COMPUSOFT, An international journal of advanced computer technology, 3 (4), April-2014 (Volume-III, Issue-IV)

ISSN:2320-0790

An International Journal of Advanced Computer Technology

BlindNav: A Smartphone Based Navigation System for the Visually Impaired

Varsha Varadarajan[1], Snehita Kolapkar[2], Monica Saini[3], Smita Dange[4]

[1,2,3]B.E. Computer Engineering Student at F.C.R.I.T., Vashi, Mumbai, India

[4]Assistant Professor in the Computer Engineering Department at F.C.R.I.T., Vashi, Mumbai, India

Abstract: Navigating in an indoor building and finding path to common locations is one of the primary concerns for visually challenged people. When the blind or visually impaired find themselves in an area they are not familiar with, they feel lost and their safety is at great risk. Current systems do not function in GPS-denied indoor environments and only do identification of particular landmarks encountered by user. As an attempt to address this problem, we present an indoor navigation system based on WiFi strength calculation which is easy to use and highly efficient. This paper discusses a smartphone based system 'BlindNav' that provides voice based navigational assistance to the blind or visually impaired by informing the user about the current location, assisting in point-to-point navigation and employing audible interfaces. Our system is supplementary to other navigational aids such as canes, blind guide dogs and wheel chairs.

Keywords: Indoor navigation; WiFi strength calculation; android; visually impaired; talk back feature; indoor maps

I. INTRODUCTION

According to a factsheet published by World Health Organization, 285 million people are estimated to be visually impaired worldwide: 39 million blind and 246 have low vision. The problems faced by them are of great concern. Their ability to navigate is very limited and is often a difficult challenge. There is therefore a need for a system that assists these individuals to overcome their difficulty. We believe that the plight of visually impaired people can be solved by technology. However, current technology solutions in the market are heavy, expensive and not suitable for an indoor environment. Hence, a solution should aim at providing a tool that is reliable, inexpensive, and easy to work indoors.

In recent times, there has been an exponential growth in the mobile telephony market. Handsets are now embedded with motion and rotation sensors, Internet connectivity, high-end camera functionality and audio assistance. All the sensing and computing technologies available in a common smartphone makes it ideal for BlindNav application aiming at supporting the navigation of users in an indoor environment where common localization systems, such as GPS (Global Positioning System), fail due to severe attenuation or obscuration of the satellite's signal.

Thus, in this paper we propose the design and implementation of a system that will locate a user inside building and assist in navigation. The system operates as a smartphone application, wirelessly calculating a user's specific location within a building. The focus end-user is the blind, allowing him/her to locate himself by providing audible feedback and turn-by-turn instructions on how to reach a desired destination. The key functionality behind the application is its ability to operate without the use of a GPS signal. Instead, a modified version of signal strength calculation will be used to aid in navigation. The path will be announced to the user using audible interfaces. During the course of navigation, the location of the user will be constantly calculated in order to determine the navigation path and the destination.

The paper is organized as follows: in the next section we describe the existing and related work in the field of indoor navigation systems. The third section introduces the topic of Indoor positioning system. Then, in the fourth section an overview of the Wi-Fi positioning system is presented. In the next section, the concept architecture and implementation of the application is presented. We then present the working application and user evaluation. Finally, in the last section we draw conclusions and present the planned future work.

II. EXISTING SYSTEM

Attempts at solving the problem for visually impaired have been implemented many times in the past, each time with different versions and different deficiencies. Every design that has been made based on this idea has or had its advantages and disadvantages. These designs range from animal solutions to computerized solutions. The following designs have been implemented:

i. Guide animals can help a blind person become more mobile, avoid obstacles, and remain safe while travelling. Guide animals are a wonderful way to get help for indoor navigation, but in this way the blind person is leading not the animal. The animal can just avoid obstacles but it certainly cannot know the destination. Also, large amount of time is required to train the animal.

ii. White canes are another tool that helps in many of the same ways as guide animals. According to the National Federation of the Blind (NFB), "we believe the long white cane is a means to independence. The white cane has proved a useful tool to millions of blind people in navigating their environments with confidence and safety". Canes, however, are only able to detect objects in the vicinity; it has no means of knowing the destination.[27]

iii. Some buildings provide Braille on walls and signs to help blind people with indoor navigation. This is a great help when present, but there are problems with consistency. First, it is never sure which buildings have it and to what extent. It can be embarrassing to feel a wall for Braille as people watch knowing that there is none. Second, there is inconsistency in the dialect used when the Braille is present. Finally, the percent of blind people that actually read Braille is rather low.

