A Robust Tracking Method Using Smartphone Sensors

PROJECT PLAN

Team Number

27

Client

Optical Operations

Advisers

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Team Members/Roles

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1 Introductory Material

1.1 Acknowledgement

Sdmay17-29 would like to thank Andrew Guillemette and his engineers from Optical Operations for their contribution to our project. Andrew contribute significant assistant informing our team with technical advice and equipment contribution.

1.2 Problem Statement (2 paragraphs+)

In the construction industry there is no form of tracking personnel and machinery to help keep track of what goes on in a specific zone at a work site. Construction sites are very dangerous and there is no real time solution that keeps track of each individual. GPS accuracy is within ± 3 meters and doesn't always work indoors because there is a lot of interference with steel, concrete, and large objects (skyscrapers). Many large tech corporations have tried to improve indoor navigation but have been unable to find a scalable solution.

The purpose of our project is to make an application that can track an individual indoors within ± 1 meter as a proof of concept so our client can create a prototype that can be used as a construction site tracking solution.

Our goal is to create a mobile application that tracks construction workers and estimates their current location using two forms of tracking. Our solution must locate a user within ± 1 meter utilizing phone sensors. To achieve our goal, we will assume that the GPS signal on the cell phone is very limited. Therefore, we must rely on secondary phone sensors to calibrate the users' position. the data obtained will be monitored with the Microsoft HoloLens.

1.3 Operating Environment (one paragraph +)

Our operating environment is going to be for a construction site. Our end product will be using a mobile device application to gather a user's location with little to no assistance with a GPS sensor. We will be using other secondary sensors on the phone and bluetooth beacons to track the user location inside buildings. Due to extreme weather and dangerous conditions our device must secured on the person's body. The device must not impede the workers ability to perform on the job site. The mobile device will track accident reporting and identify if a collision has occurred.

The consumer must wear this device at all times while on the job site. This application must be able to store the location data where there is no access to a connection for a long period of time (4hr) and then be able to update that data to a server when we have access to an access point. Also, the device must not be too CPU intensive where the device can last for an 8-hr day.

1.4 Intended Users and Intended Uses (two paragraph +)

For this specific project our intended user base is construction workers. Our smartphone application will track its users using a combination of the phone's sensors. Doing so will provide a level of supervision over construction projects. It is our hope that this additional level of supervision can be useful in solving logistics issues. It will also provide a record of daily work, which will detail the productivity and current progress of the construction project.

Branching out from the Construction industry, this method of smartphone tracking could also have applications in other fields, such as medicine. For example, Doctor's could use the application for monitoring their patients. The app could send alerts to the Doctor if a patient has left their room, or gotten out of their bed.

1.5 Assumptions and Limitations

We assume that all equipped phones have the following sensors:

- Magnetometer
- Gyroscope
- Accelerometer

We also assume that the audience will be either walking or running when wearing the device. This algorithm is not meant to track people riding in vehicles.
To ensure the accuracy of our tracking algorithm, we require that user's wear the smartphone device on their right arm. We are also limiting the environment to Durham. Aside from this, the application is expected to work regardless of a user's trajectory, or type of movement. They can be walking or running

1.6 Expected End Product and Other Deliverables

The end product will be an Android application with the following functional requirements:

- Will track a user within an accuracy of 1 meter
- Will run on all Android phones which have SDK 21 (Lollipop) or higher
- Will use the phone's Magnetometer, and Gyroscope to determine the direction of motion
- Will use phone's accelerometer to measure movement
- Will use the phone's speaker's in combination with Bluetooth to implement a time dilation of arrival for determining phone's distance from a sound source
- Will include a web interface which displays the phone's movement in relation to Durham

2 Proposed Approach and Statement of Work

2.1 Objective of the Task

We intend to develop software that can be used to track the movement of construction workers while on-site. This will be done by having the workers wear phones on their arms, and activating an app that we will create. This app will use the various sensors available through the phone to determine how the subject moves through the site. It then relays this information to a server, where it can be translated and used for a visual representation in Hololens. The application should be able to store the tracking data locally in the event that it is disconnected from the network, and is unable to upload for a time.

