ESE-519: Real Time Embedded Systems

Project Rahee - Project Report

Jatin Sharma and Nikhilesh Behera

1. Project Title: Rahee (inSole navigation system)

2. Team:

A. Nikhilesh Behera (Embedded Lead)
B. Jatin Sharma (Haptics Lead)

3. Motivation:

Globally, the number of visually impaired people, either partially or completely, is estimated at 285 million, according to the World Health Organization. More than 90% of visually impaired people live in developing countries, the WHO data show. Common causes of visual impairment are myopia, astigmatism, cataracts and glaucoma.

Visually impaired people in developing countries usually rely on basic walking canes to detect obstacles around them. While there are technologically advanced walking canes—such as those equipped with ultrasonic sensors or laser technology—some young engineers are trying to provide blind people with alternatives to canes. We want to solve this problem by aiding the traditional cane way via navigational cues. We plan to design a low cost, off the shelf sole that can be put in any shoe for intuitive navigational cues. A typical user should be able to use offline maps on these insoles and mark obstacles on the way that he may want to prevent colliding to.

4. Goal:

1. Designing a low cost, off the shelf sole that can be put in any shoe for intuitive navigational cues
2. Using GPS offline maps to help visually impaired

5. Methodology:

1. Detecting foot gestures to mark events(eg: mark points) during the course of walking
2. Producing vibration patterns in the shoe which would guide the person while walking
3. Integrating GPS module to get the GPS coordinates
4. Integrating WiFi module for commands and syncing the static map being stored
5. Periodic downloading of offline maps and storing in SD card
6. Map parse and lookup based on GPS coordinates
7. Integrating all the above components inside the shoe sole
8. Simple and light weight mobile application for user input

