comments, naming conventions, and use of whitespace. Again, this is not a standard administered by IEEE or ABET. These conventions are important for our project and we will use them when we program in Python for the Raspberry Pi we are planning to use for our hardware component.

https://www.python.org/dev/peps/pep-0008/

2.4 Technology considerations

The strengths of our technology decision for localization, Channel State Information or CSI, is that it is very accurate (with 1 meter) and highly configurable. The weakness is related to our lack of experience with this and similar technologies.

An alternative is picking a simpler but less accurate technology; however, we are not willing to compromise on quality and therefore we have decided to still implement CSI for our project.

2.5 Safety considerations

Safety is a huge concern for our project. In regards to the tracking devices we will outfit each worksite personnel with, we have discussed it being small enough to not interfere with their work. This factor has a lot to do with safety for the fact that if it was too heavy it could cause strain on the wearer. Another consideration we have made for our project is that we will be limited the amount of sensors and additional infrastructure that we will be adding to the construction site.

2.6 Previous Work and Literature

The tracking portion of our project is not a novel idea. There has been many attempts at tracking personnel and localizing objects in familiar and unfamiliar environments. For the initial phases of the project we looked into solutions that used gps before switching focus to an entirely Wi-Fi based approached as it has the capability to support indoor localization while GPS does not. The WiFi-based approach have decided to try and implement is one that relies on channel state information. We will be using a localization algorithm detailed in *SpotFi: Decimeter Level Localization Using WiFi* [1]. Although this paper has been published fairly recently, it is one of the leading papers in localization based on CSI and has been cited in many other papers already. One such paper we draw additional inspiration from is *Decimeter-Level Localization with a Single WiFi Access Point* [2]. These papers will be the guidelines for implementing our own personnel tracking system.

2.7 Possible Risks and risk management

One risk we may face is exceeding our allotted budget. While our budget is significant ($3000), we could potentially be purchasing another Hololens device, which would cause us to exceed our budget. However, we can mitigate this risk by using the Hololens device that our client currently owns since we will not need to use it extensively until next semester when the other senior design team will be done using it. We can also mitigate the budget risk by selecting alternatives to hardware the cost less (for example, we used the Raspberry Pi Zero as oppose to the Adafruit Flora for the hardware token).

Another risk with this project is that we are working with technologies that our team has little to no experience with. For example, we are using the Microsoft Hololens, and in order to develop for it we need to use Unity and C#; while one of our team members has used Unity and some others have used C#, none of us have a lot of knowledge of both. Additionally, in order to do tracking, we are using a technology called Channel State Information or CSI. Understanding this fully is challenging and requires a decent hardware background, which none of our team members had. In order to manage this risk, we have been working with our advisor, who has expertise in CSI, as well as doing extensive research into CSI and how to implement it.

2.8 Project Proposed Milestones and evaluation criteria

Key Milestones in the project:

- Choose which hardware we are going to use for the project
- Have an initial working prototype for tracking location

- Develop initial Hololens application to display location information
- Design experiment for final demo and prepare our final demo

2.9 Project Tracking Procedures

To track project progress through the course, we will be using Git's issue tracking system for development work. For work that is not development and deals with some of the hardware, research, and documentation aspects of our project, we will be using Trello, a virtual Scrum board. This will allow us to keep track of both our technical and non-technical aspects of our project and be sure we complete all of our tasks and hold each team member accountable.

2.10 Objective of the Task

The objective of our project is to have a hardware/software product to deliver to our client that we will design and implement using the Microsoft Hololens, a Raspberry Pi Zero, an Intel 5300 CSI chip, and a server. We will program the software in C# and Python.

