The MIT Tour-ing Machine

Smriti Pramanick and Natasha Consul

6.s062 Spring 2016

Abstract

The MIT Tour-ing Machine provides those that frequent MIT (students, tourists, etc.) an interactive and informative tool to learn about MIT's rich history, such as hacks. We designed and developed an iOS application focusing on a tour of the Stata Center. The application provides a "museum tour" highlighting some major events that have taken place at MIT. Using a combination of different sensor technologies (BLE beacons and built-in phone sensors), we determine the exhibit the user is closest to and provide the user with relevant information.

Approach

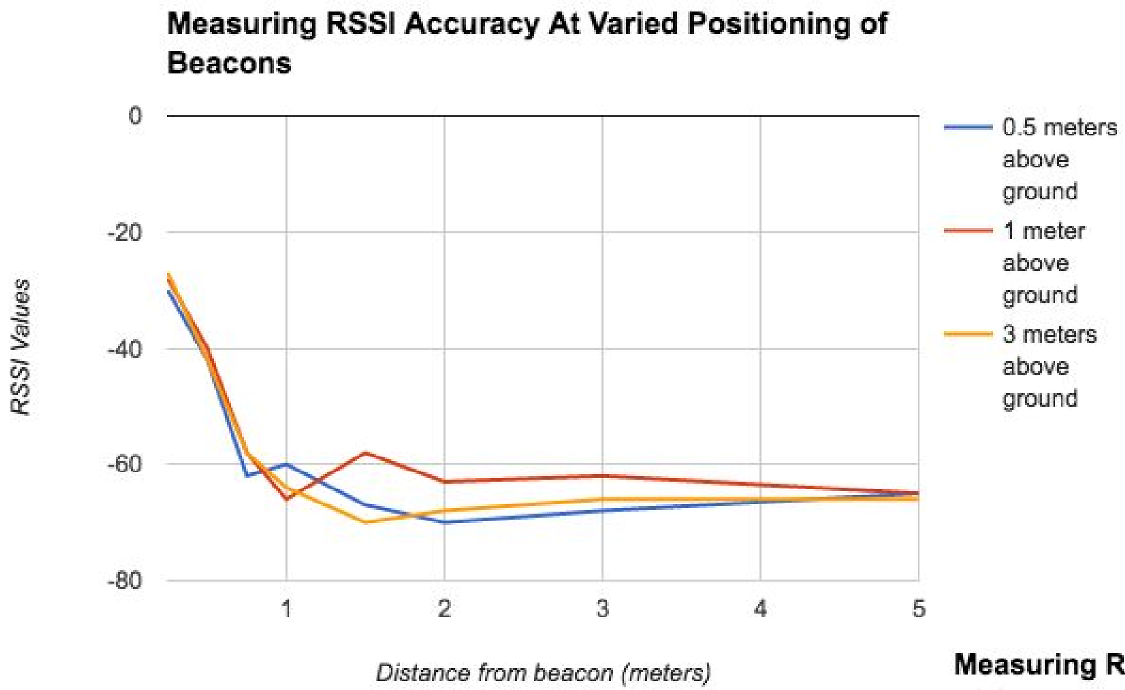
We focused solely on using sensor data from BLE beacons and from the phone’s built-in accelerometer and compass to determine the user’s position relative to the exhibits of interest. We combined a subset of these technologies, as an alternative to using indoor WiFi positioning, GPS satellite positioning, and cellular tower positioning because these technologies would not be precise enough to determine the user’s location relative to exhibits indoors.

Below, we describe our findings on using BLE beacons, accelerometer data, and compass data for estimating the position of a user relative to the exhibits in Stata. The exhibits we chose are the Fire Hydrant, the Cranes for Collier, the Phonebooth, and the MIT-Stanford Video Camera, all located around the Stata Cafe.

Bluetooth Low Energy (BLE)