iv. Use of SONAR technology for indoor navigation is also an aspect that has been looked into. SONAR can help a visually impaired person to navigate as SONAR would reflect back from the surroundings and let the person know his/her surroundings. The main disadvantage of using SONAR is that it is expensive. Some commercial products are available in the market which uses the SONAR technology like Deeper.

v. Trinetra (the third eye) design built by students of Carnegie and Mellon; to date they have used a Barcode based solution on an Bluetooth and Internet enabled smartphone to aid grocery shopping for the visually impaired.[4]

vi. iDOCENT- Indoor Digital Orientation Communication and Enabling Navigational Technology uses a modified version of signal strength triangulation to determine a user's location on a smartphone within four feet accuracy.[7]

A. Wireless Technologies

Any wireless technology can be used for locating; so many systems take advantage of existing infrastructure. Others provide increased accuracy at the expense of costly equipment and installations.

- Choke Points
- Grid Concepts
- Long Range Sensor Concepts
- Angle of Arrival
- Time of Arrival
- Received Signal Strength Indication

III. INDOOR POSITIONING SYSTEM (IPS)

An indoor positioning system (IPS) is a network of devices used to wirelessly locate objects or people inside a building. There is currently no de facto standard for an IPS systems design, so deployment has been slow. Nevertheless, there are several commercial systems in the market.

Instead of using satellites, an IPS relies on nearby anchors (nodes with a known position), which either actively locate tags or provide environmental context for devices to sense. The localized nature of an IPS has resulted in design fragmentation, with systems making use of various optical, radio, or even acoustic technologies.

In contrast to the common title suggesting that a position may be affected by a system, this assumption is not correct: Despite naming, most of the IPS do not position an object, but just detect location of an object, not including the detection of the orientation or direction of that object. All known indoor positioning systems (IPS) neither affects nor detects a direction nor offers the option to change the position. Also other various systems titled as local positioning system and so on offer detecting an object in a certain known fixed location, report a measured location or just report the presence of the object in such location. [22]

IV. WIFI POSITIONING SYSTEM [25]

Wireless Indoor Positioning techniques have become very popular in recent years. These systems have been successfully used in many applications such as asset tracking and inventory management. These systems provide a new layer of automation called automatic object location detection. To name a few, one can consider the location detection of products stored in a warehouse, location detection of medical personnel or equipment in a hospital, location detection of firemen in a building on fire, detecting the location of police dogs trained to find explosives in a building, and finding tagged maintenance tools and equipment scattered all over a plant. [3]

The most favoured IPS technology in development provides location from radio mapping; "fingerprinting" of

Wi-Fi emitters and emissions. Analysis usually involves the low cost but crude received signal strength method. Where necessary, Wi-Fi location for IPS is enhanced by inertial navigation using the accelerometers, gyroscopes and, for height, recalibrated barometers already fitted in many mobile phones.

GPS does not operate indoors since the satellite signal cannot penetrate through buildings. This is why Wi-Fi routers, which triangulate a device's position, are common in indoor locations. Four Wi-Fi categories of systems determine position based on the following parameters – cell of origin, distance, angle and location patterning.

- **'*Cell of origin*'** – this approach's advantage is the ease of implementation and its drawback the fact that a device can get associated not with the closest cell but with another, more distant one.
- **'*Distance*'** – this method requires precise knowledge of transmission times, and is most accurate in semi-indoor locations.
- **'*Angle-based*'** – a technique, the major drawback of which is susceptibility to interference, thus it is barely usable in indoor navigation.
- **'*Location patterning*'** – does not require special hardware, and has the user carrying anything as simple as a bar-coded sticker. Receiving sensors track the signal via an interference created by the tag. A cheap and easy to implement solution, with a downside the user's unease with the gadget after having left the building.

A. Wifi Positioning Technology

Crowdsourced Wifi data can also be used to identify a handset's location. Poor performance of the GPS-based methods in indoor environment and increasing popularity of WiFi has encouraged companies to design new and feasible methods to carry out WiFi-based indoor positioning. Most smartphones combine GPS with Wi-Fi positioning systems.