6. Architecture

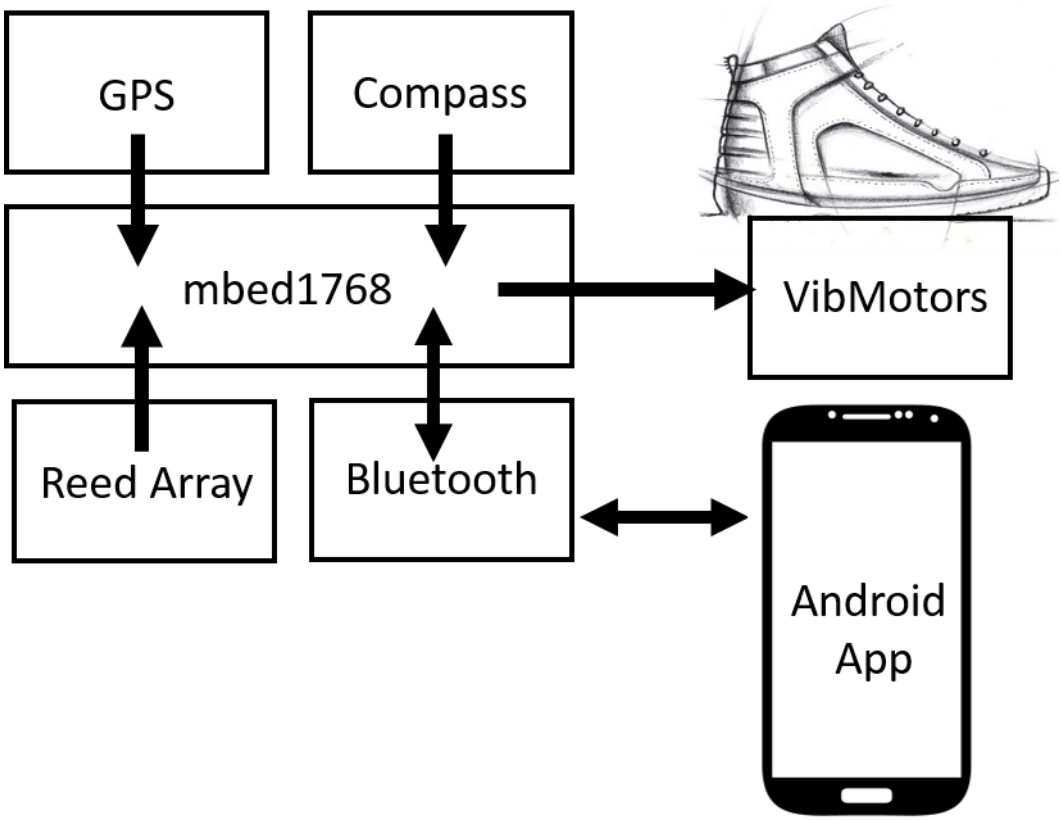


Fig1. Rahee Architecture

- Mbed receives current coordinate from GPS and direction from Compass at all time.
- When user requests for navigation, Android app queries OpenStreetMaps to get a routeList.
- Mbed utilized Remote Procedure Call (RPC) over Bluetooth backhaul to invoke mbed's RTOS functions to execute PWM.
- Mbed listens to ReedArray interrupt for new hotspots and add them to list.

7. Project Components:

Hardware	Software
Sensors – Pressure & Flex	Maps and Navigation
GPS – Current Location	Storage for static maps (SD card)
Actuators – Vibrations	Light weight Android app

7.1 Hardware/Mechanical Effort

- Sensor Interfacing (GPS, 9-DOF, Flex, Reed, Bluetooth, Vibe, Boost)

- PCB Design (Compact, 2-level circuitry)
- Soldering
- Cutting shoe
- Haptics
- Sensor placement/Pinout restrictions
- Weight balancing
- Recharging and Programming

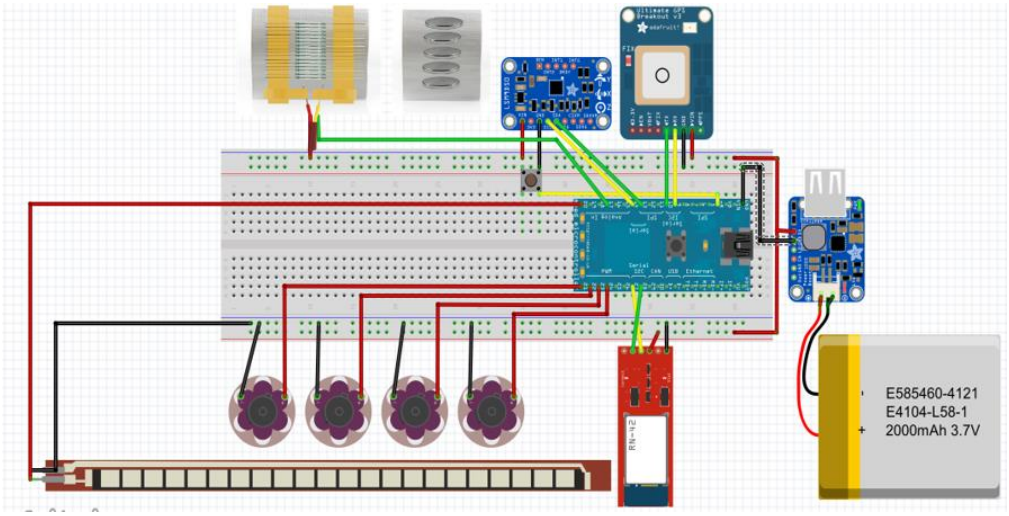
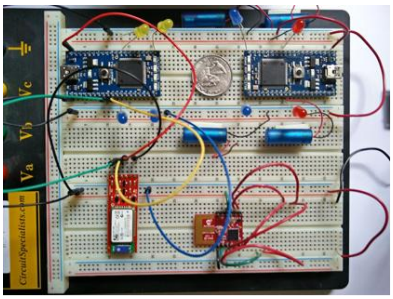
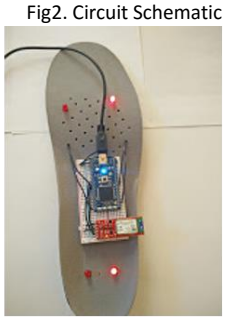


