SoccerBeacons: tracking player movements in a soccer game using iBeacons

CS 6235 Project

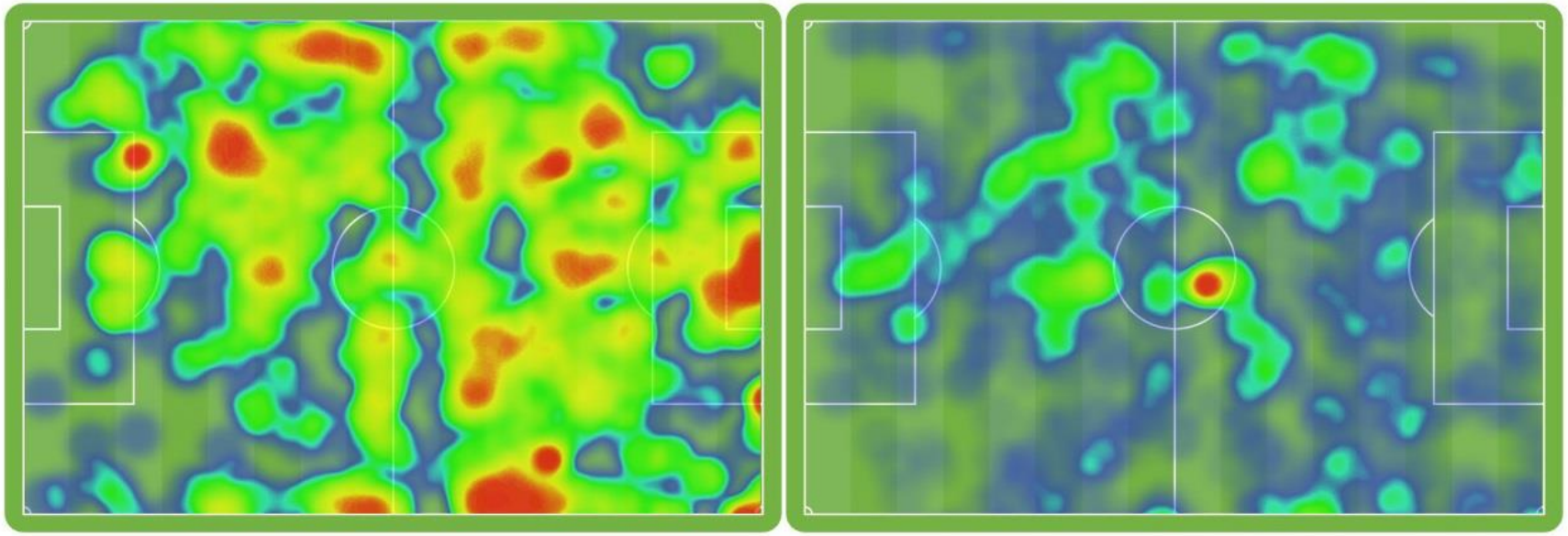
Suk Hwan Hong

(shong38@gatech.edu)

Motivation

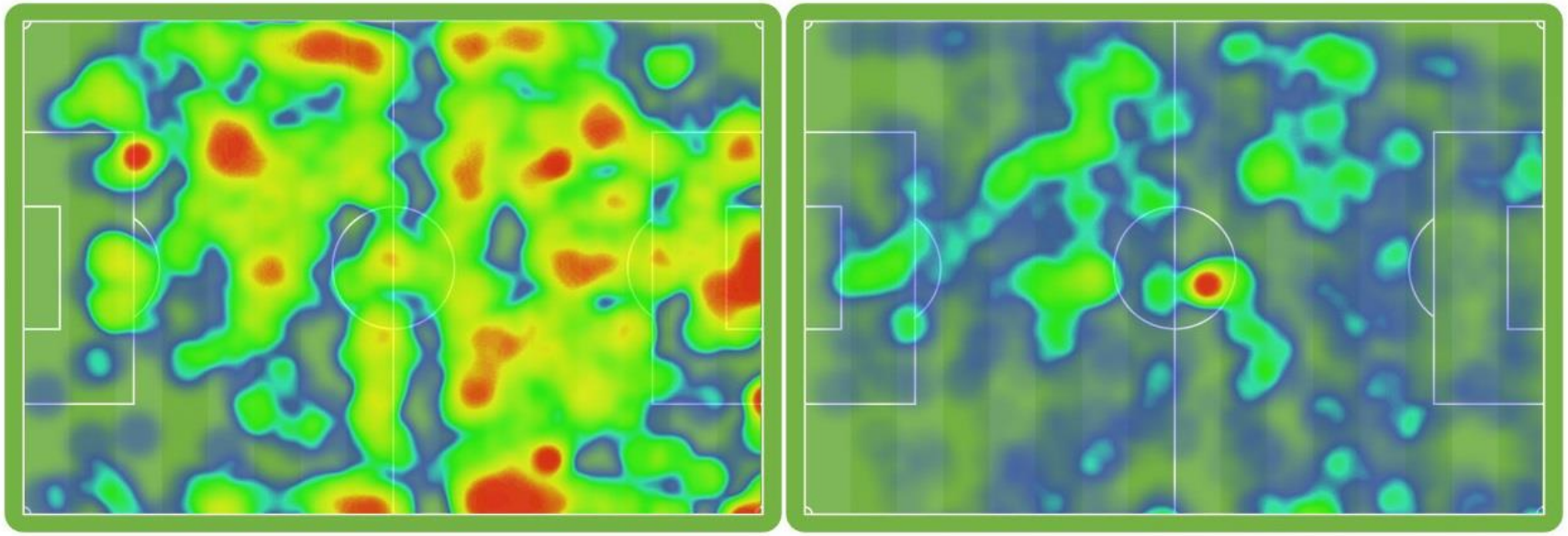
- My friends and I gather together to play soccer together every week.
- Players love to compare their performances in a game with each other afterwards.
- # of goals scored often not fair enough.
- Is there any other metric that can represent the performance in a soccer game more fairly?
- Movement Heat map is a good candidate!

Movement Heat Map



Which side seems to have performed better in this game?

Movement Heat Map



Which side seems to have performed better in this game?

Heat map from Brazil vs. Germany semi-finals match in 2014 World Cup
Germany's historic 7:1 victory over Brazil.
Left side is Germany, and right side is Brazil.