Cell ID, Triangulation, Trilateration and Fingerprinting are the most popular techniques used in WiFi positioning.

i) Cell ID: Cell ID WiFi-based positioning reports back the closest AP as the location of the mobile client/user. Cell ID positioning can be extended by the user reporting back areas where it can 'see' some combination of APs. This requires the mapping of the coverage area to determine which areas can detect which APs. Similar to Cell ID in mobile network positioning, the accuracy of WiFi-based Cell ID positioning depends on the density of the APs and the size of each AP's cell coverage.

ii) Triangulation: Given the coordinates of APs, and the angle between client/AP and North, Triangulation can give a positioning result by calculating the location of the client.

A Wi-Fi node can also be located by triangulating its position with respect to at least three access points whose locations are known. In order for triangulation to work, we need to know the distance between the mobile node and each of these access points. This distance can be estimated from RSS value since a radio signal loses its energy as a function of distance travelled, described by the popular radio propagation path loss model. Triangulation works by solving a set of circle equations, where the intersection of all three (or more) circles denotes the mobile node position However; Triangulation requires a directional antenna, which is expensive and not available in mobile phone devices. Furthermore, the error is huge in indoor environments which degrades the angle measurements, and impacts on the positioning result significantly.

iii) Trilateration: Ideally, given the coordinates of APs and the distance from APs, Trilateration (or Multilateration) can also determine an accurate result. However, it is difficult to accurately measure the distance from the client/user to each AP. Using the time taken to send a packet from the client to the AP will not yield an accurate result as there are many factors that will affect the time for a packet to arrive. This is because the environment through which the signals propagate is so variable, different from location to location due to walls and objects blocking signals.

iv) Fingerprinting: Each location has a unique set of detectable APs and associated signal strengths. This set is known as a 'fingerprint'. Fingerprinting involves surveying the coverage area and recording the WiFi fingerprints across the area and storing this data in a database. Finding the location of a client or user involves measuring the current fingerprint at the unknown location and performing a comparison procedure against the fingerprint data stored in the database in order to find a match. The matched fingerprint's position will be the estimated location of the client. However, if there are significant structural modifications to a building, the system may give degraded results. The coverage area must then be re-surveyed.

V. BLINDNAV CONCEPT

The project 'BlindNav- A Smartphone based navigation system for the visually impaired' is an application that makes use of the principle of Wireless Positioning System in order to develop a system for the blind to navigate. Principles of indoor positioning based on WiFi strength calculation is used to determine where the user is currently positioned. Depending on the current position of the user, a path is generated on the pre- loaded map in the application. The blind person is then guided using voice instructions on how to reach his destination.

The main objective of our project is to make navigation in a new building easier for a blind or visually- impaired person. This application though is not a complete replacement to the traditional assistance that blind people use, can be used in a way along with traditional systems to help the blind navigate in easier way.

On careful analysis it was decided that the most feasible solution for indoor navigation could be accomplished using the Android smartphone platform.

The particular accessible smartphone available both featured Wi-Fi capabilities and the processing power to deliver accurate results.
The smartphone will scan all access points that are in range and determine the signal strength in dBm (or dBmW). The strength measurements are translated into percentage, and the access point's MAC address is compared against a list of known access point locations. All of the quantified location coordinates are analyzed to gain a location of the phone. The lesser the intermediate obstacles will be, the stronger the WiFi signal strength will be, and thus, the more accurate the location reading will be. The calculated position will be displayed on a pre-loaded map on the smartphone.
The map coupled with the calculated location will allow the application to give directions to reach a desired location.

VI. ARCHITECTURE

A. Modules

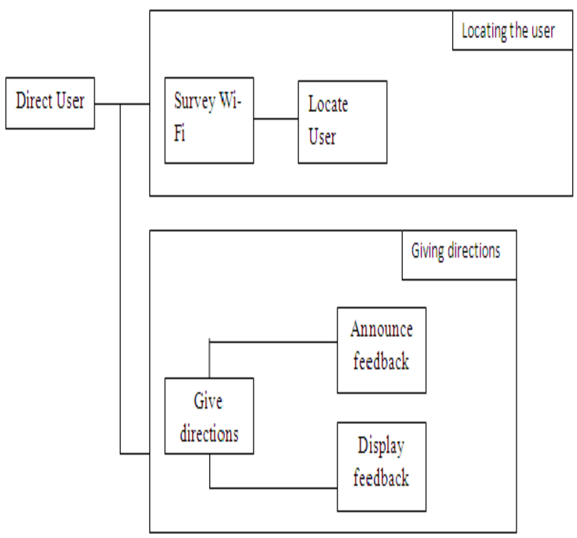

Fig i: System modules

The diagram elaborates the focus of the project, which is to direct a user to their preferred destination.
The task of directing the user consists of two main ideas:

- Locating the user.
- Giving directions.

