# NETCPS REU
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# Pedestrian Navigation for the Blind: Can We Do Better than Google Maps?

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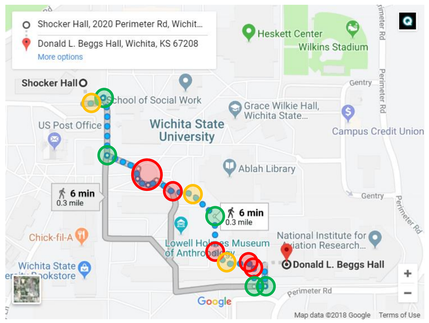
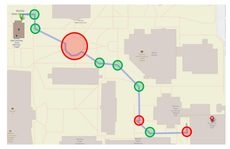
## The Problem




- = Usable turn instruction
- = Unclear/confusing section
- = Missed turn

- Google Maps gives very rough instructions:
  - It fails to notify the user of bends and slight turns, and
  - It fails to notify the user of around half of all major turns
- These instructions assume the user is sighted and can correct for all of the shortcomings and inaccuracies.
- This is very difficult to navigate for the Blind and Visually Impaired (BVI).



- Other map software like Bing Maps or OpenStreetMap suffer from the same issues, especially at the roundabout.
  - OpenStreetMap is by far the best, with instructions like slight/sharp turns, but is far from perfect.

Bing maps

OpenStreetMap

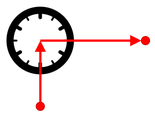
## Improvements on this Design


Go 0 o'clock for 30m.
Go 12 o'clock for 21m.
Go 10 o'clock for 5m.
Go 12 o'clock for 40m.
Go 3 o'clock for 2m.
Go 11 o'clock for 1m.
Go 12 o'clock for 1m.
Go 1 o'clock for 1m.
Go 11 o'clock for 2m.
Go 12 o'clock for 2m.

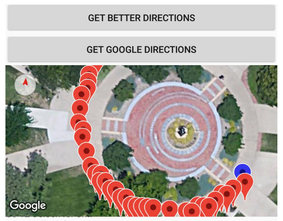
Example of a route

- Better Navigation was developed for the Android operating system.
- It uses Google Maps and Google Directions API to get a route, then creates custom, improved directions designed specifically for the BVI.
- Google gives a "polyline" as part of its directions, describing the path. For each point between line segments on the path, this app generates a clock direction and a distance to the next point.
  - This allows for concise yet very precise directions each step of the way.
- The first instruction currently instructs the user to walk in the "0 o'clock" direction because this app is to be integrated into SmartCityGuide, where the initial instruction will be handled externally based on cardinal directions.

**Example:** 3 o'clock turn:



## UI on the Improved Design

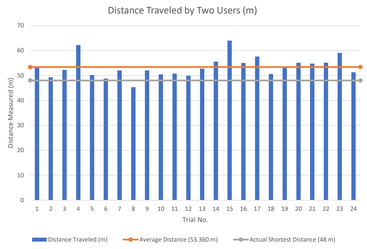



Go 12 o'clock for 1m.
Go 10 o'clock for 1m.
Go 2 o'clock for 1m.
Go 12 o'clock for 1m.
Go 10 o'clock for 1m.
Go 12 o'clock for 1m.
Go 2 o'clock for 1m.
Go 10 o'clock for 1m.
Go 1 o'clock for 2m.
Go 2 o'clock for 26m.