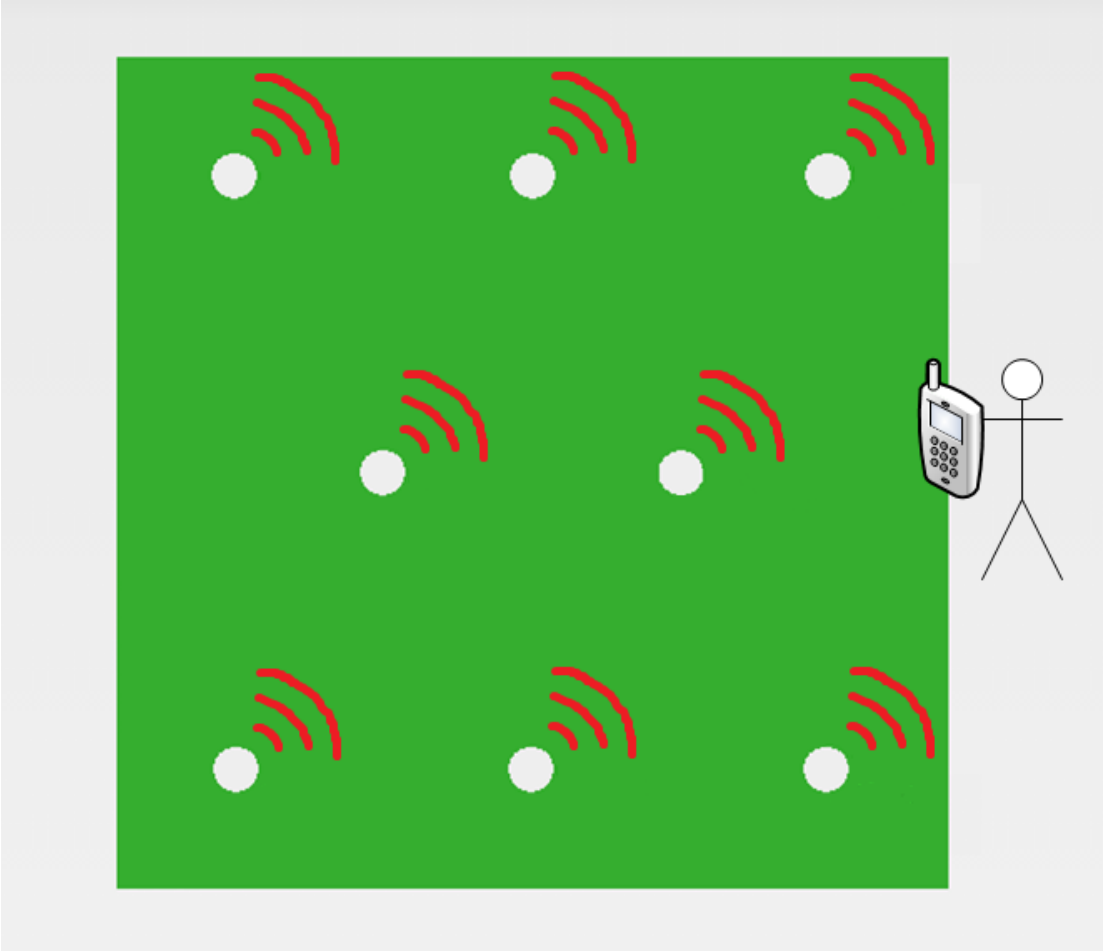
Tracking movements in outdoors

- GPS not suitable for tracking movements in a soccer game because of its coarse granularity.
- iBeacons are currently being used for tracking indoor movements.
- Why not apply it to outdoors? More specifically, to a soccer field!
- I developed an Android application that can track movements of a person for any rectangular-shaped field.

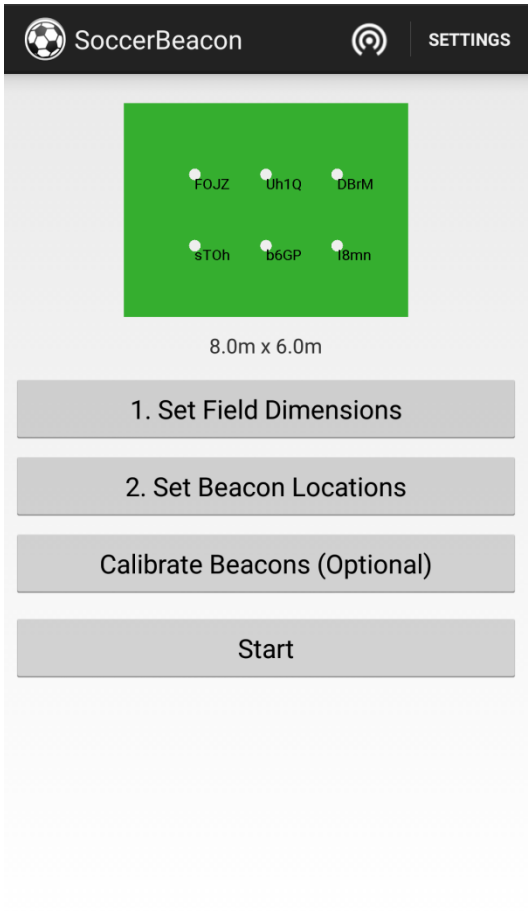
Application Workflow

1. Beacons will be placed in a rectangular-shaped field at certain positions.
2. After placing all beacons, users manually specify the dimensions of the field and coordinates of each beacon in my Android application.
3. Users have an option to calibrate beacons before starting to track positions.
4. Users also have an option to adjust certain parameters to make tracking result more accurate.
5. When a user ready, he/she can start the tracking process. The user carries the phone (with my Android application running) and moves around the field.
6. My Android application will track current position and show a live tracking result on the screen.