2.11 Task Approach

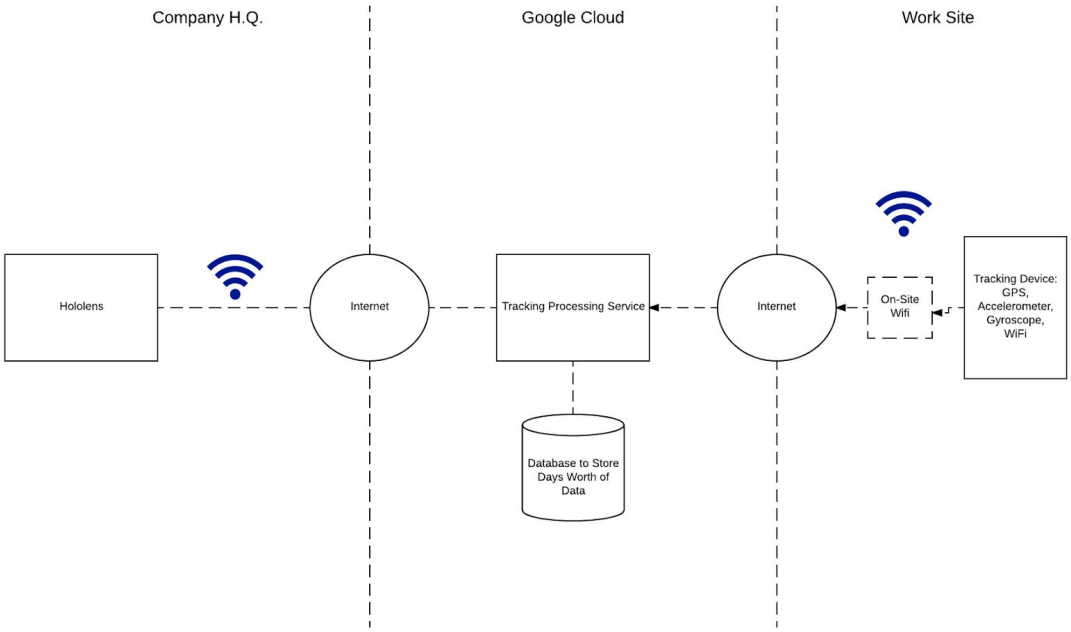

Figure 1: Architecture diagram

2.12 Expected Results and Validation

The desired outcome is a Microsoft Hololens application that works as intended to track individual employees on a construction site. The desired outcome for tracking accuracy is within 1 meter. Additionally, it is a desired outcome that we create a product that will not interfere with our end user's PPE and required equipment and have a Hololens application that will be easy for a construction manager to use.

We will confirm that our solutions work by testing the accuracy with the CSI technology data acquisition tools. We will confirm that our software works as intended through unit testing and user testing.

3 Estimated Resources and Project Timeline

3.1 Personnel Effort Requirements

Task	Project Effort Required to Perform Task Correctly
Set up laptop/server for our system	We have been working on this task for 2 weeks already and it will take an additional week, putting the task at 3 weeks total for 4 hours per week
Configure Raspberry Pi Zero hardware token	This task involves programming the Raspberry Pi. We have a decent amount of knowledge in the programming language we will likely be using, Python, so we estimate it will take approximately 2 weeks for 10 hours per week.
Implement CSI code into our system	This involves writing code based on open-source implementations and and setting up a hardware configuration that works with our code. Since we have very little experience with CSI, we estimate it to take 3 weeks for 10 hours per week.
Put together prototype of our product	We will need to design an experience to show our system works and act as a proof of concept and it will take about 5 days to a week if all preparatory work is complete for 10-20 hours.
Brainstorm improvements to our prototype	This involves thinking of ways to improve our prototype for first semester based on how our presentation/demo goes at the end of fall semester. This should take the duration of winter break, or 3 weeks for 6 hours per week.
Implement improvements to our prototype	This involves making changes to our code and hardware based on the improvements we brainstormed. It should take 1.5-2 weeks to complete for 10 hours per week.
Develop basic Hololens applications	This involves working on the Unity and C# aspects of the Hololens application and should take approximately 2 weeks at 10 hours per week.
Test Hololens application	This involves doing unit tests on the code and user testing with the Hololens device. It should take about 1 week at 10 hours per week.
Configure app with server and hardware	This will involve integrating the hardware (Raspberry Pi token and localization setup), the server, and the Hololens device/application and should take approximately 2 weeks at 10 hours per week.
Integration testing on Hololens/Server/Hardware system	We will be testing how the software we wrote for the Hololens works with the Hardware/Software for the token, the CSI configuration, and the server by using it