2.2 Functional Requirements

Requirement	Title
Indoor/outdoor user tracking	The software shall track 3 individuals following separate trajectories which span through both indoor and outdoor locations (proposed test site is in and around Durham).
Movement sensitivity	The software shall track user's moving at basic walking and running speeds.
Store tracking information in the internal device	The software shall relay sensor information from the cellphone device, to a server using Wi-Fi connection.
Distance Accuracy	The software shall track the location of the user within a radius of $\pm$ 1 meter.
Delay accuracy	The shall allow a 5 second delay to run the data collected through a smoothing/prediction algorithm to produce an estimation within 1-meter radius.
Drift accuracy	The Software shall allow a radius of 1 meter.
HoloLens	The software shall use the location data stored from the data based to monitor construction vehicles/workers movement within a conference room.
Monitor accuracy	The converted translation location recorded on the cellphone shall be displayed within 1 minute from when the location was captured.
Bluetooth sensor	When the Bluetooth sensor on the cellphone receives a signal from a beacon, the software shall update the users position.

Low Battery notification	If the battery on the cellphone device gets below 10%, the app shall send alert to the HoloLens
HoloLen Low Battery notification	The HoloLens shall notify the user when its battery is below 10%.
HoloLens notification	If the database receives an update, then it will notify the HoloLens.

2.3 Constraints Considerations

2.3.1 NON-FUNCTIONAL REQUIREMENTS

Battery	The android application shall run in a background service, and last for an entire work day.
GPS sensor	The tracking algorithm shall work without the user of GPS.
	The tracking device shall be comfortable to be worn for the entire work day.
	HoloLens simulation shall be used in indoor conference rooms

2.3.2 CONSTRAINTS

The phone shall be strapped to the right arm in a vertical position with the screen facing outwards.
The application must be turned on before going inside a building.
There shall be no movement until the application has been initialized and calibrated to the user's current position.
The cellphone shall be an android device

2.4 Previous Work And Literature

Our project consists of tracking individuals more accurately then the current GPS system which is 3 meters. Our client's last team used a raspberry pie API that used RSI triangulation (WiFi) which turned that information into latitude and longitude coordinates. The solution that the team provided wasn't very accurate because of floating point inaccuracy conversion from RSI values to longitude/latitude coordinates. Our team performed a market analysis of indoor tracking techniques that utilize hardware sensors.

The first piece of literature that was read refers to reference 7, an indoor tracking solution that utilizes insole sensors. To be able to track a location this literature uses insole sensors that can estimate the walking distance by counting walking strides to detect human movement. They used accelerometer and pressure sensors to record each movement. They then transmit the data to a cellphone that filters out the error and records the distance that the user has walked. The advantage of this approach is it that uses a better method for tracking the footsteps of a user instead of using the phone sensors to track the footsteps. The cons of this approach are that there are still some significant errors when they walk over 80 meters. If a user walks less than that then the error accuracy is under 1 meter which is a requirement of our project. Also, our client wants a solution where there is less hardware overhead for the company to maintain (reference 7).

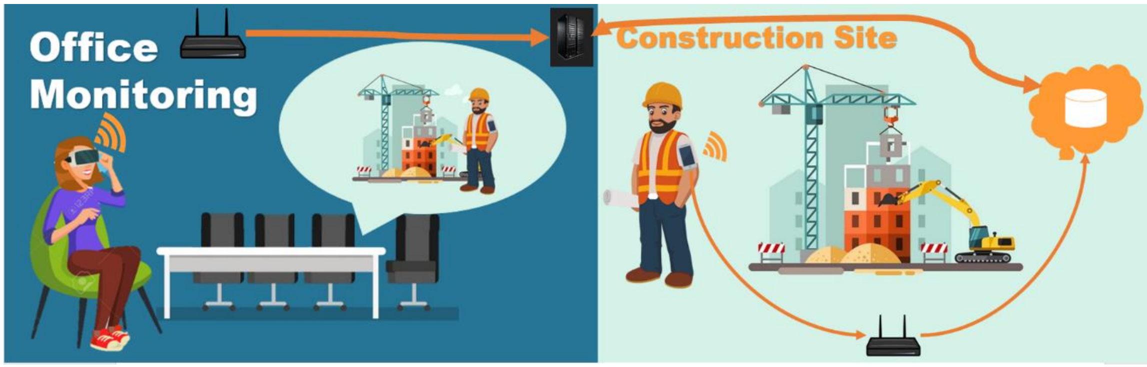
The second piece of literature refers to reference 1, a human posture tracking solution that uses the accelerometer, gyroscope and magnetometer to determine the different posture (walking, running, etc.) the user is currently in. Their solution operates at lower frequencies by using signal filtering which could be an advantage for our team because that could help reduce battery life. They use the gyroscope to determine how much the body was displaced over a certain period of time. The gyroscope gives you the acceleration of the different axis. To find the change in posture over time by double integrating the acceleration to find the new position. This technique has a big advantage over magnetometer because there are a lot of errors due to different electric fields in a room. An example would be if there were a lot of user in the same room that are producing magnetic fields. The discovery helped our team determine if using the gyroscope and magnetometer combination can be used to determine orientation. Landmarks can be used to compensate and adjust inaccurate user locations.