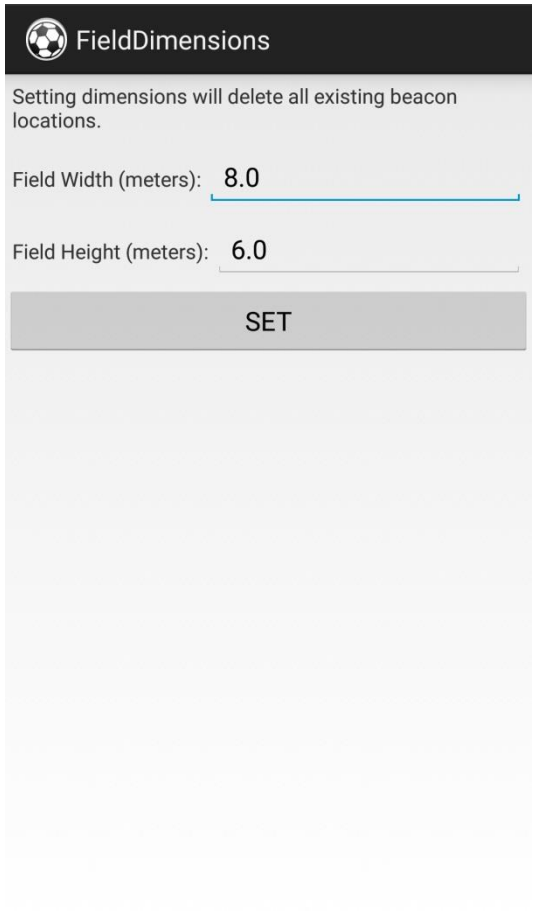
Example Setup



User Interface

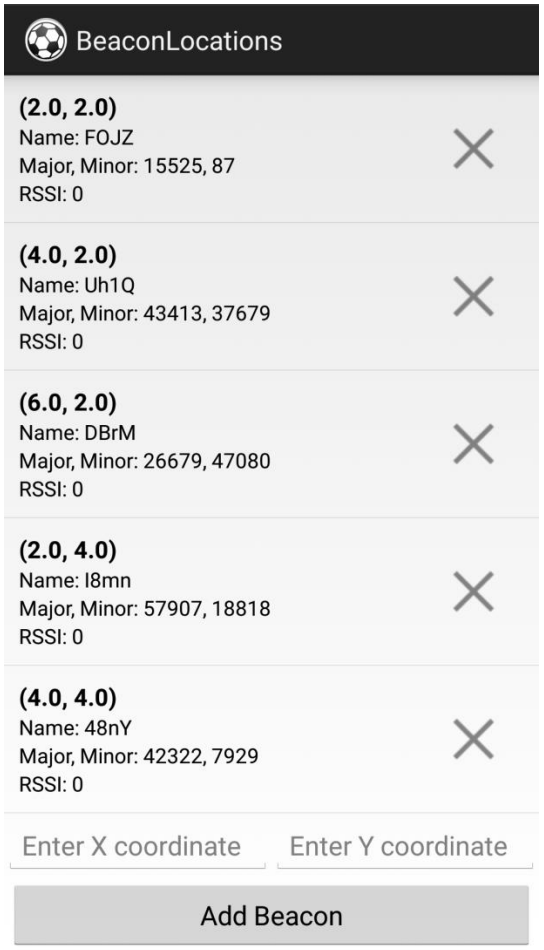


Main Screen

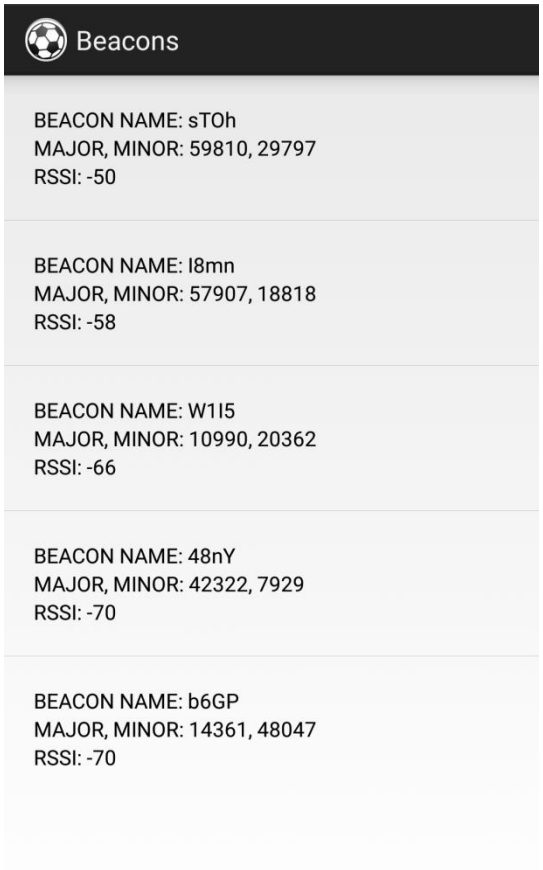


Enter Dimensions

User Interface

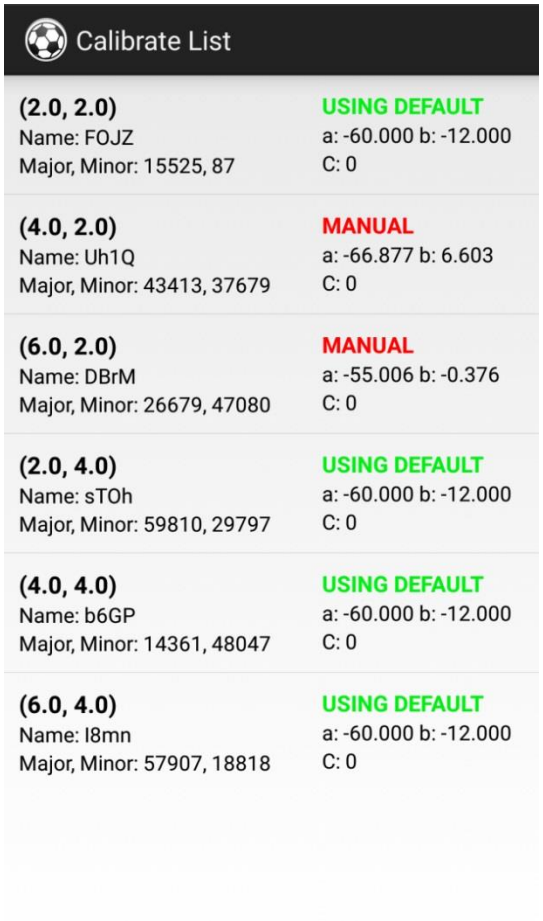


View/Add Beacon Locations



Beacons List

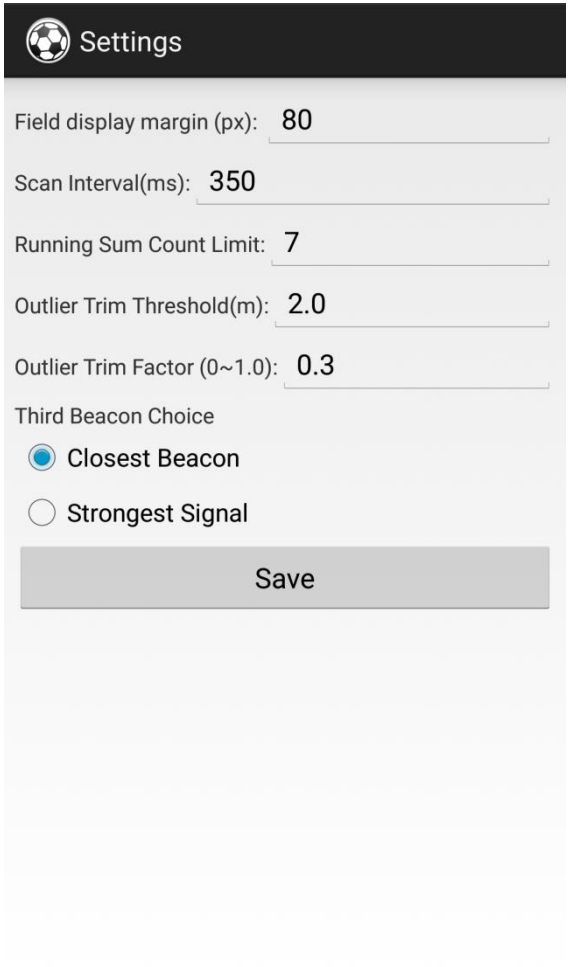
User Interface



Select a beacon for calibration

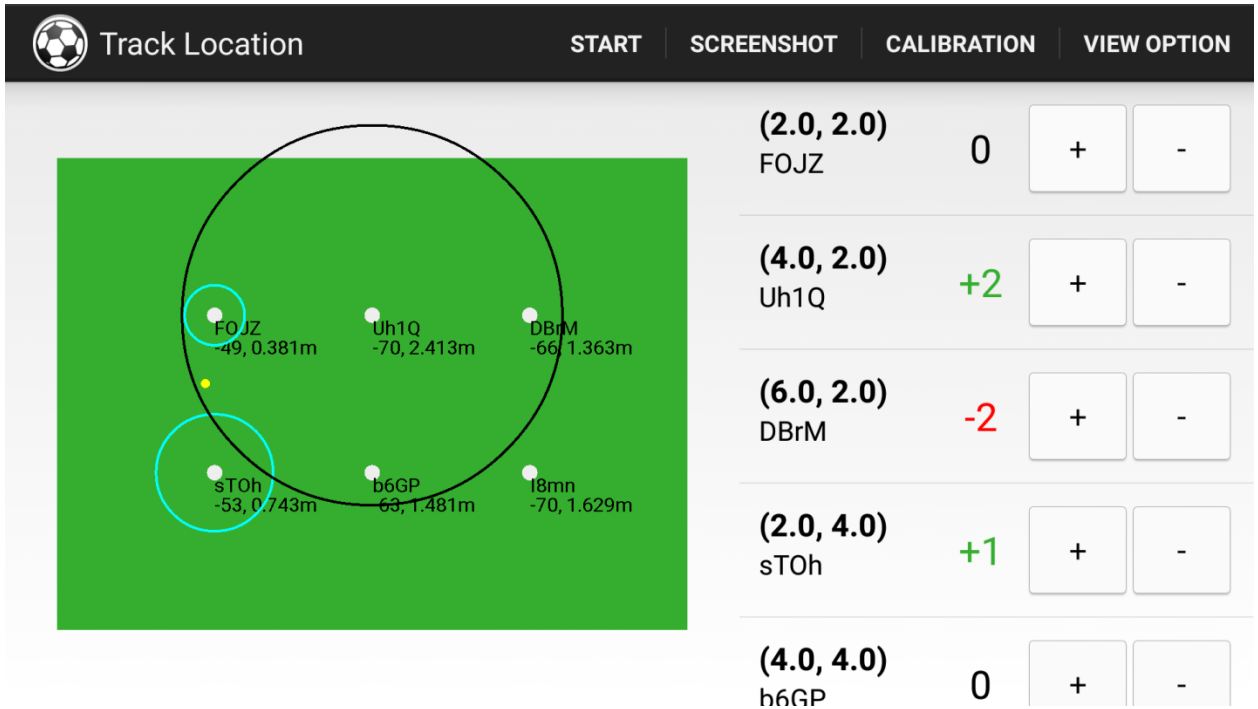
Manual Calibration

User Interface



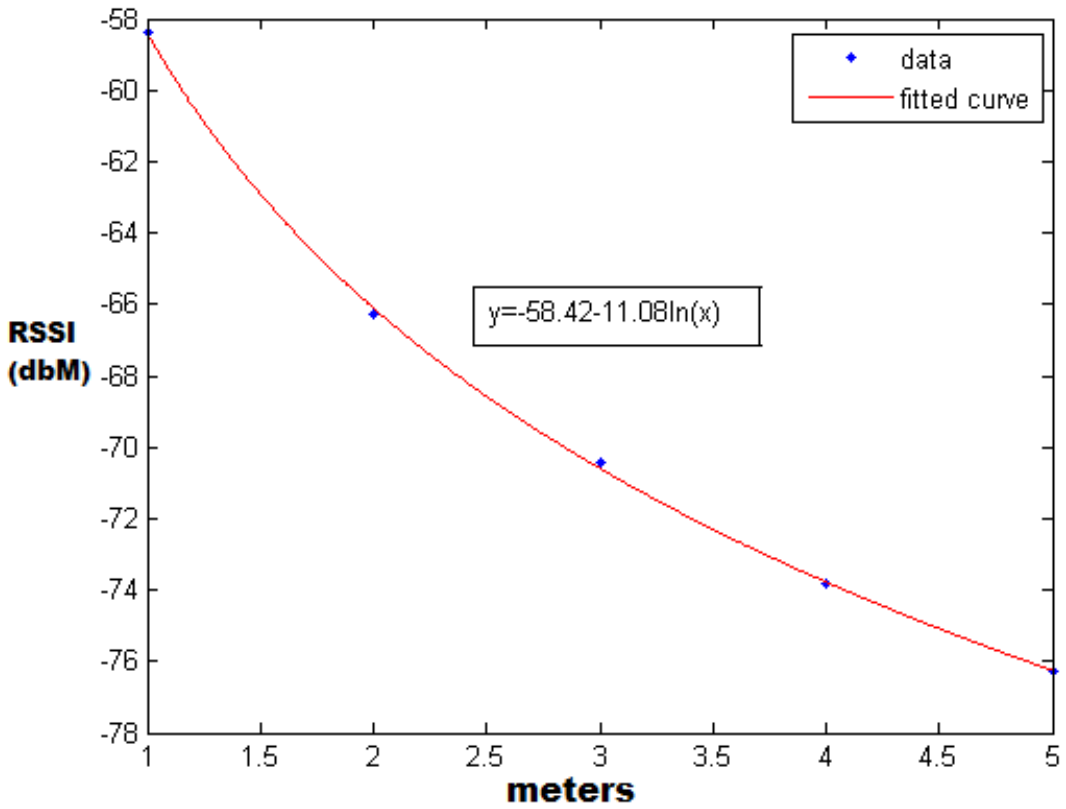
Settings

User Interface



Track Locations

Estimating Distances



- Sampled and averaged beacon signals at 1m,2m,3m,4m,5m from beacons
- Fitted a logarithmic curve to find a distance function