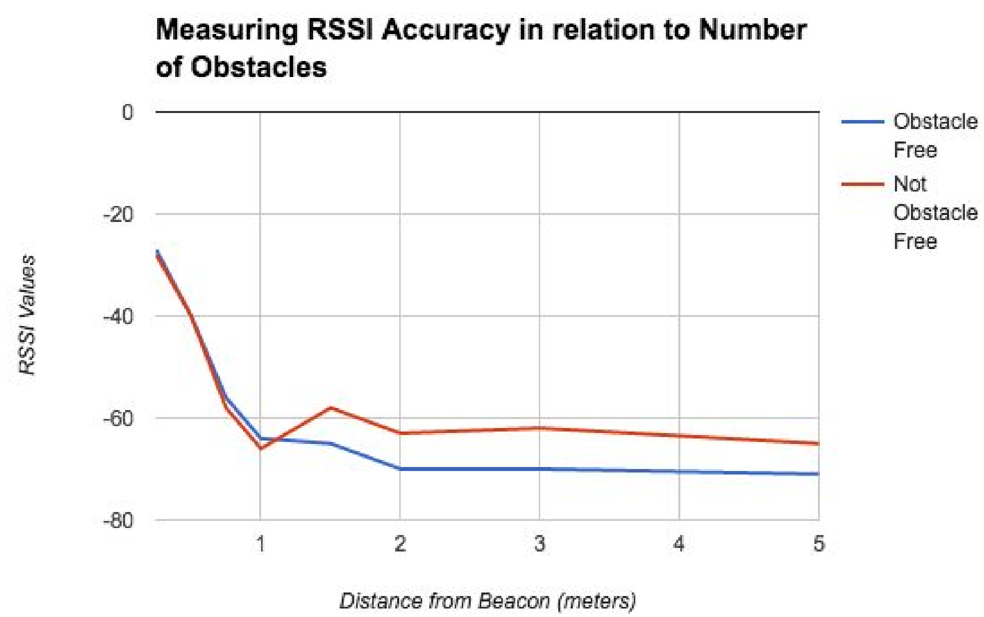
BLE Beacons provided RSSI values that are used to determine which cluster of exhibits a user is closest to. The closer a user is to a beacon, the stronger the signal strength. Thus, by analyzing the signal strengths from two beacons, we determine which cluster of exhibits a user is likely to be at, based off of expected signal strengths. Challenges faced include:

- Low range: BLE becomes unreliable when more than 1-2 meters from an emitting beacon
- Physical obstacles: BLE signal accuracy diminishes with physical obstacles that come between beacon and the receiver (people, physical objects, etc.)
- Limited beacons: With a limited number of beacons, we cannot rely solely on BLE signal readings to pinpoint the user location.



The plot below shows that the RSSI values measured seem to be larger when there are no obstacles in the path, compared to when there may be obstacles in the path. This correlates to having more accurate measurement for a larger range of distances.

The plot above shows that the RSSI values measured appears to fluctuate beyond 1-2 meters. Broadcasting from a beacon 1 meter above ground is more ideal than broadcasting from 0.5 m and 3m above ground. This is most likely due to the trade-off between the number of obstacles in the path and the increased distance.



iPhone Accelerometer and Compass

Accelerometer data is used to determine velocity and position by taking the integral and double integral of the data points over time. By pre-calculating the distance vectors between pairs of exhibits, we aimed to determine the user's movement between exhibits using accelerometer data. However, the following challenges of using the iPhone's built-in accelerometer prevented us from accurately estimating the user's position relative to exhibits.

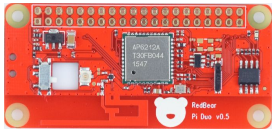
- ❏ Drift errors: The iPhone's accelerometer is prone to drift errors that accumulate over all position updates, which happen 1-100 times per second. A single error in acceleration will result in inaccurate velocity and position calculations to larger degrees.
- ❏ Built-in iOS acceleration: The iOS CoreMotion module handles acceleration due to gravity internally, creating unknown behaviors when working with acceleration data.

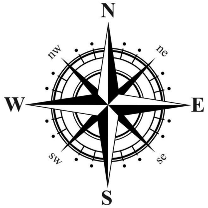
- Bounds: The acceleration data must be within -2*G and +2*G m/s^2. Outside of these bounds, data is lost and must be estimated or ignored.
- Filtering: Applying a high-pass filter to the data removed some drift errors and avoided the errors of exceeding the acceleration bounds, but we lost the ability to measure movement between exhibits. Applying a low-pass filter to the data does not properly handle exceeding acceleration bounds.

Overall, using accelerometer data was too inaccurate for estimating the user's position overtime.

Compass data is used to determine the direction a user is headed based on the heading of the phone. By measuring the absolute heading, we could estimate which exhibit a user was facing, based off of the exhibit's absolute position. We assumed that the user would face the exhibit within a 120 degree range. With more exhibits, this angle would become narrower. Thus, we used *sensor fusion* and combined the compass data with BLE readings to determine the correct exhibit within a sub-cluster of exhibits.