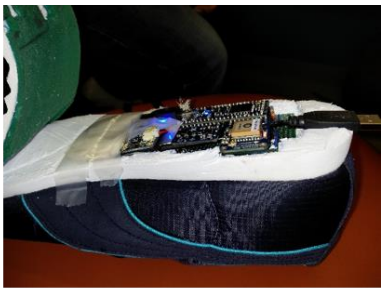
Fig2. Circuit Schematic



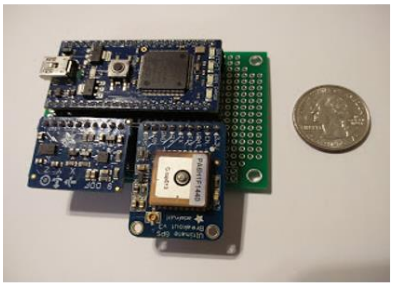
RaheeTestbed



RaheeSole



RaheeShoe



Main Circuit

Packing

WalkReady

Fig3. Hardware Effort

7.2 Software/Firmware Effort

- Offline Maps storage, rendering and marking
- XML Parsing
- Navigation (JumpList, Segments, Haversine)
- Direction (heading, bearing, margin)
- Hotspot Marking and Detection
- Bluetooth Communication over Serial port
- Remote Procedure Call
- Voice Recognition and Voice Feedback
- Android Programming
- ShoeSimulation
- Debugging over Bluetooth
- Source and Destination Rerouting
- Interactive UI
- RTOS
- C/C++, Java
- I2C
- Mutlithreading
- ISR – Interrupt handling

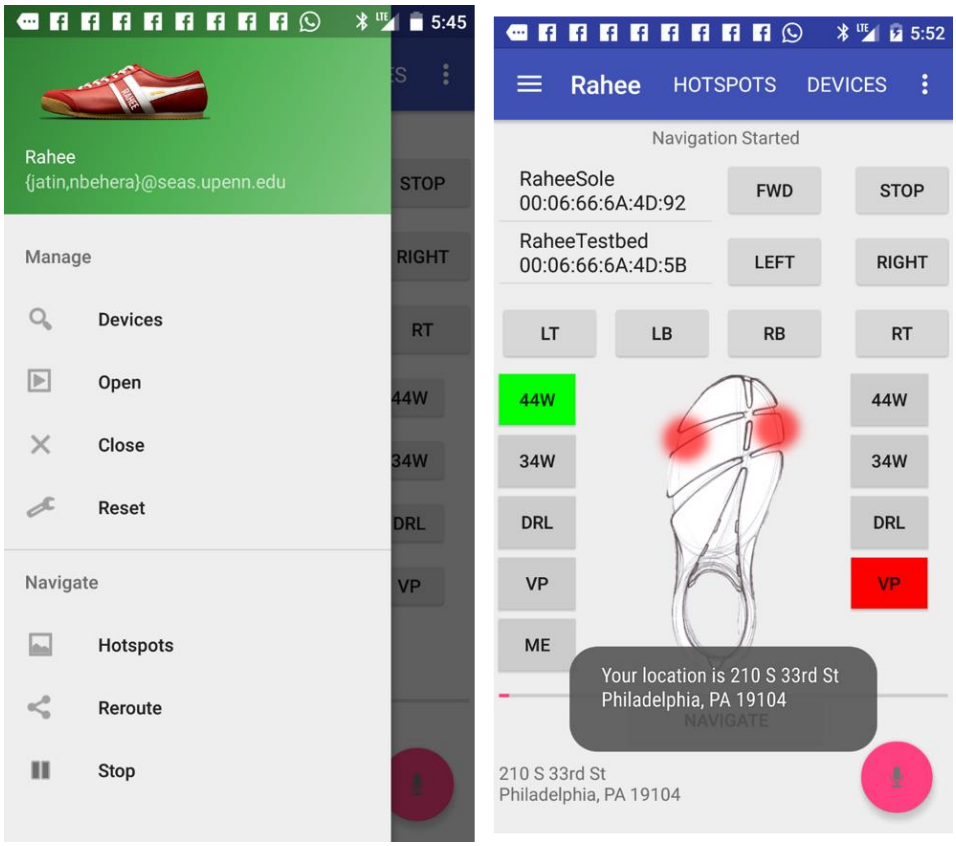


Fig4. Software Effort

8. Testing and Evaluation:

- Testing
  - User input from the phone (Src, Dst)
  - Outdoor navigation from source to destination
  - Mark / Detect obstacles
  - Detect source and destination points
  - Appropriate and intuitive vibration patterns
- Evaluation
  - Self testing in a given environment
  - User study with visually impaired people.
  - Fine tuning and device adjustment based on user feedback