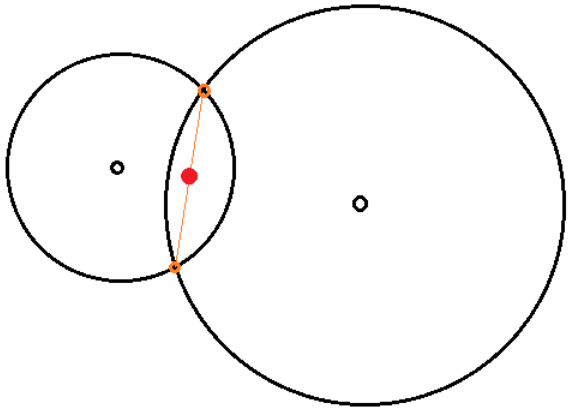
Algorithm

- I used a variation of a trilateration algorithm used by GPS to determine a location.
- We need distances from at least three beacons to pin-point a location.
- In my experience, using more than three beacons to determine a location actually degraded an accuracy of the application.

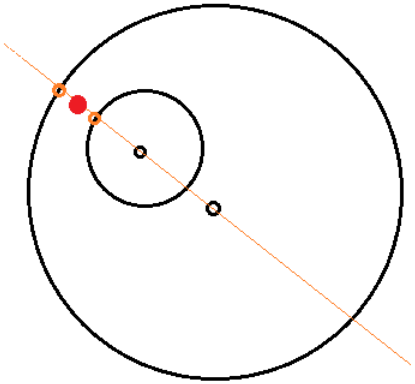
Algorithm

- 1. Find two beacons that are giving the strongest signals. Given two “range circles” from each beacon, there are three cases:
  - two range circles intersect with each other: take the middle point
  - one circle is contained in another
  - two circles are disjoint

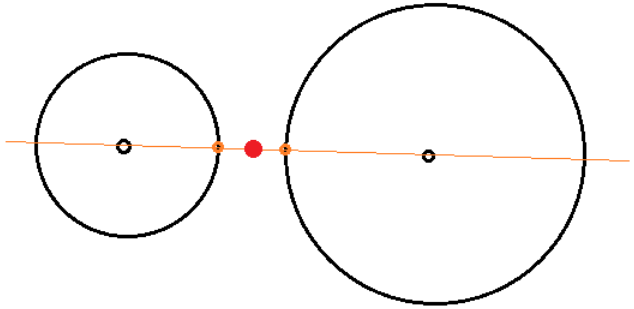
Algorithm



Two circles intersect



One circle is contained in another

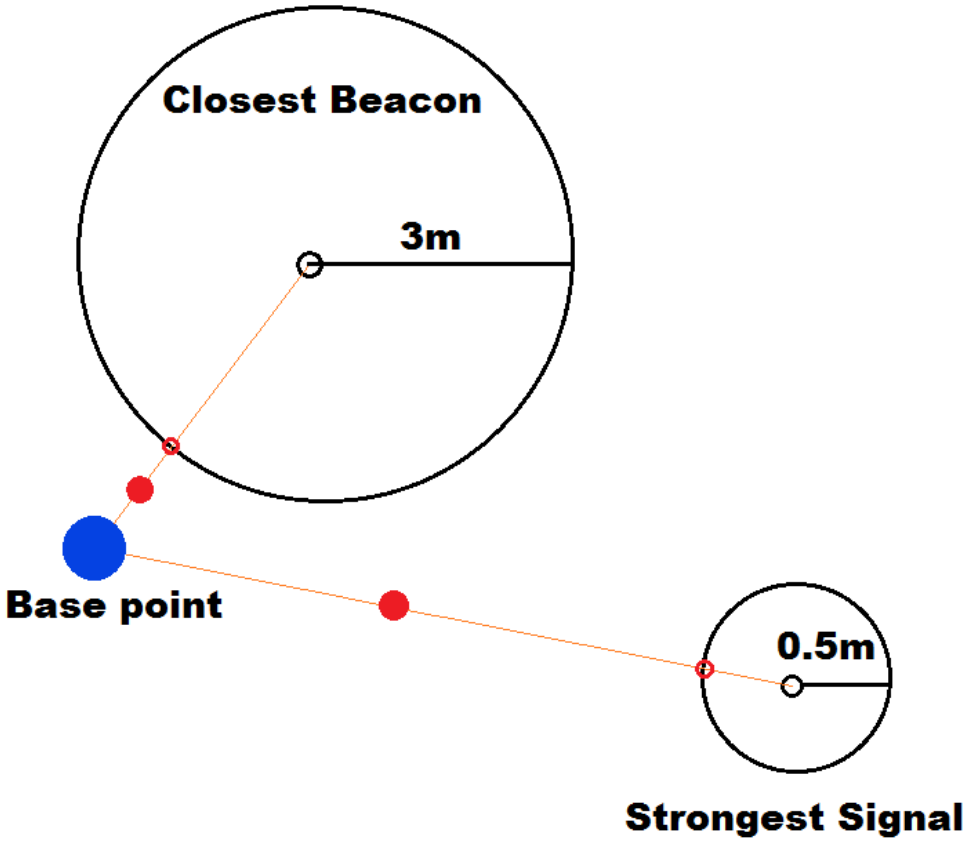


Two circles are disjoint

Algorithm

- 2. Using this base point, I find a third beacon to use for determining the location. There are two possible choices here:
  - Use the closest beacon from the base point
  - Use the beacon that is giving the strongest signal
- There is a high probability that the closest beacon from the base point is a correct choice even if it doesn’t give the strongest signal.