Locating the user is dependent on the value of signal strength, utilized within the Wi-Fi algorithm. This is accomplished by surveying the site for available access points. Finally, directions will be provided to the user through an on-screen map and audible directions.

B. Flowchart

The application begins by putting On WiFi in the phone in case it is not ON. It then scans for the nearby APs in the area. Readings of unknown APs that are obtained are not considered.
Depending on the level of the signal obtained using WiFi Manager class of Android, the signal strength in percentage is calculated. This signal strength is used to determine the current location of the user. [16]
Path is calculated and displayed on the map based on the selected destination. Displayed path can also be used by people with partial vision.
The flow of the application is as follows:

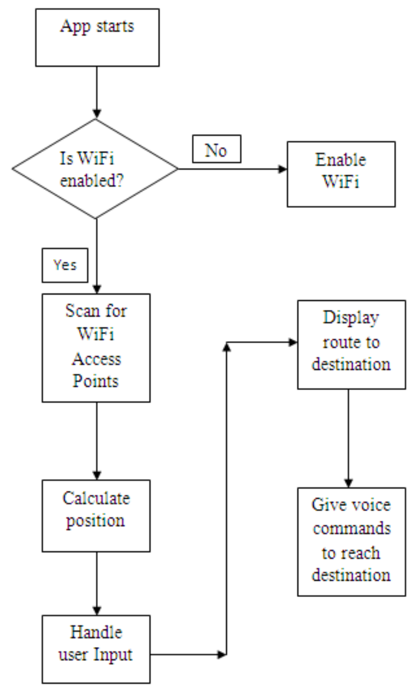

Fig ii: Flowchart of the working of 'BlindNav' application

C. BlindNav Implementation

BlindNav will be implemented on the popular Android platform.
The implementation of the application majorly consisted of the following modules:
i) User Module: The user module consists of only a smartphone which the user can either wear around the neck or hold in his/her hand.
The smartphone has to be connected with an earphone since all instructions given to the user will be through audio interfaces.
ii) User Interface: The application makes use of the talk back feature in Android smartphones that help visually impaired people to use a smartphone. Also, Test-To-Speech (TTS) API of Android is used to give voice commands to the user to specify his current location.[1]
Keeping in mind, limited vision of the user, the application provides easily accessible buttons, of large size, which will help blind to access the application. (Figure viii)

iii) Maps: The blueprint of the college was obtained from the college office. This blueprint was in traditional non-digital form. The map was converted into .png format manually.

The map of the first floor of F.C.R.I.T College was used in the application. The map was designed using JOSM (Figure iii) in order to get actual to-scale mapping and was then loaded into the Android app as an image.

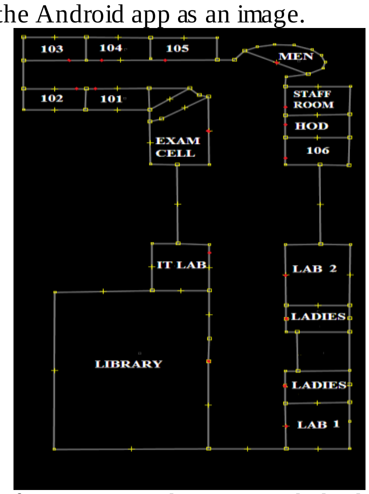

Fig iii: Map of F.C.R.I.T First Floor Degree side developed in JOSM

VII. WORKING APPLICATION

The application can be used in the following manner:

- Launch the application: Tapping the app icon once reads aloud 'BlindNav' under the talkback Feature. The user must double tap the icon to launch the application. (Figure iv)

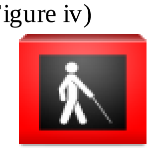

Fig iv: Launcher icon

- The application gets loaded and the map is displayed. All visual displays have been generated keeping in mind people with partial vision. (Figure v)
- The user is notified of the drop down list and asked to select the destination. TalkBack feature helps in user interactions. (Figure vi(a) and vi(b))
- Depending on the user's current location and destination a path is generated and displayed on the map. The user is given instructions to move based on his current position. As the user moves, his location and landmarks on the way is announced. Upon reaching the destination, the user gets a voice alert to notify that destination has been reached. (Figure vii)