9. Proposed Project Deliverables:

Baseline1: Single sole with online maps and navigation
Baseline2: Baseline1 + mobile application + data storage(SD card) for landmarks Baseline3: Baseline2 + offline maps + storage for static maps

Reach Goals - Extra Credit:

1. Map sync when Wifi available for updates on the maps being stored
   a. Requires downloading a new map on active device wirelessly
   b. Migrating and mapping all marked points from current map to new map
2. Automatic charging
   a. Consumers will not want to charge their device by plugging in their shoe to wall socket. We need an inbuilt charging circuit.

10. Offline Map Update [Stretch Goal-1]

You just need to download a map for your preferred region from OpenStreetMaps website and place that in Downloads folder in the phone.

11. In-Circuit USB Charging [Stretch Goal-2]

As we have all the basic functionalities ready and integrated into the Shoe, we felt a strong need for in circuit charging so that –

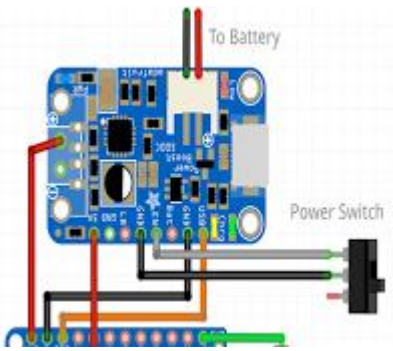
a) We can get rid of programming cable
b) We can charge and walk at anytime

But this requires an extra circuit to be placed inside the shoe. Lithium Ion battery operate on 3.7V and

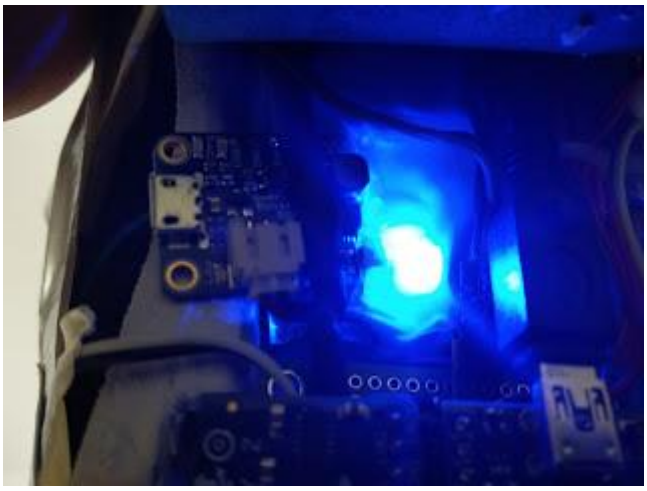
cannot directly power mbed. We need a power boost to level shift it to 5V. Also as we require both charging and discharging at the same time we need complex circuitry.

Our first choice was Lithium Backpack by liquidware as it was readily available to us. I had an inbuilt battery, power boost circuit and on/off switch. The size however was pretty bulky.

We then decided to create a custom backpack using LiIon 2000mAh battery and adafruit power boost circuit. Together they are pretty compact and fulfill our requirements.



We deployed the circuit in the sole and it worked marvelously giving us 5-6 hours of walking time.



12. Source and Destination Rerouting [Stretch Goal-3]

While testing Rahee, we realized that we cannot work with a few fix Start Locations. A user's location can be anywhere and he should be able to navigate from his current location. We enabled the feature for test purposes and it proved to be pretty useful for us.

Extending the capability, we now have rerouting as a primary production feature rather than just a test feature. We have upgraded the code to include-