Algorithm

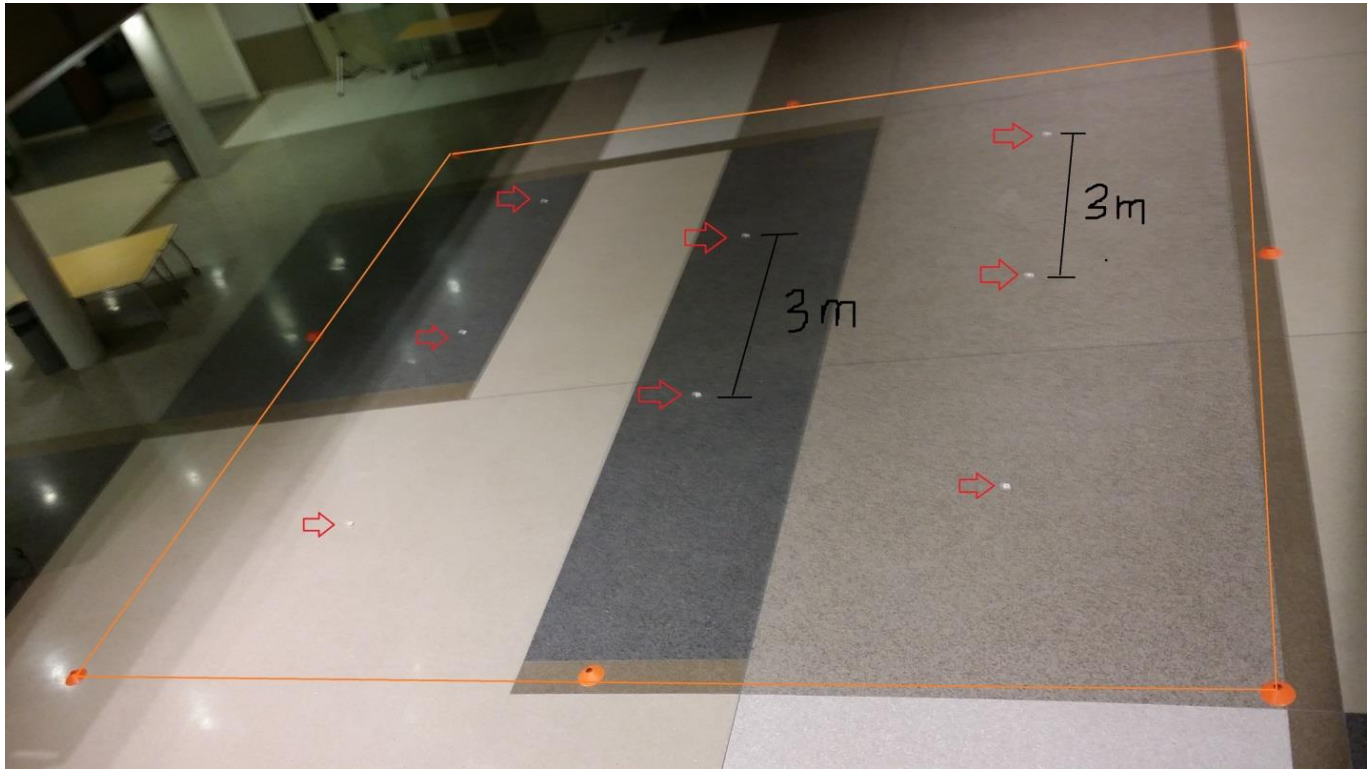


Configurable Parameters

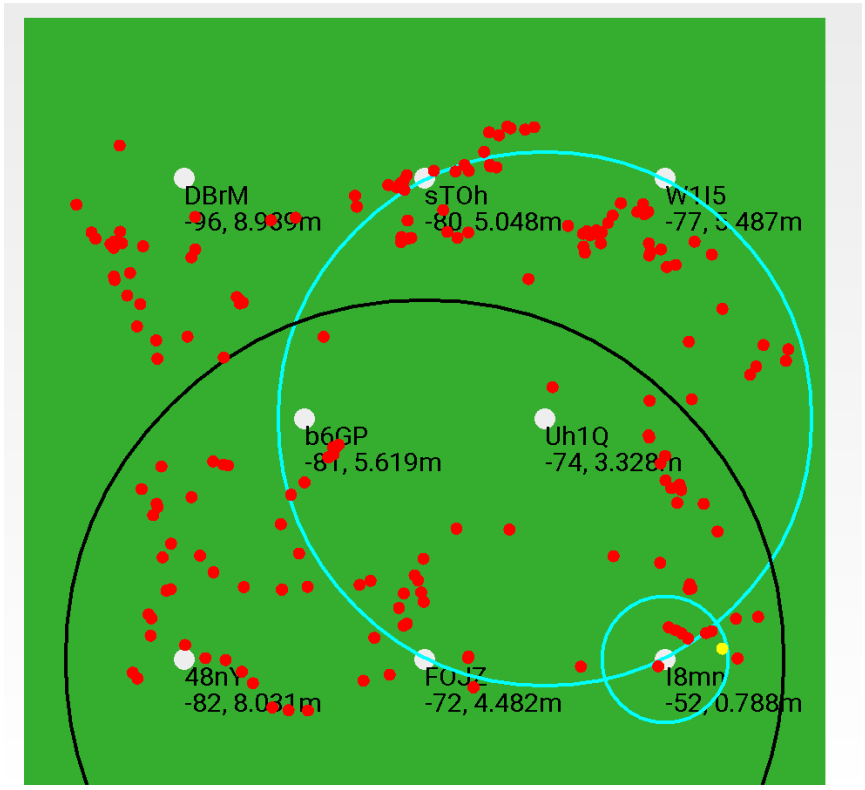
1. **Field display margin**: display purpose
2. **Scan Interval**: interval between each scan
3. **Running Sum Count Limit**: affects running sum average
4. **Outlier Trim threshold**: determines outlier
5. **Outlier trim factor**: multiplied to outliers
6. **Third Beacon Choice**: Closest Beacon or Strongest Signal

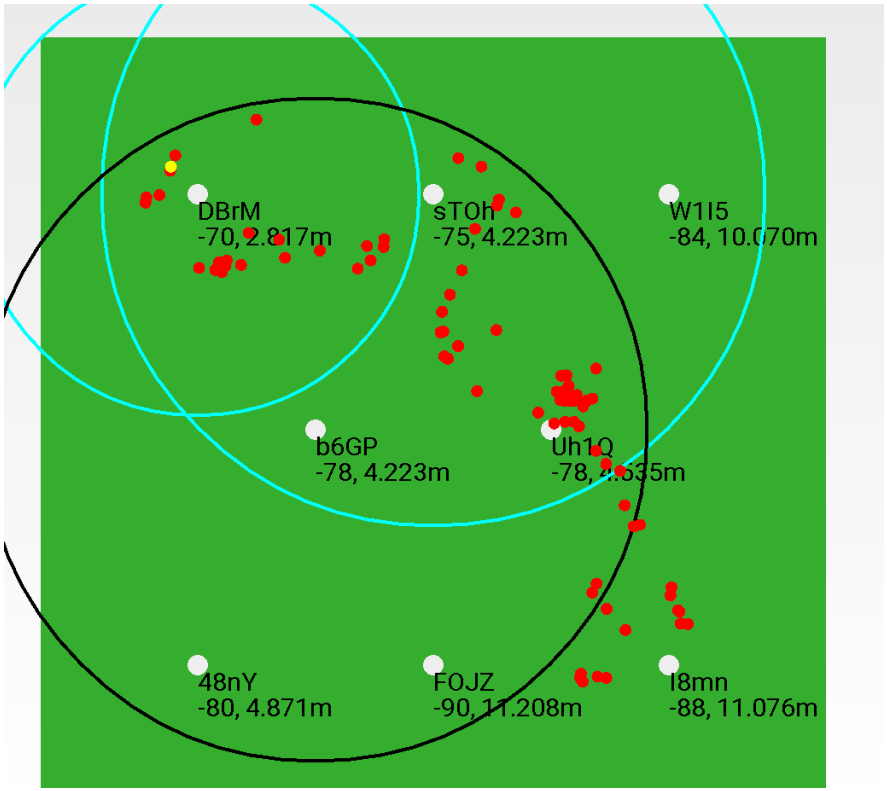
Experiments

- 10m x 10m square field in Klaus Atrium
- Two movement patterns: border and diagonal