The third piece of literature refers to reference 4, a pedestrian tracking solution that uses the accelerometer, magnetometer and step detection to determine if a user made a 90 degree turn. The literature focuses on having a map and used the dimensions of a building to determine where a user was at. Their solution uses machine learning to determine if a user turns down a different hallway. By know where a user is from an earlier state you can predict the location they will be at in a later state. The disadvantage of this approach is that this would be very processor heavy and take to much battery for our cell phone solution. The advantage of this is we could send this information to a server that processes the information and then broadcasts it back to the phone.

Our team will be looking at the techniques these literatures have done to develop a unique solution that hasn't been done before

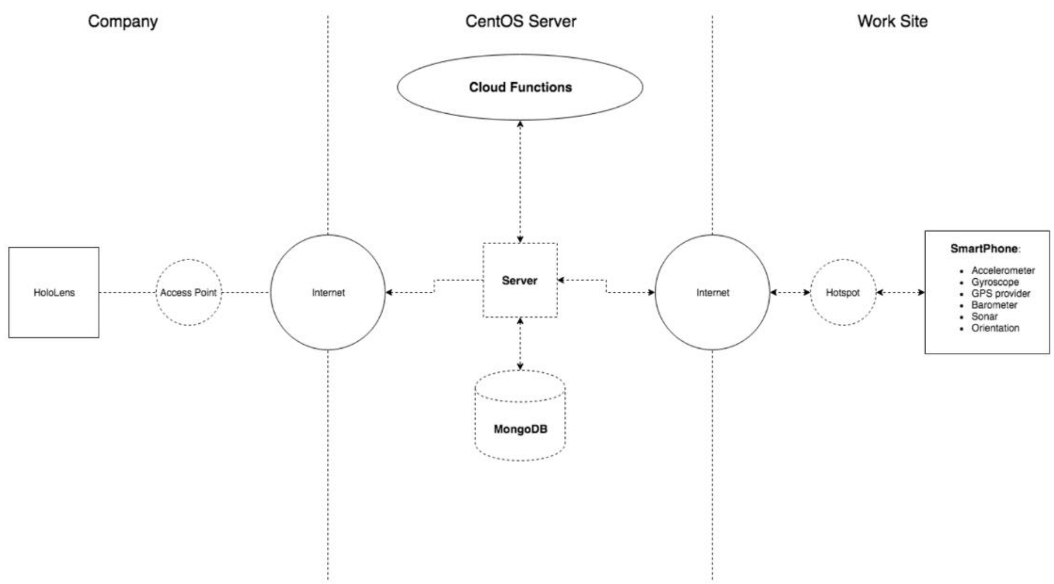
2.5 PROPOSED DESIGN

Discuss possible solutions and design alternatives.



Our project consists of two components: the mobile application that is responsible for collecting secondary sensor data from the cell phone device and convert that into X,Y,Z coordinates that will be sent to the database. The HoloLens is responsible for collecting the real time locations from the database and display it in real time on 3d objects the device.

In our conceptual sketch you have the worksite with a smartphone attracted to a construction worker. The phone will use the phone sensors to determine the user current location within 1 meter accuracy and convert it into X,Y,Z coordinates. It will then use an WiFi access point to connect to the database and send the data collected to the MonoDB. The HoloLens will use the Wifi access point to connect to the server using web sockets and request the current locations of the vehicles/workers on the construction site and then render it on the HoloLens.