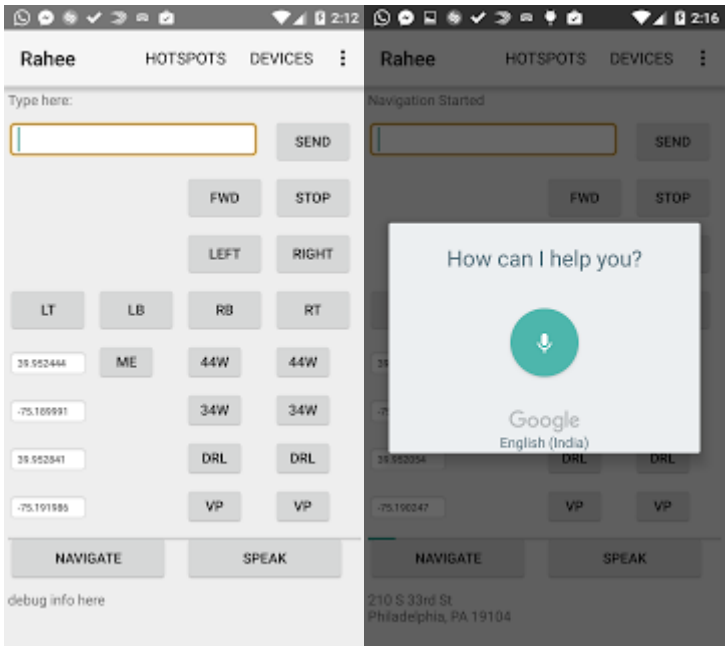
a) Source Rerouting: While walking on the sideways a user may want to take a detour (buy groceries, take a jog, meet someone on the way etc) and follow a different path than what was proposed to him by Rahee. User can now keep the destination same and request Rahee for a new path. Rahee will propose a new path based upon user's current location.

b) Destination Rerouting: Sometimes you just change your mind and want to go to your friend's place for a beer or to a different restaurant. Well, you can just ask Rahee to reroute you to the new destination.

c) Waypoint Rerouting: **Not yet supported**. User may want to request for a path that goes through a particular location (through the park, via CVS/Dunking Donut etc). We are considering this feature for future releases.

13. Voice Recognition and Voice Feedback [Stretch Goal-4]

To make the Rahee app easier to use and accessibility friendly, we have added Voice Recognition and Voice Feedback. A user can say - "Navigate to 34th and Walnut" and the app will automatically start navigating him.



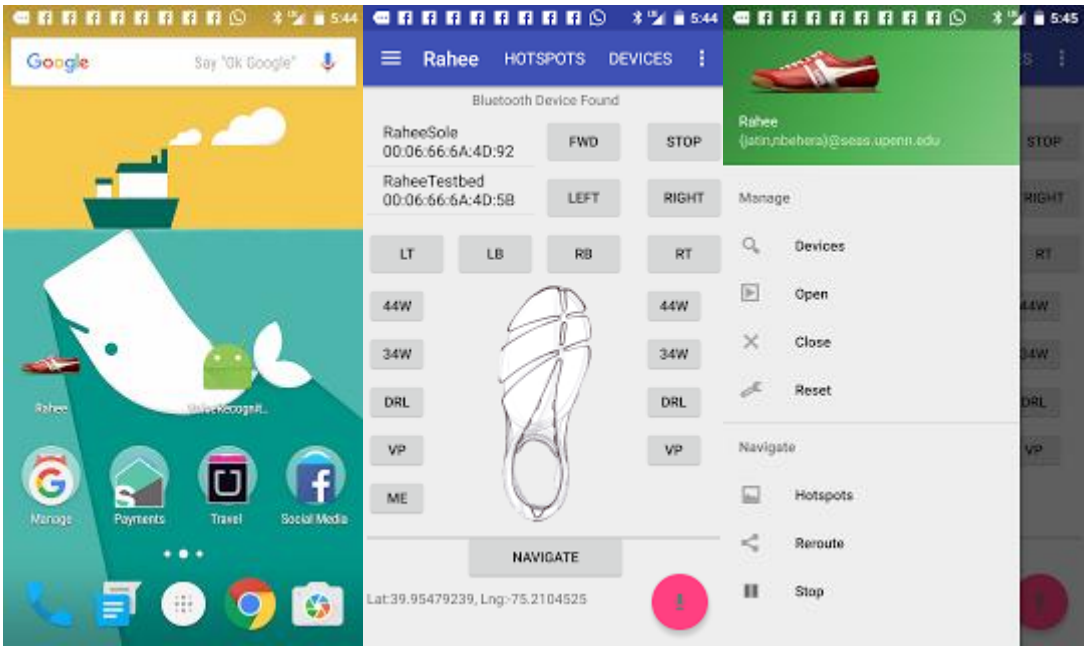
Voice Command Supported

Where am I? : Tells you your current location address
Navigate to ... : Navigate to Destination
Reroute : Reroute to same Destination via new path
Reroute to ... : Reroute to new Destination
Stop Navigation : Stop navigation
Information : About Rahee