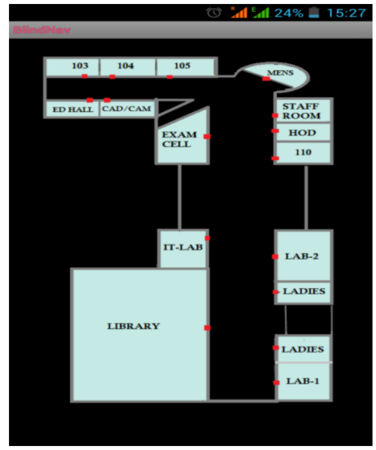

Fig v: Application loaded

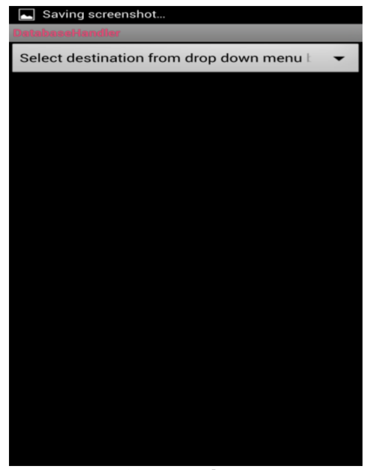

Fig vi(a): Drop down menu

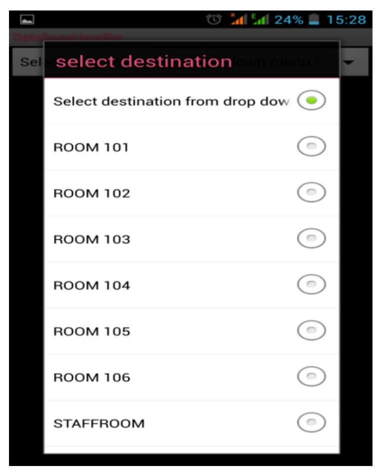

Fig vi(b): Drop down list, destination list read aloud

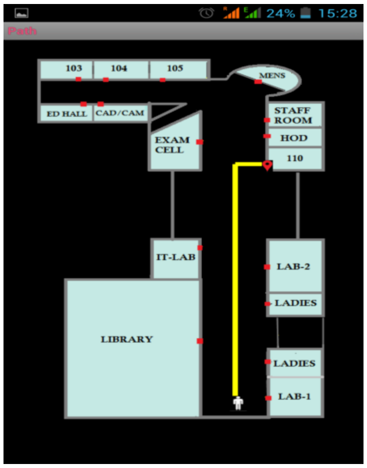

Fig vii: Path generated

- On the way, if the user wants to know his current location, with respect to any landmark, a large button is provided to help him find his current location. (Figure viii)

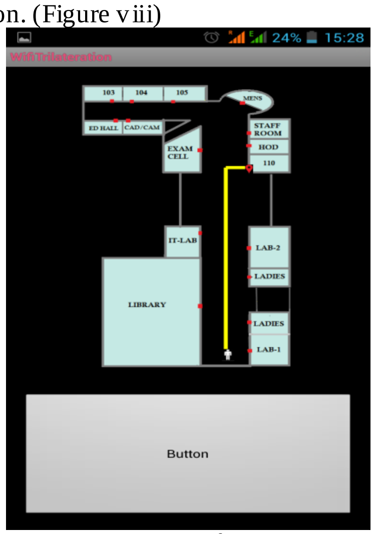

Fig viii: User Interface- Button

VIII. USER EVALUATION

Goal: To determine whether the system works properly when deployed in the environment.

Experimental setup: 8 WiFi Access Points were setup on the first floor of F.C.R.I.T College.

Participants: The system was preliminarily tested with 5 individuals of both sexes posing as blind people. These people had English knowledge and adequate knowledge about using a smartphone.

Results: Results show that the TalkBack feature helps blind people to use the smartphone without hassles. Our application helps in directing user to the destination accurately. Appropriate voice commands are given to the user that helps him/her in reaching the destination correctly. Future test plans involve testing the application with blind people who are entirely new to the building.

