GuideMe - Team C

Problem Space

What is the problem you're addressing?

The problem we are addressing is that blind people cannot walk independently and safely without external help, especially when crossing crosswalks. While external help like white canes or guide dogs are helpful for general navigation, they are not infallible and can lead to some errors. In fact, according to this source around 7%-13% have an accident at least once a month that often require medical attention. This is further compounded by the inherent dangers that the visually impaired face when it comes to crossing a crosswalk. To further illustrate this, we can first break down the steps a visually impaired person would have to take as follows:

1. Detecting and identifying the street
2. Aligning self to cross
3. Identifying when they can cross
4. Maintaining crossing alignment

Most, if not all of these steps are not fully aided by the tools currently available to the visually impaired. Furthermore, the common techniques used by the visually impaired can be prone to errors due to factors such as incorrect or missing information (source)

This changes walking habits and reduces confidence of being an independent traveler. In our project, we want to create a system that improves the safety for visually impaired travelers crossing a crosswalk, and thus make them more independent and reduce potential harm.

Who is the target population/user?

The main target population/user would be blind/visually impaired people who are unable to see/have difficulty seeing what is in front of them without the use of tools (such as a white cane). More than 1.3 Million people in the US are legally blind and around 8 Million people have a visual disability (source). In particular, we are focusing on visually impaired in urban areas as they have significantly more traffic and streets to cross than rural areas. Furthermore, in comparison to the general public, blind people are over represented in cities (source). To narrow it even more, we want to focus on younger visually impaired that are at the beginning of learning to navigate independently.

Why is it important?

Still, current infrastructure is not fully accommodating of blind people. Take tactile paving for example. Although it's common in many countries around the world, there is no good standard for tactile paving (source). In fact, there are even documented cases in which the paving leads people into obstacles such as trees or ledges, making it outright dangerous instead of helpful (source). This can be extra dangerous with crosswalks, where detecting the street and aligning oneself with the street can have an error happen due to the incorrect info from the tactile paving. Furthermore, over 60% of blind people travel more than 5 times a week outside one's own residence where they require support. On top of that, almost half of the blind travelers travel an unfamiliar route which requires good systems to make them feel comfortable, safe and independent.

What previous work has been done in this space? Where did it succeed? Where did it fail?

Stanford researchers created an improved version of the white cane that has sensors attached to it that allow the cane to "self-navigate" (video). It works by using similar sensors to the ones used in self-driving vehicles to detect when obstacles are in front of the user, and adjusts itself accordingly via a spinning wheel mechanism. When the wheel spins, the user feels a "tug" that tells them how to move in order to avoid the obstacle. It succeeded in a way, that with 5 minutes of training, blind people increased their walking speed by 38%. Another aid for blind people was made by a Korean researcher to aid in crossing traffic crosswalks. It works by scanning for a pedestrian signal light and determining when it shows the walk signal. The device succeeded in that it had a 96.2% color interpreting accuracy, however overall it only managed to get a 74.4% overall accuracy, showing room for improvement (source). Finally, this article outline many apps made with the visually impaired in mind (source). However, upon checking the apps all of them no longer seemed to be supported. Thus, these works for some reason or another showcase a potential avenue of exploration: allowing for safer crossing of crosswalks. The Stanford study doesn't help in this regard as it only augments what the white cane can already do in detecting obstacles, and thus doesn't help with dangerous tasks that don't involve obstacles such as crossing a crosswalk. The Korean study, while similar, is narrower in scope in that it only works with crosswalks with a pedestrian signal, thus limiting the crosswalks it can support. Finally, the discontinued apps showcase the need for further improvement in supporting the visually impaired. This was also stated by a visually impaired person we talked to. Especially crosswalks still seem to be a big problem for them and the need for external device is huge. He did not know about any successful commercial product.

Intervention

How do you plan to address the problem/part of the problem?

The way in which we want to address the problem and improve safety for the visually impaired is by providing assistance in actually crossing it. To provide assistance in actually crossing the street we would attach directional sound microphones to the white cane to measure the incoming traffic. Furthermore, sensors from the smartwatch (such as the compass and GPS again) would be used to alert the user if they are veering off course. This would help with the other two steps (determining when it is safe to cross and maintaining the crossing alignment). All information will be sent over Alexa to inform the user about detected cars or deviations.

Why do you think it will help give your problem space (related work, target population, etc.)?