14. User Interface [Stretch Goal-5]

We developed a fully functional production level android app. Here is a list of UI feature and then screenshots of the real UI-

1. Main screen launcher icon
2. Shoe sketch at center of the screen
3. Drawer to manage device
4. Real Time Navigation Emulator


Google
Say "Ok Google"
Rahee
Manage
Payments
Travel
Social Media
Rahee
HOTSPOTS
DEVICES
Bluetooth Device Found
RaheeSole
00:06:66:6A:4D:92
RaheeTestbed
00:06:66:6A:4D:58
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STOP
LEFT
RIGHT
LT
LB
RB
RT
44W
34W
DRL
VP
ME
NAVIGATE
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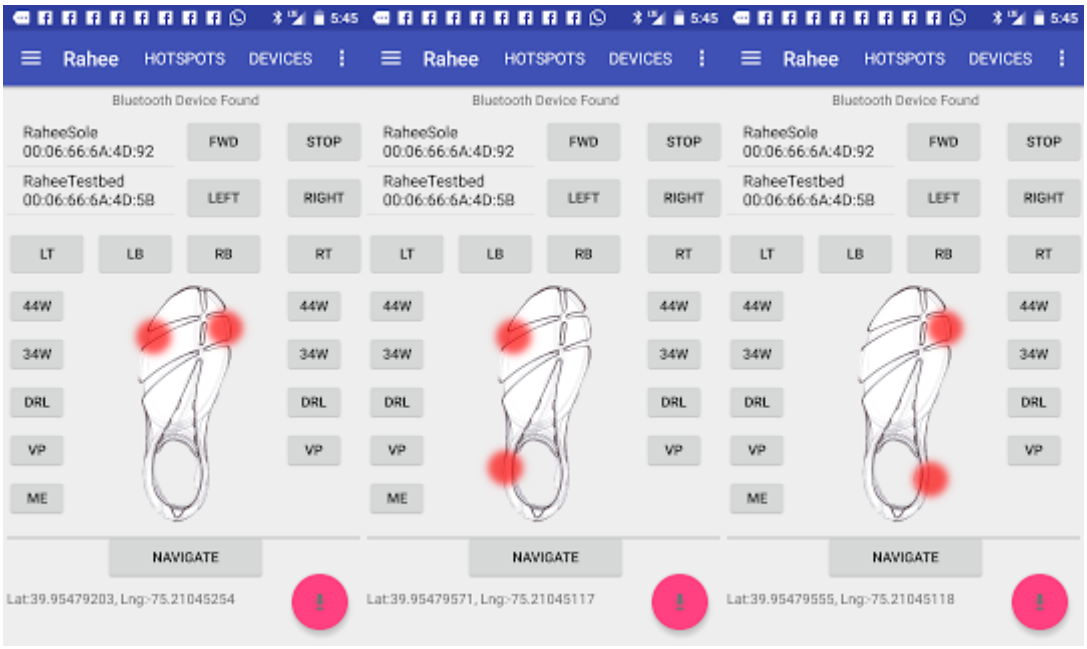
Rahee
Manage
Devices
Open
Close
Reset
Navigate
Hotspots
Reroute
Stop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RB
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44W
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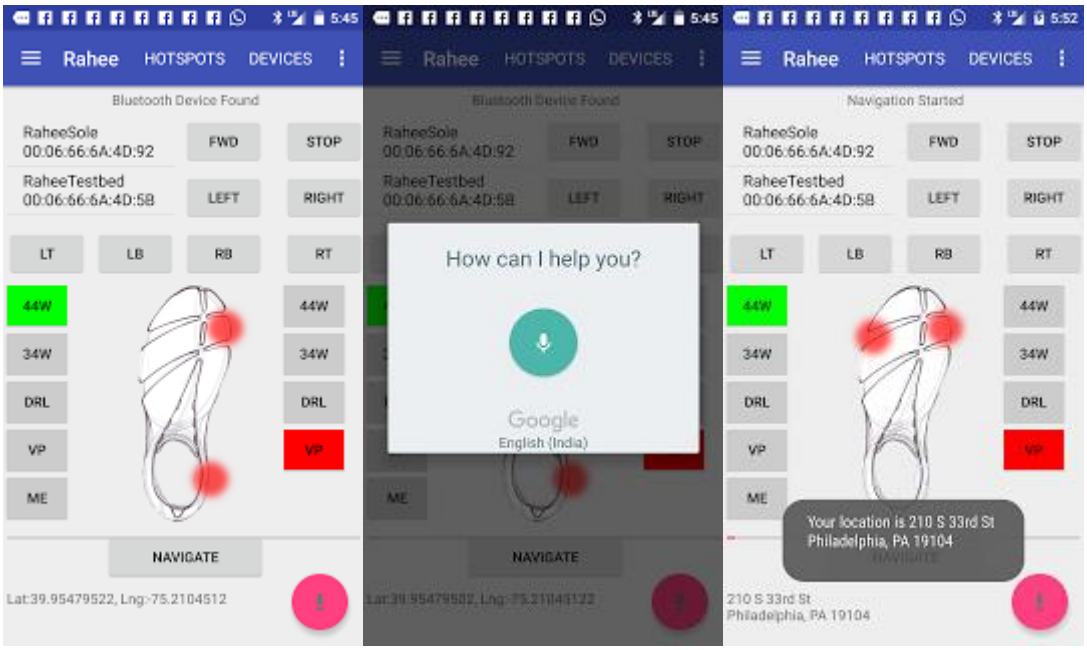