	and performing more unit tests. This should take 2.5 weeks at 5 hours per week.
Make improvements to the system	We will do bug fixes and make changes based on what we found in our integration tests. It will take 1.5 weeks at 10 hours per week.
Perform more integration tests	After making improvements based on the first round of tests, we will do another one to make sure the new code did not affect the old code/system parts that were working and ensure bugs have been fixed. It will take 1 week at 10 hours per week.
Put together final demo	Design experiment to demo in our final presentation for Senior Design. It will take 2-3 weeks at 10 hours per week.

Table 1: Tasks and personnel effort requirements

3.2 Other resource requirements

To get our product to work, we have been given four Intel 5300 WiFi chips that allow us to collect the channel state information. We also need tokens for the personnel to carry around that communicate with the access points, which we are in the process of developing. We are trying to use raspberry pi's as the token, as they have a lot of customization available. We also have several laptops to work with as either our server or towers for the CSI chips to communicate with. In addition to this, we will need our site to have WiFi access across the entirety of the area. This will be provided by our client. The final thing we will need for our product is a Microsoft Hololens to show our data in, which has already been provided by our client.

3.2 Financial requirements

Our team has been allotted a budget from our client, Optical Operations LLC, to use for this project. Our budget for hardware and supplies is $3000. Optical Operations LLC has also allowed us to use a Microsoft Hololens device for our development that was purchased in a previous semester. This will prevent us from having to make the large investment of our budget in buying a Hololens device for our project.

3.3 Project Timeline

Our steps for this project for Fall and Spring semesters, as well as our Gantt charts are listed below.

3.3.1 First Semester

1. Research many solutions to solve the problem of tracking personnel in an outdoor environment
2. Work with 492 team to better understand how to design mixed-reality application
3. Review tracking solutions with advisor and client
4. Determine top solutions listing pros and cons of each
5. Order parts for best solution while writing corresponding software
6. Implement and demo tracking solution prototype

3.3.2 Second Semester

1. Prototype for tracking portion of the project is completed at start of semester
2. Begin work on Hololens application
3. Work on connectivity between tracking tokens, servers, and Hololens
4. Test how all parts work together
5. Discover errors and make changes after collaborating with the client
6. Repeat testing and fix different errors
7. Make finalized product
8. Demonstrate final product

Gantt Chart for the Remainder of Fall Semester:

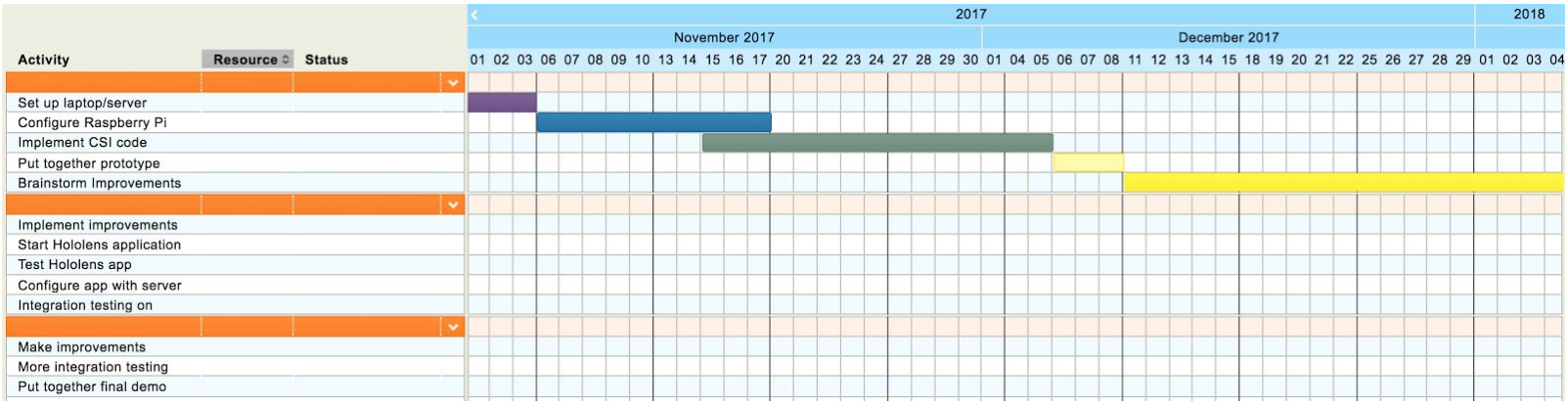

Figure 2: Fall Gantt chart

Gantt Chart for Spring Semester:

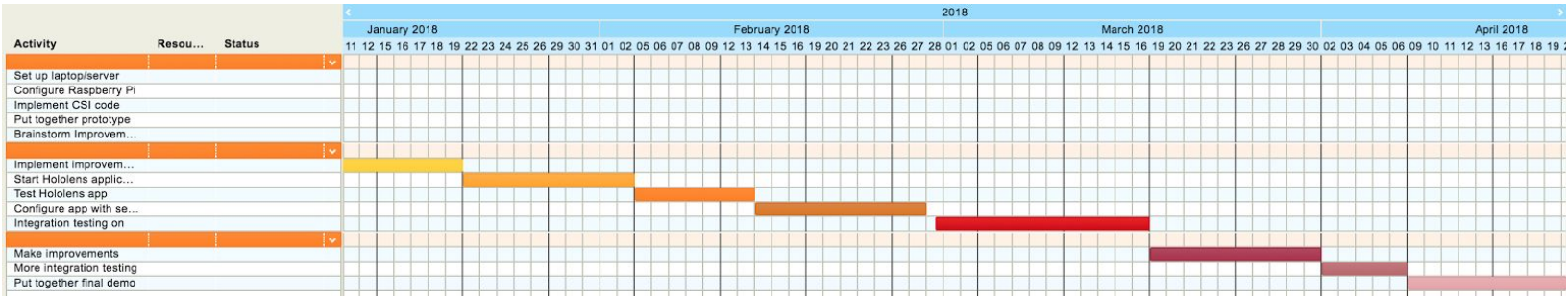

Figure 3: Spring Gantt chart

4 Closure Materials

4.1 Conclusion

Our goals for this project are to enable our user, a construction supervisor, to visualize where their employees are at a given time for safety purposes. We will accomplish these goals using various cutting edge technologies that are proven to work well for this type of localization. Our solution is to use a Raspberry Pi Zero for the hardware token and use CSI, channel state information, to achieve tracking of personnel and the Microsoft Hololens for visualization. We will track progress using Git Issues and Trello, and working in accordance with our project schedule as much as possible. Overall, we believe we have a strong start on our project and will continue adhering to our project plan and working diligently with the oversight of our client and the guidance of our advisor to solve this problem and accomplish our goals.

4.2 References

1. Kotaru, Manikanta, Kiran Joshi, Dinesh Bharadia, and Sachin Katti. "SpotFi: Decimeter Level Localization Using WiFi." *Proceedings of the 2015 ACM Conference on Special Interest Group on Data Communication - SIGCOMM '15* (2015): n. pag. Web.
2. Vasisht, Deepak, Swarun Kumar, and Dina Katabi. "Decimeter-Level Localization with a Single WiFi Access Point." *Proceedings of the 13th USENIX Symposium on Networked Systems Design and Implementation (NSDI '16)*. CA, USA, Santa Clara. N.p.: n.p., 2016. N. pag. Web.