2.6 Technology Considerations

The primary technology considerations are what phone to use. At the very least it needs to be an Android with all the required sensors (accelerometer, gyroscope, magnetometer, ect.). Additionally, a longer battery life would be appropriate due to the many hours it would be expected to run per day. Battery packs could be used in a full implementation to extend duration. The other consideration is a Microsoft HoloLens. There is little a lot less flexibility being that there is only one option.

2.7 Safety Considerations

No safety considerations will have to be taken that are outside of normal behavior. For the scope of our project, there will be no safety issues so long as the users behave normally. Even in the case of the project being implemented on a construction site, there would be no "new" safety consideration. While a construction site may have dangers, this project won't introduce any new risks.

2.8 Task Approach

At the beginning of the semester, our client, Andrew, proposed his idea for a product to track someone's phone without relying on GPS and still have an accurate reading. The result we lead to managers on construction work sites to be able to see where every employee is all at the same time. Using an android app, the phone will access the sensors and calculate the path the person is moving relative to the entry point. To minimize the latency of the information relay, there are multiple checkpoints that will send data periodically and at the same time correct any drift.

2.9 Possible Risks And Risk Management

Few risks are foreseen for this project. Due to the need for this system to have many phones in a construction area and mobile for several hours each day, there is risk for these phones to be dropped or struck and damaged. This threat can be minimized by using bands that are secure, so the phone won't fall, and padded, so that the phones aren't damaged by bumps. The equipment shouldn't pose any risk to users' safety beyond the risks they would otherwise face. Our client is risking different investments, such as time and money, in entrusting us with this project. The risk of losing these in the event of an inadequate product can be controlled by working hard to create a worthy product. It can also be lessened by avoiding expensive purchases whenever possible, either finding cheaper alternatives or using equipment we already own.

2.10 Project Proposed Milestones and Evaluation Criteria

1. Meet client
   Meeting with the client would include meeting them, but also figuring out what their needs are. Emphasizing what their problem is, and figuring out how you can solve their issue.

2. Develop relationship with client to continue product production
   Continue talking with the client to build a relationship. This is needed for continued success of the project.

3. Ideating - concepting ideas for the solution
   Generate ideas on how we can solve the clients issue. These need to meet their needs and requires feedback from them. We don't want to create a solution we think is right, but does not meet their needs.

4. Create design requirements
   Functional and nonfunctional requirements of the project as well as things that will not be included with the final product.

5. Create designs for software
   Create drafts of what the final product should look like. This should be a prototype and be designed to fail quickly. We would need to rapidly iterate what the final product should look like.

6. Prepare for product demo
   Present data to client to get approval for a prototype to be created.

7. Create prototype
   Get code to a state in which is acceptable to present to the client. Present to the client for approval to move forward with product.

8. Reiterate on prototypes (phase gates)
   If prototype fails to meet expectations, continue to iterate on the prototype, or scrap the prototype to meet client needs.

9. Work on project
   This is the actual design and coding phase of the full project. Kanban, sprints, and or other project management will be utilized here to complete internal milestones for this.

10. Testing
    Once the project is approved, we will conduct testing to ensure quality for use with the client.

11. Go Live
This is the final project delivered to the client. All needs have been met or modified to meet client needs for a final project.

2.11 Project Tracking Procedures

- Trello
  - For managing Kanban tasks
- Github
  - For tracking code production and updates
- Weekly Status Reports
  - For monitoring weekly accomplishments, and updating timeline as needed
- Slack
  - For group messaging
- Google Docs
  - Shared documents for weekly reports