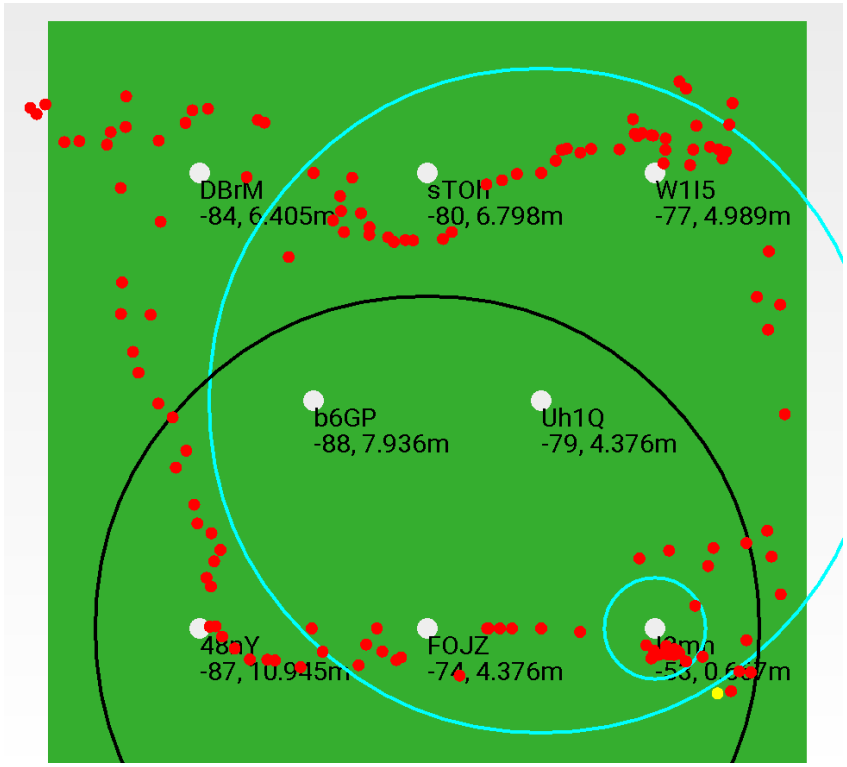
Third Beacon Choice

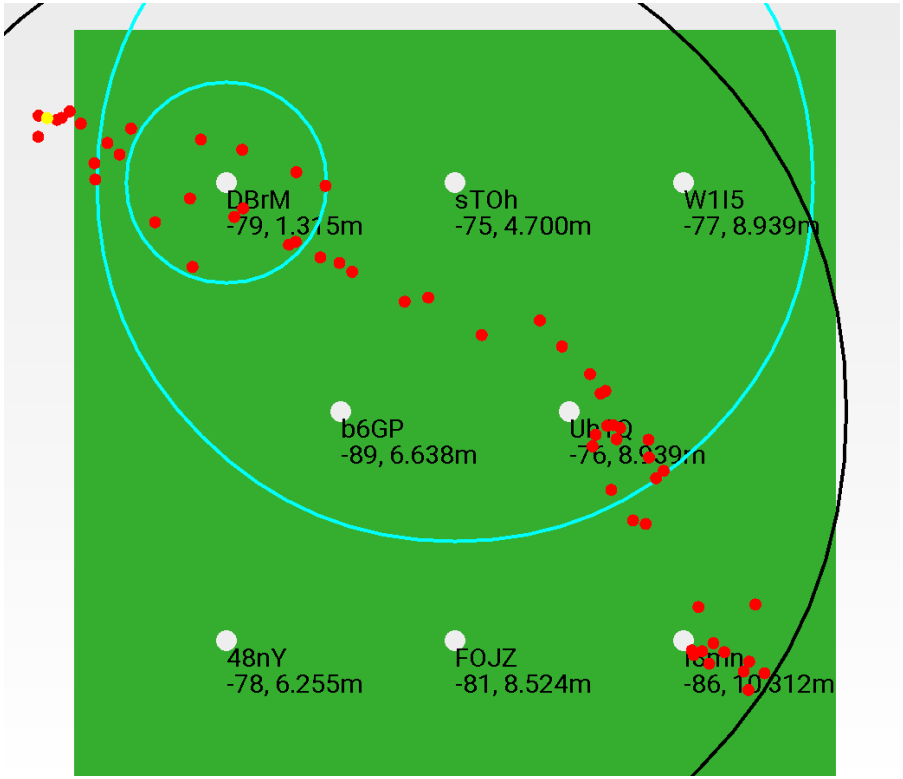




Strongest Signal (border and diagonal)

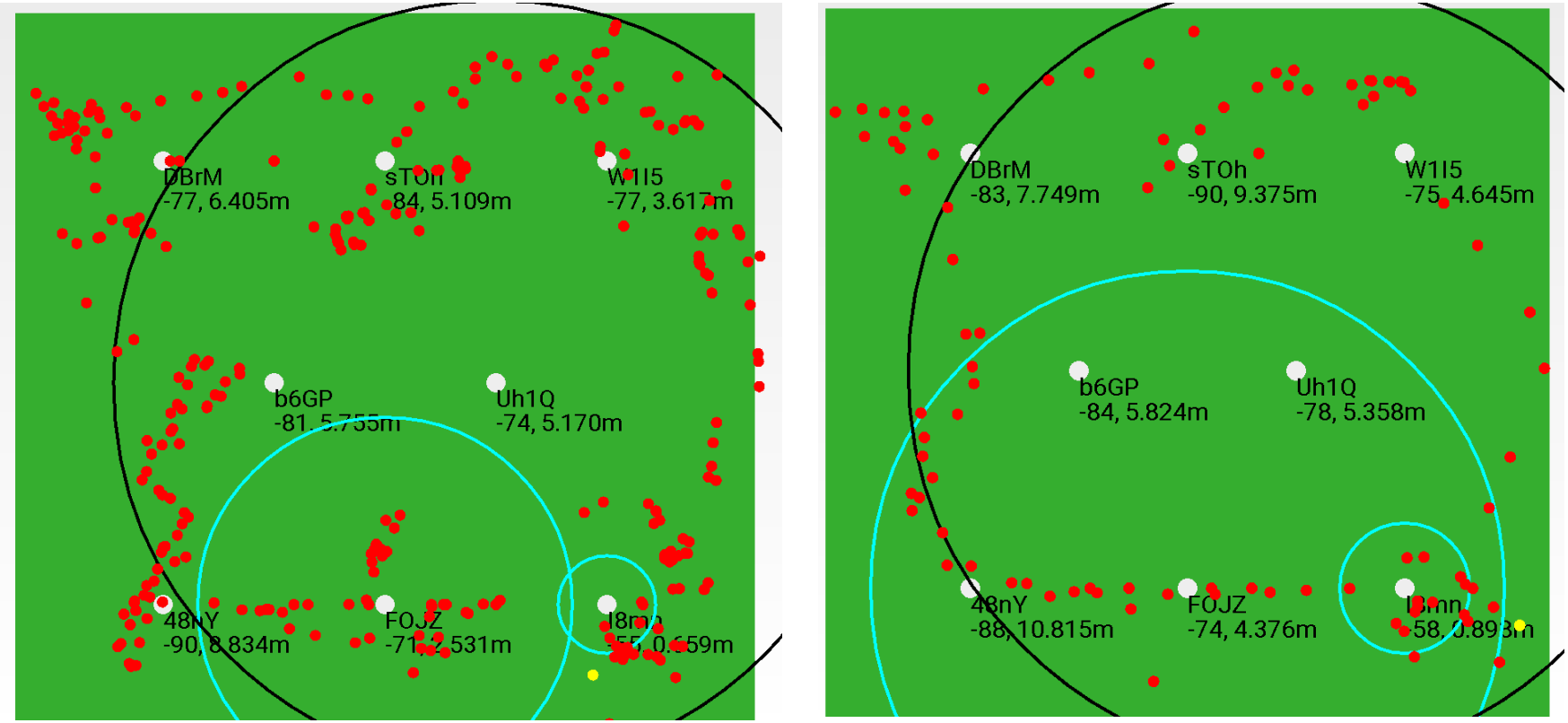
Third Beacon Choice





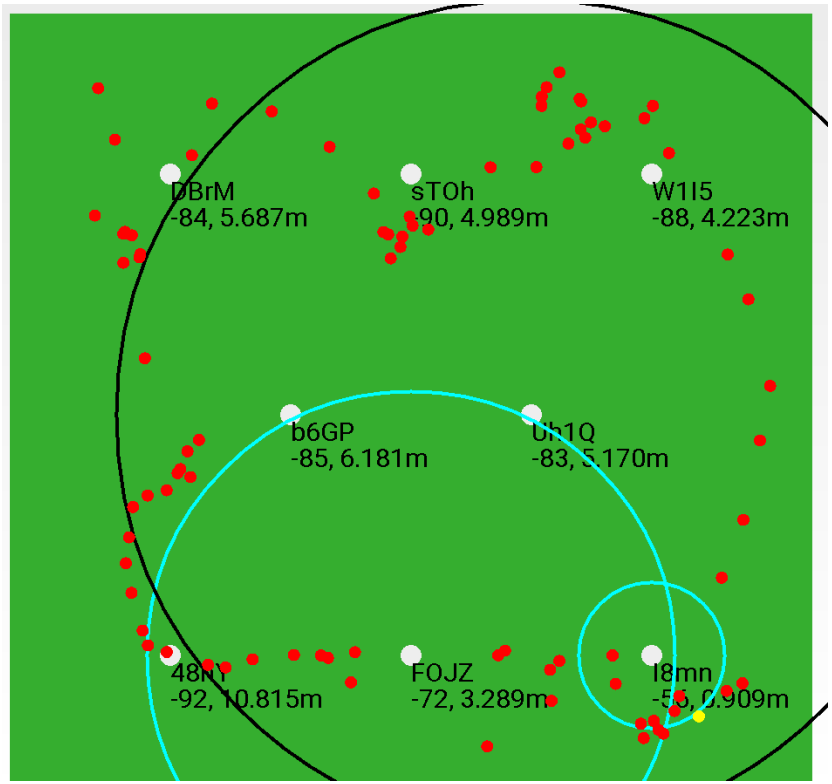
Closest Beacon (border and diagonal)