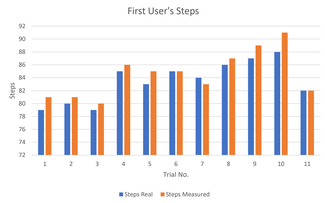
Example of a roundabout

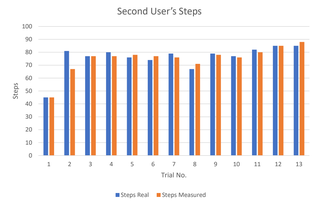
- UI for Normal paths:
  - Start
    - At the beginning, a 45 second delay is introduced in order to give time for the GPS accuracy to improve. This value is based off of experimental data which showed that GPS accuracy typically levels off at around 45 seconds.
  - Next location(s)
    - When the next location is detected within a 5 m radius, the user is told auditorily how they will turn next and how much distance they will have to travel in a straight line. This app also uses the user's step size (with the help of an input from the separate step-counter app) to tell the user approximately how many steps they should walk in that direction.
- UI for Curves and Roundabouts.
  - Before entering curve
    - Whenever the user nears any point on a detected roundabout within a 2 m radius, the GPS is calibrated. The user is informed about the existence of the curve and its nature (clockwise vs counter-clockwise). Then the user is given an instruction and invited to press a "Check" button at the bottom of the screen to signal the completion of the instruction, after which the next instruction is read out. Once all the instructions for the roundabout have been read out, the GPS is calibrated again. Finally, if the user is not near the end point of the roundabout, the user is instructed approximately how many steps they are away from the end point and in which direction. The user is then advised to start walking in that direction until the endpoint is detected.
- Recalculation of Path:
  - At any point, if the user has walked 50 steps more than the calculated number of steps, the user is told to walk backwards and is given 100 seconds before the program recalculates the path from last known location. A "Recalculate" button is also provided for the user in case they feel lost.

## Step-Counter Analysis




- Based on this chart, the distance measured by the GPS (which was redefined using the Criteria object) was considerably accurate (the average percent error from the mean for all these trials was about 4.87%).
- During the experiment, the user walked blind and moved in a zig-zag fashion. This is represented by the fact that most of the lines are greater than 48 m (the shortest straight distance) by a few meters, which is expected because the user did not always walk in a perfectly straight line.
- The data is also consistent, as most of the bars extend down or up by only a short length from the mean of approximately 53 m.

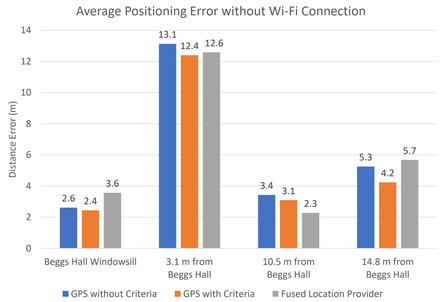


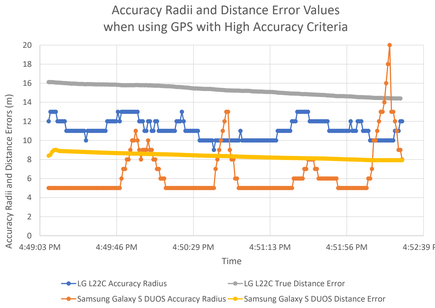

- As depicted in the above two charts, the differences in the length of bars representing real counted steps and steps measured by the step counter are small for most of the trials and for both users, and is quite accurate (average of 2.53% error between real counted steps and measured steps with the help of the step counter sensor) to be considered for finding the distance/step ratio to be used in navigation for other applications. This distance/step conversion ratio is useful in:
  - Determining the approximate number of steps required to go from one location marker to another can be further utilized to ascertain whether or not the user is lost (which can happen due to GPS inaccuracies and its inability to detect desired locations within a 5 m radius.), in which case the path will be recalculated from the user's last known position.
  - Giving step-by-step instructions in number of steps is easier for blind users to understand and execute, especially in roundabouts and sharply curved roads, which require complicated instructions.

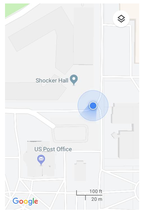
## Comparison of Location Methods

- When attempting to determine the user's location, various methods can be employed. In this context, the three primary options are:
  - GPS alone
  - GPS with high accuracy Criteria (specified in the code)
  - Google's "Fused Location Provider Client," which uses a combination of sources such as GPS, cellular, and Wi-Fi signals.
- These three location strategies were tested with two mobile phones by calling for location updates once every second for about 4 minutes. The latitude and longitude values estimated by the phones were then compared to the true coordinates of the location to obtain the data below.




- While Google's Fused Location Provider is often more accurate when the device is connected to Wi-Fi, a pedestrian is not expected to have Wi-Fi connection while walking outdoors.
- According to the experimental data, utilizing the GPS with high accuracy Criteria typically allows for the best positioning accuracy when the user's device does not have an available Wi-Fi connection. This is typically the case both nearby and farther away from buildings, as shown in the chart to the left.




- An accuracy estimation can also be obtained from Google's location services. According to Google, there is a 68% chance that the user's true location is within the accuracy radius returned by Google's built-in accuracy function. This range is typically shown on Google Maps as a light blue circle.
- Nonetheless, our testing has shown that this value is not always accurate. The chart to the left shows the results of tests performed with two different phones at a distance of 10.5 m from a building.