IX. CONCLUSION

In this paper, we have shown that indoor navigation in unfamiliar spaces is a very grave problem for visually impaired people. Moved by their plight we have proposed the design and implementation of a smartphone based application based on WiFi strength calculation that will help blind people navigate in indoor environment.

We hope that our application will help visually impaired people to navigate in a new environment. As the first step towards helping them, we have built an application that will cater to this objective in our college campus.

This project can be further extended to help blind with obstacle detection system. This obstacle detection module can be coupled with the Android application to notify the user when he encounters an obstacle in his path. Further, this project can be extended to include navigational assistance for other important places like malls and hospitals, etc.

ACKNOWLEDGEMENT

At the outset, we thank Prof. H. Kaura, Head of the Computer Department, F.C.R.I.T for having facilitated us with the essential infrastructure which helped us complete our Project.

We express our sincere gratitude to Prof. Mrs. Kiruthika, for her vital encouragement and support.

We take immense pleasure in thanking our guide Mrs. Smita Dange, who consistently endeavoured to give us valuable insights and guidance.

We would like to thank all our teachers and all the staff members of Computer Department, who provided us with thoughtful solutions, suggestions and help whenever we faced daunting problems.

We would also like to thank the non-teaching staff, our friends and family who supported us throughout.

REFERENCES

[1] Ed Burnette The Pragmatic Programmers "Hello Android, Introducing Google's Mobile Development Platform" Third edition, Android 1.5 to 2.1.

[2] Gordie Stein, Matt Gottshall, Jacob Donofrio, Andrew Kling Indoor Digital Orientation Communication and Enabling Navigational Technology.

[3] Hui Liu, Student Member, IEEE, Houshang Darabi, Member, IEEE, Pat Banerjee, and Jing Liu Survey of Wireless Indoor Positioning Techniques and Systems.

[4] Patrick E. Lanigan, Aaron M. Paulos, Andrew W. Williams, Priya Narasimhan Trinetra: Assistive Technologies for the Blind.

[5] Carboni, Davide Indoor Mobile Pedestrian Navigation System.

[6] CRS4. Indoor Navigation System Prototype in a modern smartphone (No radio beacon, no GPS, no WiFi). 30 September 2010. January 2011 http://www.youtube.com/watch?v=HTZFRDBdQck

[7] Gordie Stein, Matt Gottshall, Jacob Donofrio, Andrew Kling iDOCENT:Indoor Digital Orientation Communication and Enabling Navigational Technology.

[8] Alberto Serra, Tiziana Dessì, Davide Carboni, Vlad Popescu, Luigi Atzori Inertial Navigation Systems for User - Centric Indoor Applications.

[9] Alberto Serra, Davide Carboni, Valentina Marotto Indoor Pedestrian Navigation System Using a Modern Smartphone.

[10] Beom-Ju Shin, Kwang-Won Lee, Sun-Ho Choi, Joo-Yeon Kim, Woo Jin Lee, and Hyung Seok Kim Indoor WiFi Positioning System for Android-based Smartphone.
[11] Patil, Abhishek Pramod. Performance of Bluetooth Technologies and Their Applications to Location Sensing 2002. January 2011
[12] Work, Eric. UW Campus Navigator: WiFi Navigation July 2003. Electrical Engineering Department, University of Washington. January 2011 <http://uwcampusnav.sourceforge.net/WifiNav.pdf>.
[13] World Health Organization Fact Sheet N°282 Updated October 2013 http://www.who.int/mediacentre/factsheets/fs282/en/
[14]https://developer.android.com/training/basics/firstapp/index.html?hl=it
[16]http://developer.android.com/reference/android/net/wifi/WifiManager.html
[21] Wikipedia Dead Reckoning http://en.wikipedia.org/wiki/Dead_reckoning
[22] Wikipedia Indoor Positioning < http://en.wikipedia.org/wiki/Indoor_positioning_system>
[23]Wikipedia Real Time Locating System <http://en.wikipedia.org/wiki/Real-time_locating_system>
[24**]** Wikipedia Wi-Fi <http://en.wikipedia.org/wiki/Wi-Fi>
[25] Wikipedia Wi-Fi Positioning System <http://en.wikipedia.org/wiki/Wi-Fi_Positioning_System>
[26] http://mbed.org/users/aberk/notebook/dead-reckoning/
[27] https://nfb.org/free-cane-program