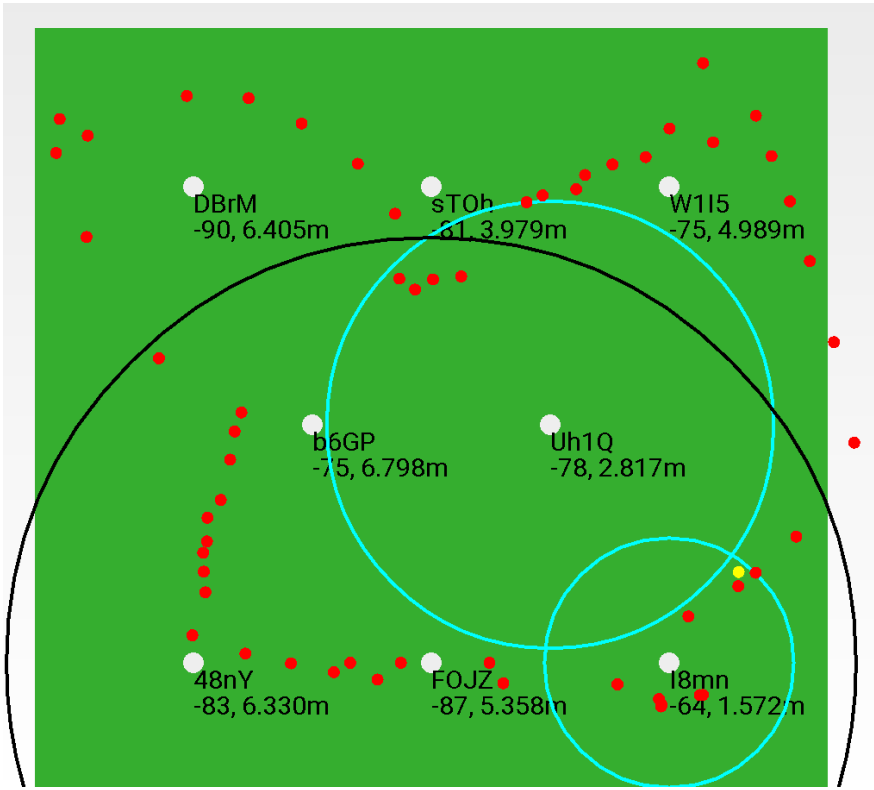
Scan Interval



150ms (Left) and 350ms (Right)

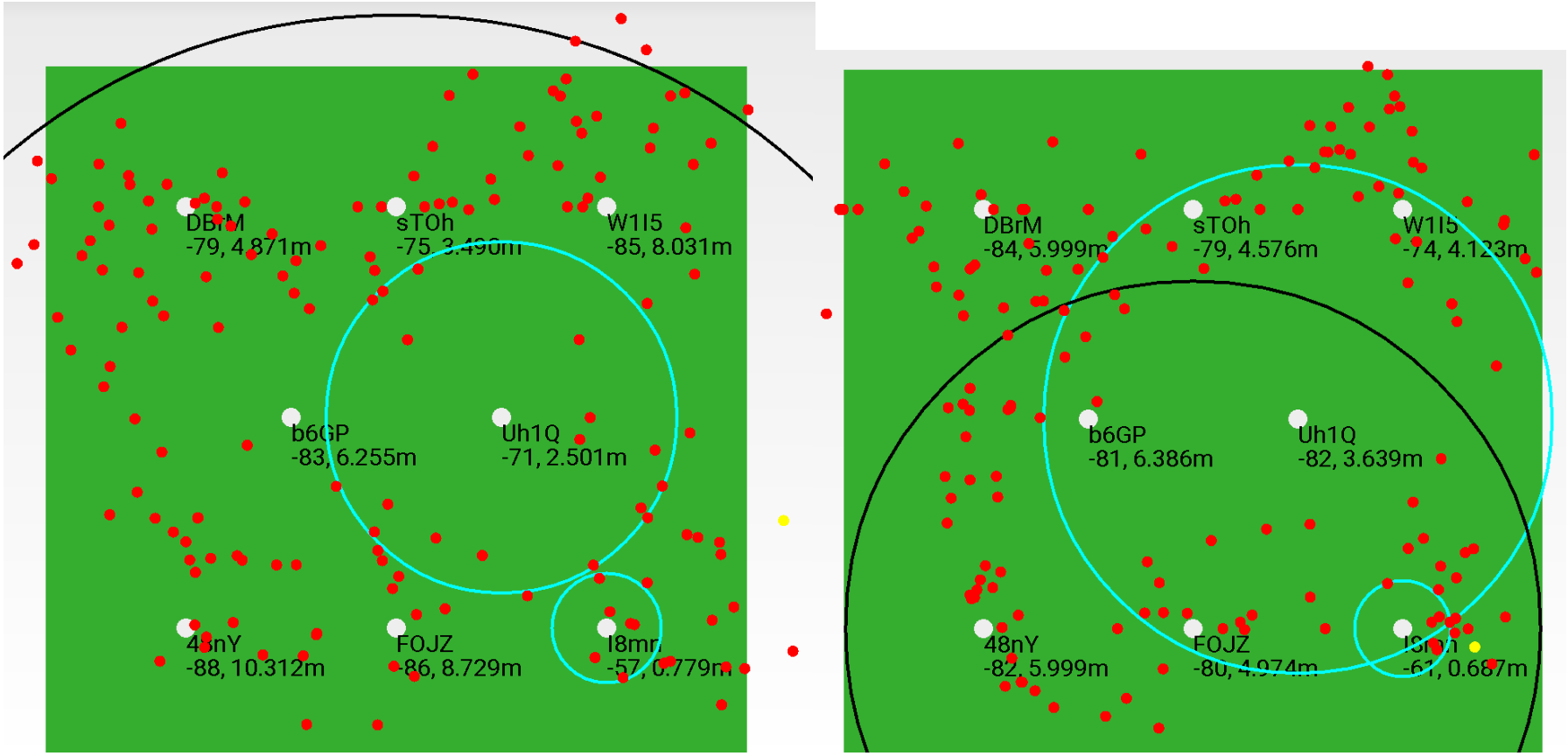
Scan Interval





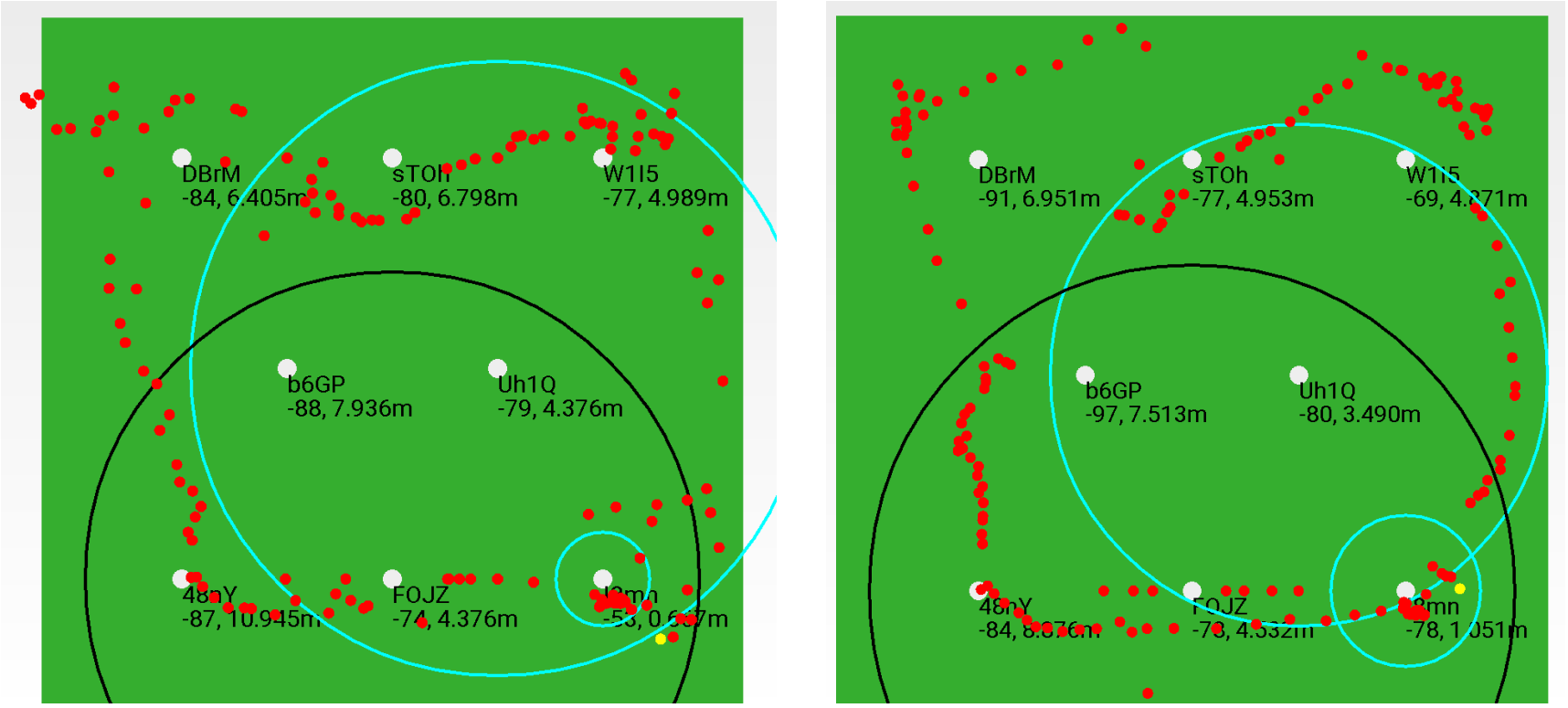
700ms (Left) and 1000ms (Right)