## Testing

- This app has been tested on six REU participants. We were not able to recruit more people due to the limited time frame, but a large number of blindly selected BVI subjects would yield more certainty in the results.
- Subjects were blindfolded for the experiment, and did not know the area or the route beforehand.
- Subjects were monitored for safety, and only received two types of interventions:
  - Basic Assists: Keeping them on their path (since BVI persons can typically do this with a white cane or dog)
  - Critical Assists: Giving the user an instruction when they are stuck and/or cannot progress further without assistance
- In all aspects of the experiment, they showed improvement with our custom instructions.
- The same navigation engine was used to give them both the custom instructions and Google's default instructions.
- The experiment begins when a team member presses the start button and the app finds an accurate GPS reading. The experiment ends automatically when the user reaches the end point. Nobody needed to stop mid-experiment.
- They walked the route with custom directions first (without knowing which directions were first). They are least familiar with the route on the first run, and yet they all still completed the route more quickly and efficiently than with Google's instructions.

## Results

- = User trails using Google's instructions
- = User trails using improved instructions
- = Points of interest
- = Other points on path

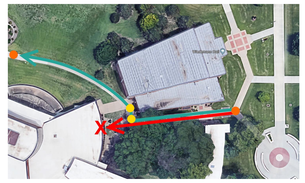


*Fig. 1*

- In many circumstances, Google's instructions miss crucial turns, which these improved instructions do not. For instance, every test subject required at least one critical assist at the location in Figure 1 marked with the yellow dots.
- Navigating this region requires a right turn, then a slight bend to the left. These steps are present in the improved instructions, represented by the teal line. However, they are completely missing from Google's instructions, represented by the red line.
- This is virtually impossible to navigate without knowledge of the turn.

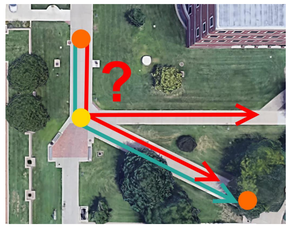
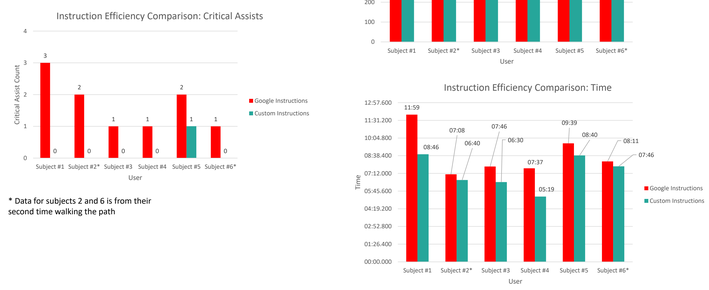


*Fig. 2*

- Google's instructions also lack the specificity of whether the user must make a slight turn, a 90° turn, or a sharp turn. This caused significant issues at the yellow point in Figure 2. Note that this is on a separate route that was used before the experimental testing began.
- This route can easily be completed using the improved instructions due to its differentiation between a 10 o'clock turn and a 9 o'clock turn. However, when using Google's instructions, users often took the wrong turn here, because all it tells them is to "turn left."










* Data for subjects 2 and 6 is from their second time walking the path

## Conclusions and Further Work

- When using our custom instructions, users took and average of 19.2% less steps than they did when using Google's instructions. Additionally, they took 16.5% less time.
- Only one person needed a critical assist while using the improved instructions. This occurred because they received an instruction early due to GPS inaccuracy and ended up missing their turn because they became confused.
- The rest of the critical assists were for users following Google's instructions when it failed to tell them when and how much to turn.

- While the app is currently very capable, it needs further improvements:
  - At the start of the instructions, the user's initial bearing is unknown. The app needs to be able to orient the user in the correct direction when starting the navigation process based on their current orientation.
  - Currently, our app does not support recalculation when the user diverts from the correct path. This feature is currently in the development process. Once completed, it would allow for less intervention during testing because the decision to reroute the subject would be automatic and made by an algorithm with strict guidelines. This would thereby decrease the amount of human error.
  - Due to time constraints, we could not test this app with actual BVI individuals. However, this would provide more realistic and useful data.