2.12 Expected Results and Validation

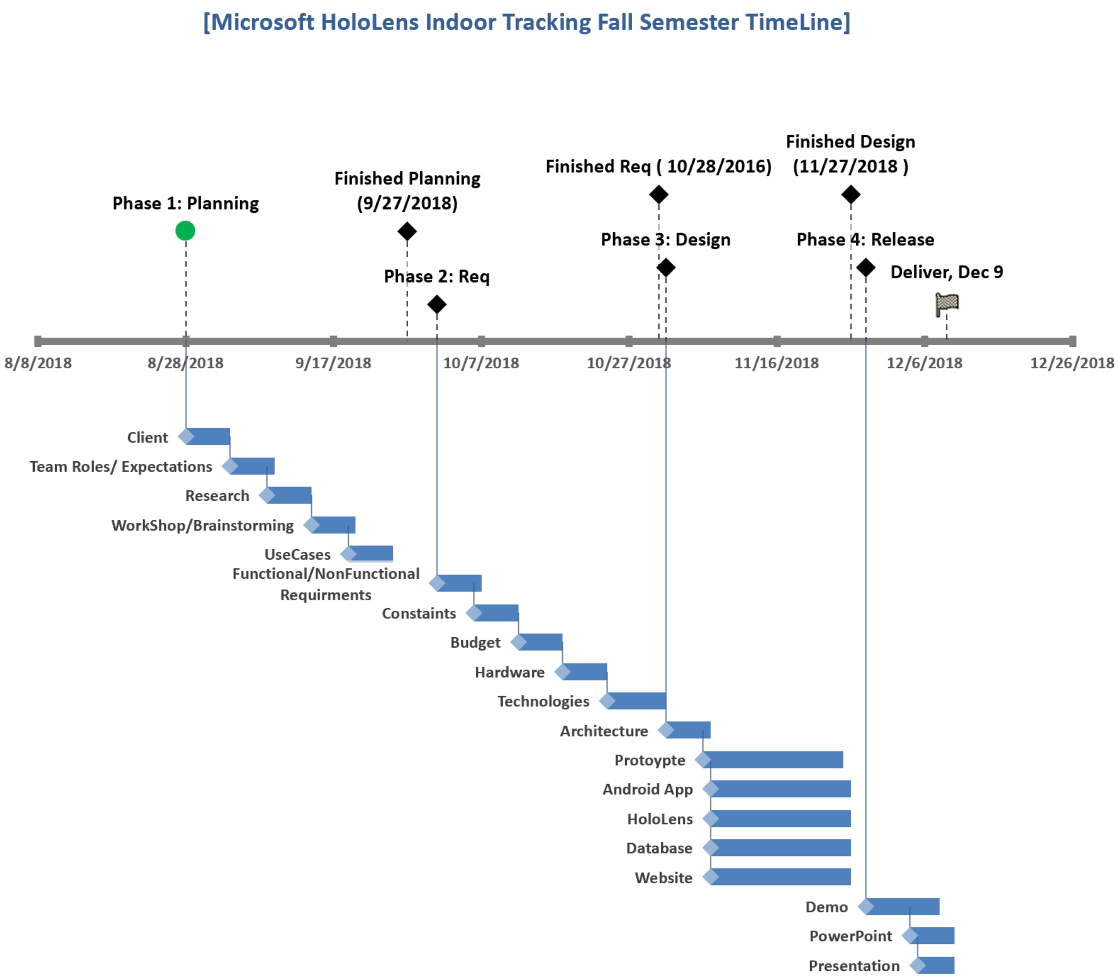
By the end of the project, we expect to have a phone application that can track a person as they move around a space. The accuracy will be within 1 meter of their actual location. The app will be able to store this location and movement data locally for up to a determined period, and send the data to a server. From there, the information will be retrievable by a HoloLens application, which can then be used to review the user's movement throughout their day at the site.