Our solution is ideal for our target audience as it provides aid on one of the most dangerous tasks a visually impaired person in a city might face. Furthermore, as mentioned in the problem space, this is an aspect that hasn't seen much focus in the past. While some studies, like the Korean study with the traffic crossings, partially tackle this issue, it has a reliance on a feature not present on all crosswalks. Thus, our solution would be more widely applicable than previous works for a dangerous situation to our target audience.

In the future, an integration with google maps could be interesting to use crosswalk identification. Google maps already supports crosswalks and other important information for people with disabilities in some cities (see here).

Give us your vision of what your intervention/solution will do and how it will do it. Walk us through what using it will be and feel like. Add pictures and drawings if helpful. Convince us that this is the right solution to your problem.

We envision the solution to require four core devices: a Raspberry Pi computer, directional microphones, Alexa and wearable Galaxy smartwatch. We want to attach the microphones to a white cane facing either side of it to detect the frequency of soundwaves produced by approaching cars. The raspberry PI is processing the frequency signals and calculates if it is in excess of a certain threshold. If the consensus comes to the conclusion that there is an approaching car, a notification will be sent to the galaxy watch that the user is wearing. We also want to let the user know if he/she is not walking straight by using the galaxy watches magnetometer to track their alignment and then correct their course, Alexa will notify the user. One vibration: going too much to the left, two vibrations: going too much to the right.

In addition to crossing the street we also want to use navigational street level data scraped from the google API, in conjunction with the galaxy watches GPS sensor to instruct the user to rotate or turn to face the crosswalk if they are not facing it. This actuation will be achieved by audio instructions from the galaxy watch.

Consider that you will be demoing this at the end of the quarter. How will you demonstrate your intervention?

We will show the functionality of our system by having one of us use the cane apparatus with the watch to cross a nearby crosswalk.

Feature List

Give us a breakdown of the features you intend to implement with your system, what it will do, why it exists, and an example of how someone might use it (a storyboard). You may find drawings useful here to describe user interactions and interfaces.

Crossing a street/crosswalk

- Detect incoming cars/safety to walk
    - Devices:
        - Directional microphones
        - Raspberry PI
        - Alexa
    - Why it exists
        - To alert the user if there are any incoming vehicles, on the crosswalk they intend to cross
    - Use Case
        - If a visually impaired person attempted to cross the street, they would stick their cane out and the microphones coupled with the pi integrated into the cane would discern if there was an oncoming vehicle. Then this information would be actuated by a voice command through alexa.
    - How it works:
        - The visually impaired person states to Alexa that he/she wants to cross the street. This command will be sent to the PI which activates the directional microphones. The directional microphone are attached on each site (left/right) of the white cane. They start sensing their direction for incoming noise changes. Depending on the noise level on each site, we want to implement certain sound/frequency thresholds to determine whether there is a car that

approaches or not. If the microphones do not detect noise changes for the next 5 seconds, the person can cross the street.

- Walking straight
    - Devices
        - GPS
        - Compass (Magnetometer)
        - Alexa
        - Glaxy watch
    - Why it exists
        - To let the user know they are deviating from their path if their intention is not to do so.
    - Use Case
        - As a blind person, I want to cross streets without going sideways so that I safely and quickly arrive on the other side of the street
            - A blind pedestrian attempting to cross an intersection needs to walk straight to reach the other side without entering the intersection. Alexa will alert the user if they are deviating from the direction they were initially facing when crossing, thus making sure they are aware if they are off track.
    - How it works:
        - Together with GPS and a magenotmeter on the watch or one attached to the raspberry PI, we want to determine which direction the user is facing. If the user crosses the street, we can draw a vertical line to the other side of the street. As soon as the user deviates from that line, we can provide feedback too the visually impaired through Alexa.

- Length of crosswalk
    - Why it exists:
        - To give direct feedback to the user on how much they have left to cross when needed
    - Use case:
        - A visually impaired/blind person might find it helpful to know the length of the upcoming crosswalk
    - How it works
        - With the map data, we want too calculate the distance between both sides of the screen. We want to retreieve the map data through a map api and then calculate the distance. As soon as we

know the distance, it will be sent to Alexa and she states the result to the visually impaired person.

Devices

What devices will you need to implement your intervention? You can use devices that we covered in class, but you are welcome to go beyond those in class if you have access to them. How do you plan to power the devices?