15. Benchmarking [Stretch Goal-6]

We decided to do some bench-marking tests on Rahee to see how well it performs and whether it is really a useful thing.

10.1 Power

Power Source : Li Ion 2000mAh
Charging : USB micro wall charging
Charge Time : 3 hours
Current Drawn : 200mA (Device ON, Navigation OFF)
: 225mA (Device ON, Navigation ON)
: 10mA (Device OFF)
Walk Time : 9-10 hours
Real Walk Time : 3 days (If person walks 3 hours a day)

10.2 Weight

Shoe Pair Weight : 350g (including circuit)
Circuit Weight : 60g

10.3 Usability

Please see the project video at the below URL -
http://raheeupenn.blogspot.com/2015/12/demo-video.html

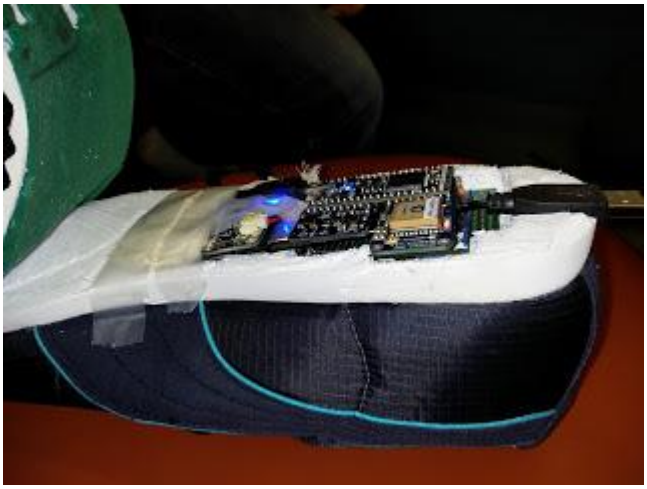
10.4 Affordability

R&D Cost : $200
Device Cost : $100
Projected Cost : $20-$30

10.5 Durability

The current version of shoes may not be the best in durability as they are in prototype phase still they are pretty reliable. We have been walking with them for more than a month now and the circuit is steady. We never had to solder anything because of wear and tear.

It is a compact design. We have components soldered on a hard surface zero PCB in two layer to reduce size. Some of the components like indicator LEDs, Programming cable etc are redundant and should be there in final design. Everything must go insole.



10.6 X-Factor - style symbol, cool

Rahee is cool to put on. In mobile first and app first world it is going to be a new trend. Just like smart watches and fitbits. It has a great potential to be the next wearable computing platform.