Setup


RedBear
Pi Duo v0.5

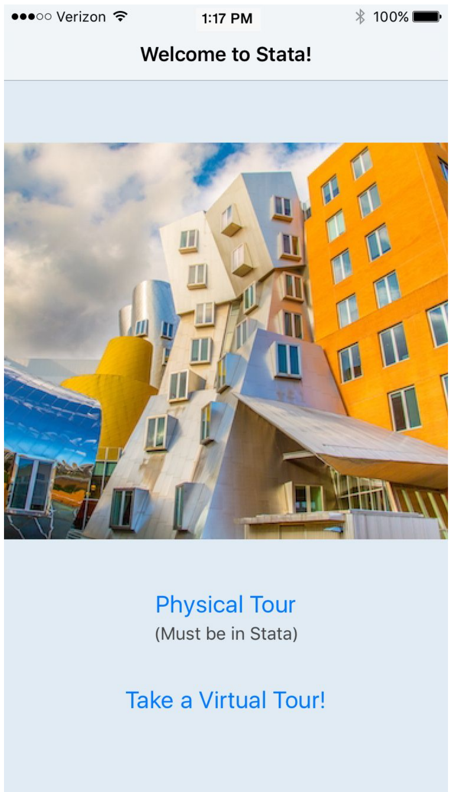

N
nw
ne
W
E
sw
se
S

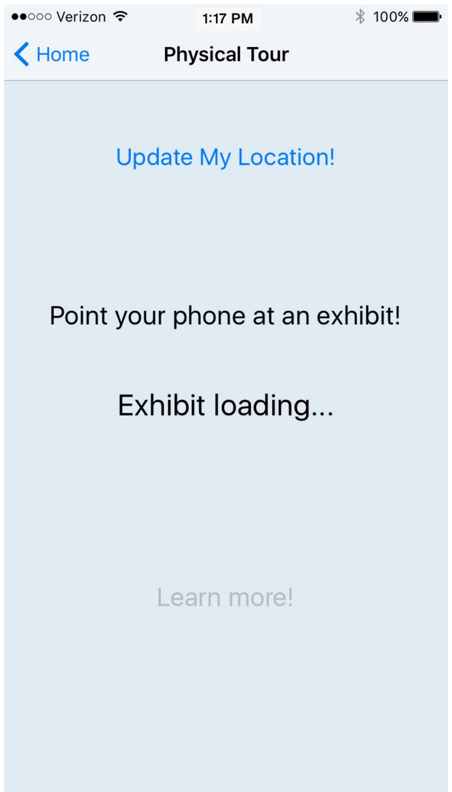

9:41
Monday, March 21
iBeacon

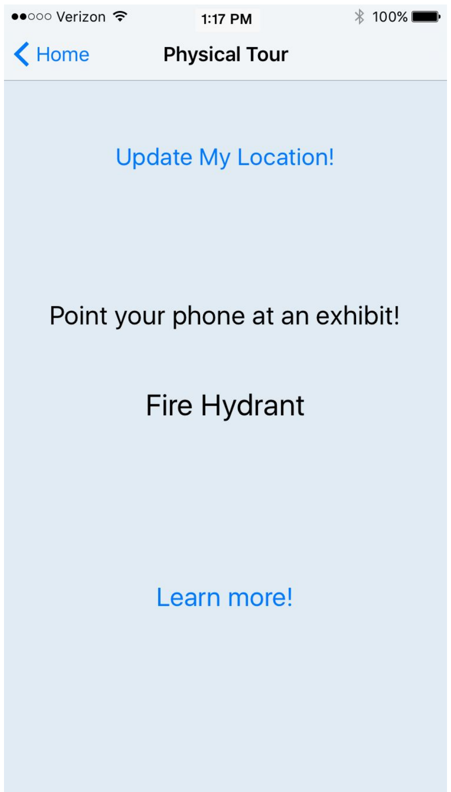

mit hacks
Fire Hydrant
Water Fountain, 1991

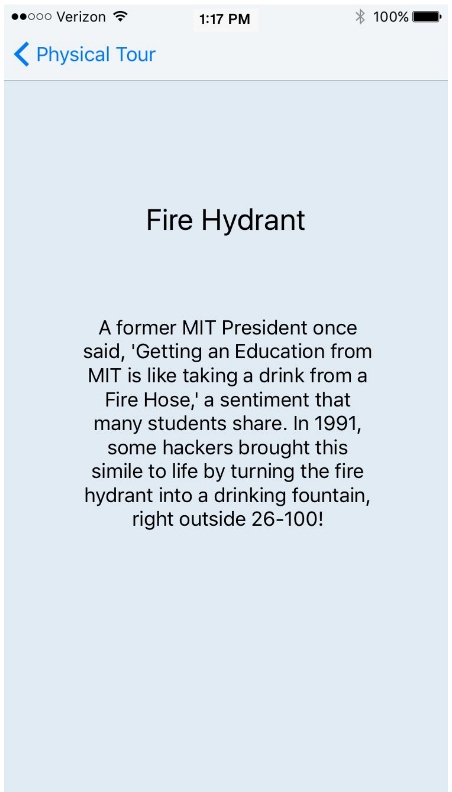
MIT Tour-ing Machine iOS Application

Physical Tour

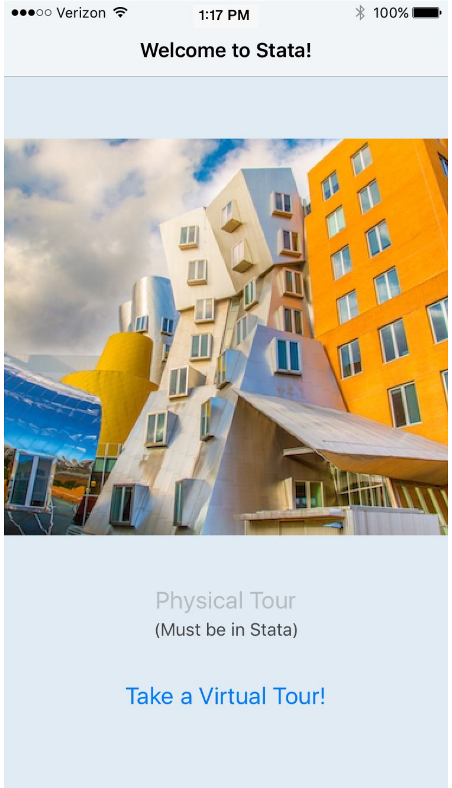


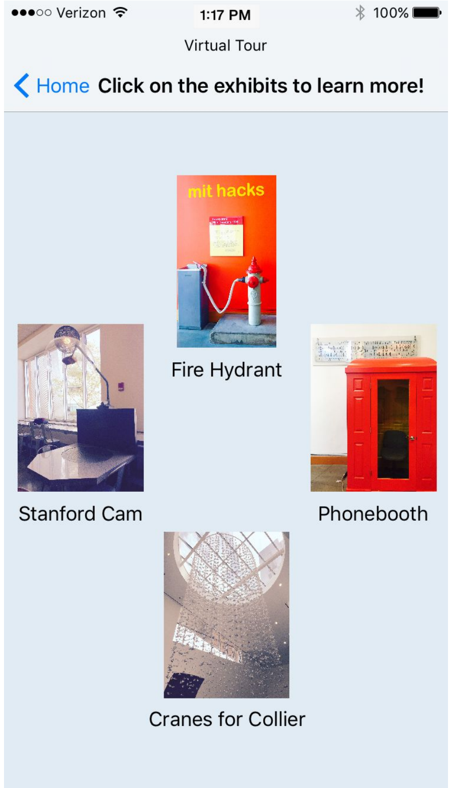


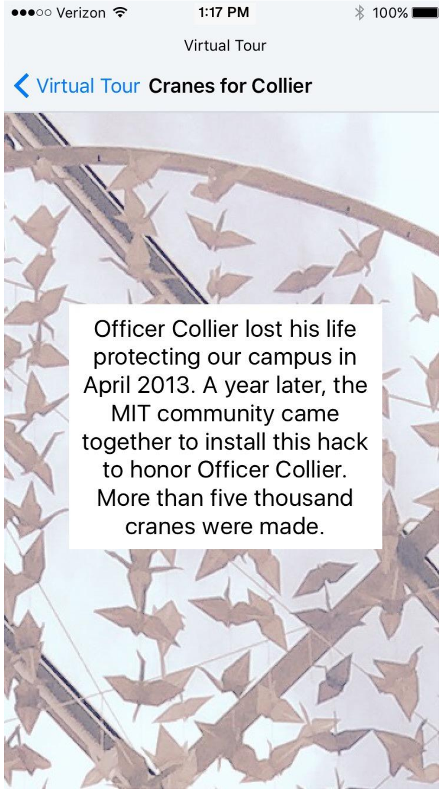




Virtual Tour







Results

The MIT Tour-ing Machine uses *sensor fusion* between BLE Beacon data and the iPhone's built-in compass readings to determine a user's location relative to exhibits in the Stata Center.

- **BLE Data**: The RSSI signal strengths from two beacons allows us to break up our exhibits into sub-clusters. Each sub-cluster corresponds to the beacon that has the highest RSSI value. Since RSSI values don't change over time (assuming the beacon positions remain the same), using BLE data is strategic.
- **Compass Data**: The absolute heading of the phone provides the direction the user is facing, which we compare to the known exhibit positions and determine which exhibit amongst the sub-cluster the user would be facing. Using compass data combined with RSSI values from BLE Beacons allow us to include more exhibits than using only compass data.

Future Work

The MIT Tour-ing Machine can be enhanced to include more exhibits around campus in larger scale. Improvements can also be made to use more sensor data to determine when users have arrived at new exhibits.

- **Exhibit Expansion**: The application can be expanded to include more exhibits around campus. This would require placing more BLE beacons around campus. One current limitation of our project is the lack of BLE beacons available.
- **Strategic BLE Beacon Placement:** Further research into determining the best beacon placement for the purposes of our application, since there will not only be low-range challenges, but also a large number of path obstacles.
- **Exhibit Detection Enhancement**: The application can be enhanced to determine when a user has arrived at a new exhibit without requiring manual user input. This can be accomplished with accelerometer data to measure gesture movements.