1) Alexa Echo
2) Raspberry Pi
3) Directional microphone
    a) https://www.youtube.com/watch?v=Yx2R3xtGRsg&ab_channel=TESRCo.%2CLTD
4) Galaxy Watch 4 (For GPS mainly and map application)

Architecture

Are you using a network?

Yes, we will set up a TCP server on the PI and Galaxy Watch that allows sending of notifications from the PI and Galaxy Watch to the Amazon Echo. We will use WebSockets to use the established connection and send out notifications.

Where is your server? What devices are clients?

The server will be hosted on our raspberry PI and Galaxy Watch. The PI, Galaxy watch and our Amazon Echo serve as clients. The PI is connected to the directional microphone sensors, calculates velocity and proximity and decides whether there is a moving object of concern around the user. As soon as a message is sent over the TCP connection, the Amazon Echo will process this signal through its VoiceFlow synchronization algorithm to forward to its voice output system.

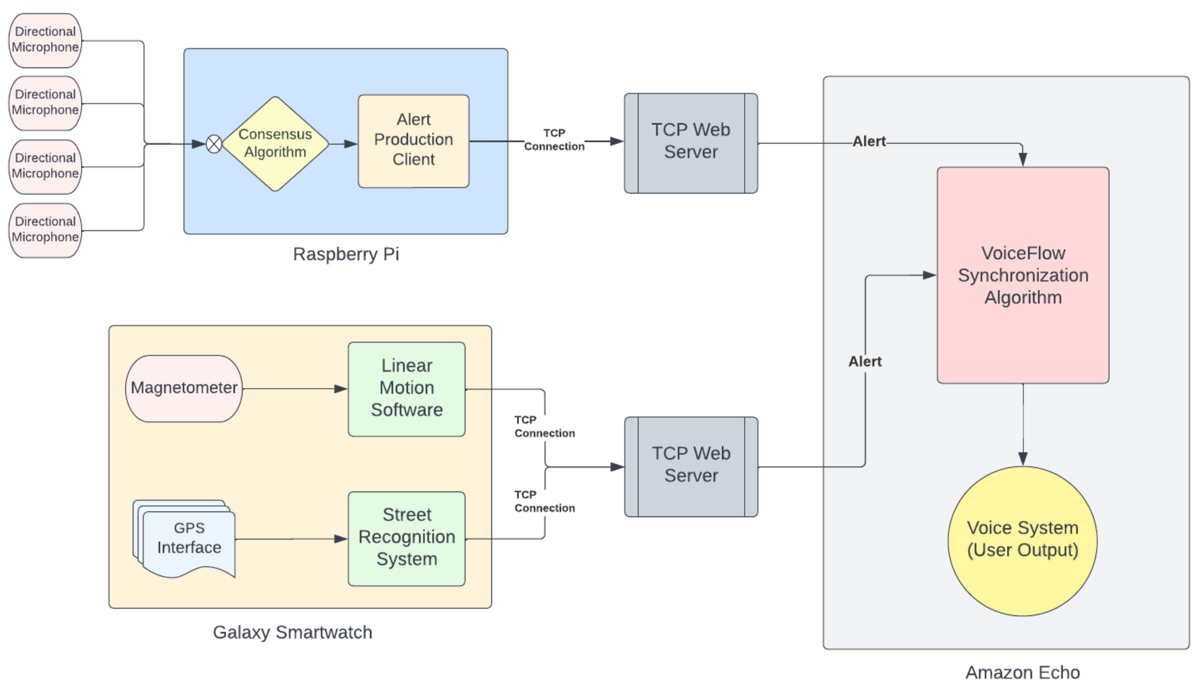
How is data stored?

We are using temporary data only and do not store any data on our servers or devices. As soon as the devices are turned off, the data is deleted.

Are you doing anything to protect user information?

For the current system, we are not planning to process or store individual information. However, we probably have to secure the tcp connection in the future to ensure the integrity of the system. Possible attacks could include the blocking of alarm messages which would not warn the blind person anymore or sending out false alarms.

Create a diagram or series of diagrams showing the flow of information through your system. Show how devices are connected and what protocols they use. Describe how information on each device is handled, whether it is saved, sent, or discarded. Give us a graphic of your system/network architecture. Don't forget to show the user where the data is relative to the user.