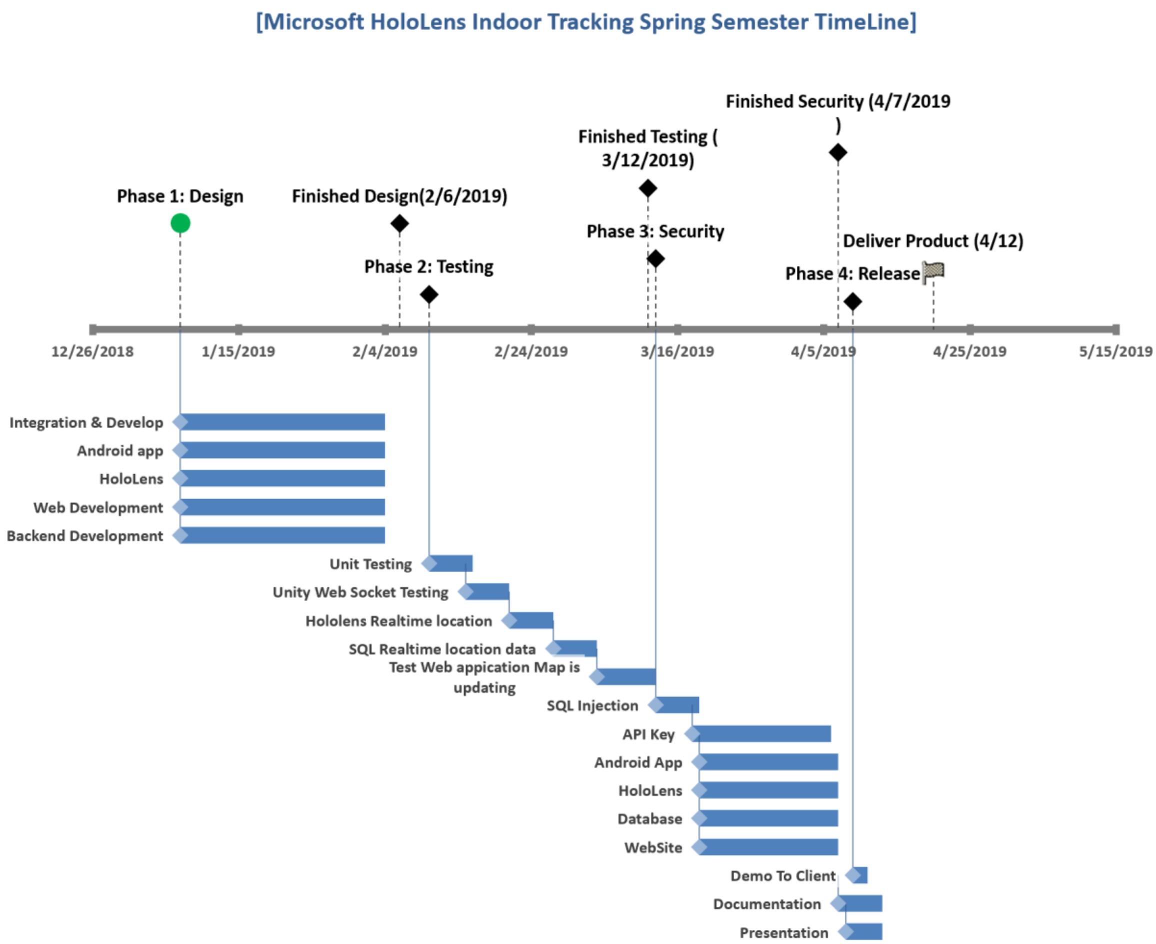
2.13 Test Plan

To test our project, we plan to demonstrate it in Durham hall in place of a construction site. With publicly available maps of the building, we can easily measure the accuracy and time delay of our project when we test.

3 Project Timeline, Estimated Resources, and Challenges

3.1 Project Timeline





3.2 Feasibility Assessment

We believe our proposed timeline is adequate and feasible for completing this project.

3.3 Personnel Effort Requirements

PERSONNEL	EFFORT
Anthony	Web Development/Security

Ben	Android application development
Ryan	Database management/Research
Cory	Research/Logistics
Travis	Hololens development
Jose	Web Development

3.4 Other Resource Requirements

- Android phones for testing
- Server space for website
- HoloLens for testing

3.5 Financial Requirements

No money is needed to complete this project, although money may be needed to make improvements. The following list represents materials we may or may not end up buying.

- Speakers
- Accelerometer

4 Closure Materials

4.1 Conclusion

We are confident in our ability to design and implement this project within our proposed time frame. We have already begun certain phases of development, including sensor implementation and data filtering. By the end of the Fall semester we will have a prototype of the android application with tracking algorithms implemented. By the end of the Spring semester we will have added the Web and Hololens functionality, providing an interface for viewing the trajectories of 3 separate smartphones.

4.2 References

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7. Truong, P, Lee, J, and Jeong, G. (2016, June, 4). Stride Counting in Human Walking and Walking Distance Estimation Using Insole Sensors. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4934249/

4.3 Appendices