Our project dataflow is as follows:

<u>Crossing a Street/Crosswalk Dataflow</u>

Detect incoming cars/safety to walk Sub-Dataflow

Initially, four Directional Microphone Sensors will collect automobile velocity and proximity information about the user when crossing a street.

The automobile velocity and proximity information will be directed to our Raspberry Pi where our Raspberry Pi will run a consensus algorithm on the data collected by our Directional Microphone Sensors to accumulate the different velocity and proximity values across all Directional Microphone Sensors.

The Consensus Algorithm module will send its data to the Alert Production Client module which will classify whether there exists one or more automobiles of pressing velocity and/or proximity.

The Alert Production Client will then send its classification data to a TCP Web Server through a TCP connection to forward to the Amazon Echo, specifically to the VoiceFlow Synchronization Algorithm module.

Once the VoiceFlow Synchronization Algorithm module receives data from the Raspberry Pi signifying that there should be an alert raised to the user, the VoiceFlow Synchronization Algorithm will send a signal to Amazon Echo’s Voice System which will alert the user of a moving object.

Length of Crosswalk Sub-Dataflow

Initially, the Galaxy Watch GPS Interface will collect user location data and street layout data for the user.

The user location data and street layout data will be directed to the Street Recognition System module which will classify whether the user is approaching a street and/or crosswalk and send the data to a TCP Web Server through a TCP connection to forward to the Amazon Echo, specifically to the VoiceFlow Synchronization Algorithm module.

Once the VoiceFlow Synchronization Algorithm module receives data from the Street Recognition System module that there should be an alert raised to the user, the VoiceFlow Synchronization Algorithm will send a signal to Amazon Echo’s Voice System which will alert the user how many meters is left to finish crossing the crosswalk.

Walking Straight Sub-Dataflow

Initially, the Galaxy Watch Magnetometer will collect linear motion alignment data for the user.

The linear motion alignment data will be directed to the Linear Motion Software module which will classify whether the user is walking in a linear trajectory or not and send the data to a TCP Web Server through a TCP connection to forward to the Amazon Echo, specifically to the VoiceFlow Synchronization Algorithm module

Once the VoiceFlow Synchronization Algorithm module receives data from the Linear Motion Software module that there should be an alert raised to the user, the VoiceFlow

Synchronization Algorithm will send a signal to the Amazon Echo's Voice System which alert the user of his/her non-linear movement.

<u>Walking Towards a Street Dataflow</u>

Initially, the Galaxy Watch GPS Interface will collect user location data and street layout data for the user.

The user location data and street layout data will be directed to the Street Recognition System module which will classify whether the user is approaching a street and/or crosswalk and send the data to a TCP Web Server through a TCP connection to forward to the Amazon Echo, specifically to the VoiceFlow Synchronization Algorithm module.

Once the VoiceFlow Synchronization Algorithm module receives data from the Street Recognition System module that there should be an alert raised to the user, the VoiceFlow Synchronization Algorithm will send a signal to Amazon Echo's Voice System which will alert the user of an approaching crosswalk.

We will cover this topic in class on 11/1/22 and don't expect you to know what protocols to use where, but do your best, it's okay to be a little vague, but try to look up what protocols will be best for your purposes.

We believe a TCP connection between the Raspberry Pi, our Galaxy Smartwatch, and Amazon Echo would be the most efficient protocol to send and receive packet data between the two devices.

Timeline

You have 4-5 weeks. Give us a weekly breakdown of what features you intend to implement for that week. Keep in mind that the best plans are adaptable and give yourself some buffer room in case you fall behind schedule; have extra/bonus features planned if you find yourself with extra time. Distribute the work between your teammates. Don't forget to leave room for testing and make everything stable for the final demo.

Week:	**Features:**

By the end of **Week 6**	**If on schedule:** Conduct research on needs of visually impaired, including interview with potential user of device to identify user needs. Order microphones, find out about alexa data communication. **Milestones:** Understanding full range of requirements with a tangible list of pain points. Understand implementation requirements. **Deliverables**: none
By the end of **Week 7**	**If on schedule:** Implement white cane with directed microphones and PI. Get audio representation of vehicle engine at various points(close/stationary, approaching slow, approaching fast) fon raspberry pi connected to microphone and develop sampling strategies **Milestone:** Having an effective model for detecting whether or not a car is approaching **Deliverable**: Cane with mounted microphones that is able to determine car states
By the end of **Week 8**	**If on schedule:** Implement car detection mode. Notify user about approaching cars through alexa. Test pi with microphones on a crosswalk under many conditions, and begin work on walking straight feature **Milestone:** Completing the car detection feature **Deliverable**: White cane including microphones and alexa that warns about approaching cars.
By the end of **Week 9**	**If on schedule:** Connect raspberry PI with magnetometer and leverage smart watch compass. Implement walking straight functionality and give the user feedback over alexa. **Milestone:** Completing walking straight feature **Deliverable:** Magnetometer added to the cane. Fully working walking straight feature. (If **ahead of schedule**, can start implementing a potential facing the crosswalk before

	crossing feature)
By the end of **Week 10**	**If on schedule:** Implement notification system if a crosswalk is close by. Polishing and testing the final product efficacy with potential to add improvements in order to prepare for the final project demo **Milestone:** Having a final working demo **Deliverable**: Fully implemented prototype with all mentioned features (If **behind schedule** at any point, then week 10 instead serves as a buffer for implementing any unimplemented features mentioned in the previous milestones)

Appendix

Interview with Gordon (a visually impaired student, that has some visualization left and is not 100% blind)

1. What are the most significant obstacles you encounter when walking and navigating independently?

   The biggest obstacles are streets without sidewalks, and complex intersections such as the ones with separate straight and turning green lights. Another obstacle is when there are branches overhead or on the ground

2. What are the current external devices that you use for independent mobility?

   I use my folding cane, iPhone, Airpods, Google Maps app, One Bus Away app, and Go MTS apps.

3. Do you think that you need help with crossing a street? If yes, what are your biggest problems/fears?

   My biggest problem is when there are complex intersections such as the one described above or when there are not enough cars on the street. This is because I use the cars to know when to cross the street. I am independent on most street crossings

4. Are you able to identify crosswalks?

   Yes, based on my usable vision

5. If not, would identifying crosswalks help you?

   N/A

6. What steps are necessary for you to cross a crosswalk?

   I have to listen for the parallel surge of cars which means cars that are going straight away from me or straight towards me. Another method is to listen for the perpendicular cars to stop crossing.

7. Would information about the length of the crosswalk help you?

   Maybe, but the timing of when to cross is more important

8. Would a system that identifies if you walk straight to the other side help you?

   Not really, but it might help other people

9. Would a system that identifies approaching cars help you?

   Maybe

10. Would a system that helps you align you vertically to the street help you?

    Not really, but it might help other people

11. If an external system gives you feedback, do you prefer voice over haptic feedback, like vibration?

    I think audio but it could be good to have options for both

12. Can you think of a solution that would help you to walk and navigate more safely and independently?

    I think if there were glasses with cameras that could detect traffic lights and tell you when to cross, that would be good. They have glasses that connect to cameras so you can make video calls but I'm talking about Ai recognizing traffic lights.

13. Do you have any other important information about mobility for the visually impaired?

    The biggest thing that helps visually impaired people for now would be if there were more accessible crosswalks. That means crosswalks that either tell you when to cross or start beeping when you should cross. Some cities are better than others in terms of how many accessible crosswalks there are.

Researched projects

https://srl.mcgill.ca/publications/2013-ICAD-WS.pdf

The study above implemented a GPS based speech guide,

https://www.eetimes.com/sensors-help-blind-people-on-road-crossings/

- Describes that street length actually matters - lets check with gordon

https://www.visionofchildren.org/voc-blog/2018/7/13/smartphone-apps-for-the-blind-and-visually-impaired

- Ardiane GPS - not really in use

https://www.nytimes.com/2004/12/02/technology/circuits/street-smarts-a-device-to-help-the-blind-find.html#:~:text=The%20Mowat%20Sensor%20is%20a,audio%20panorama%20of%20his%20surroundings.

- Camera detection for crossings - not necessary if info is included on maps like London and Tokyo

https://www.researchgate.net/publication/309173663_Pedestrian_crossing_aid_device_for_the_visually_impaired

- Camera detection for traffic crossings, using the traffic signals to determine when a visually impaired person can cross

https://www.inclusivecitymaker.com/accessible-pedestrian-signals-guiding-sound-corridor/

- Detailing why sound corridors are good for city planning
- Mfcc map, audio