Running Sum Count Limit



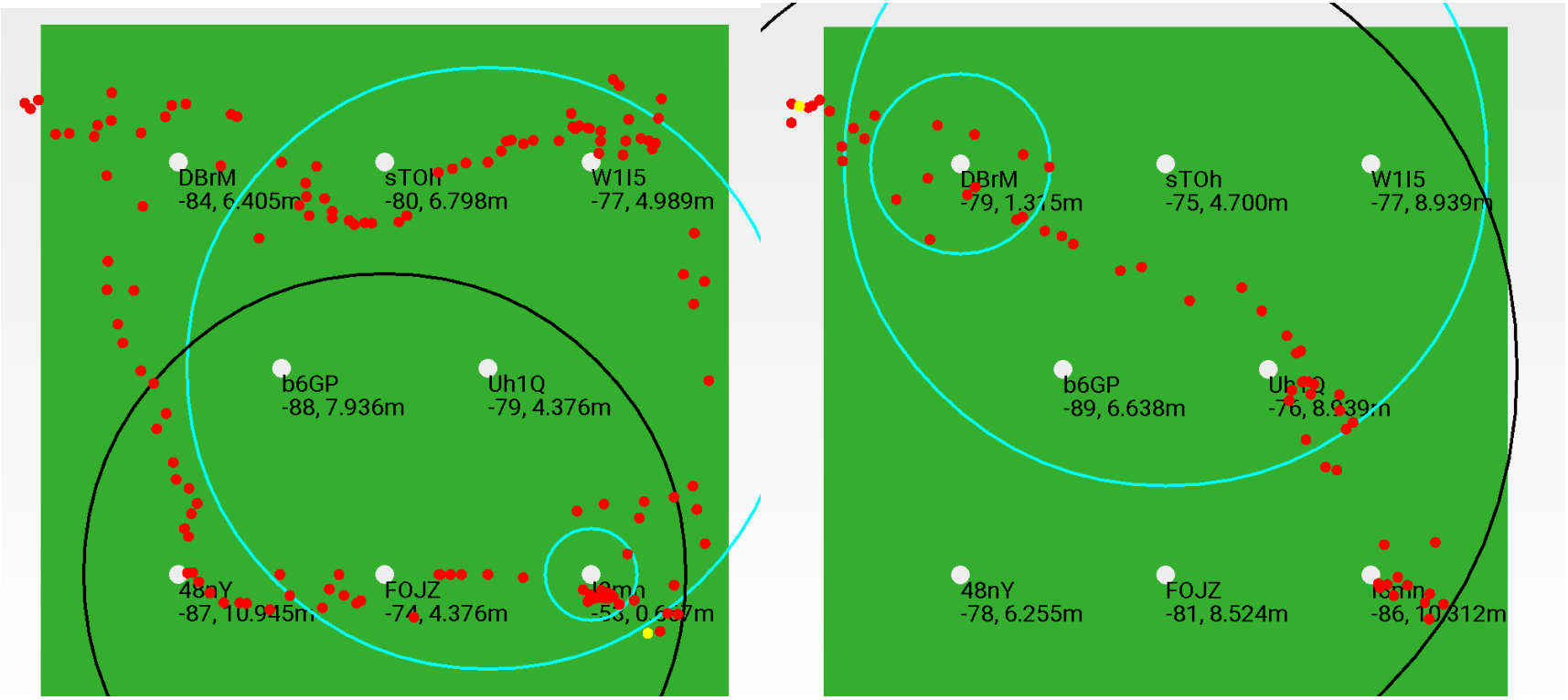
1 Running Sum Count (Left) and 4 Running Sum Count (Right)

Running Sum Count Limit



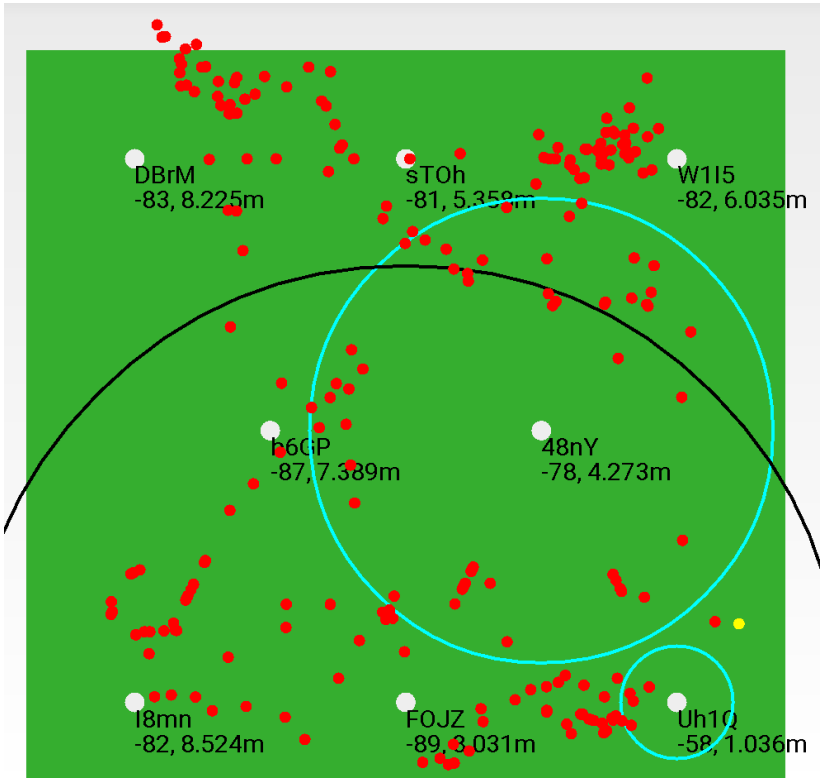
7 Running Sum Count (Left) and 15 Running Sum Count (Right)

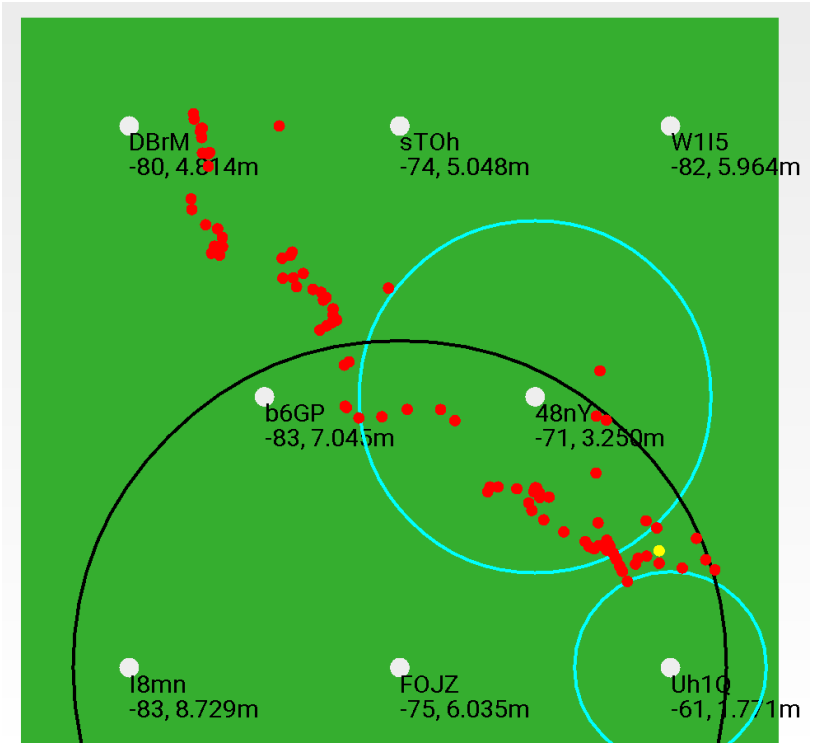
3m vs. 5m distance



3m horizontal distance between beacons

3m vs. 5m distance





5m horizontal distance between beacons

Lessons Learned

- Signal strengths from beacons can vary widely from time to time.
- Below certain signal strength, it is very hard to get an accurate estimate of distances from a beacon.
- RELATIVE distances between the beacons are far more important than ABSOLUSTE distances from the beacons.
- I overestimated the capability of beacons before this project!

Applying it to a soccer field…?

- There are some obstacles to applying this project to a soccer fields:
  1. Beacons have to be buried slightly under the ground.
  2. Players cannot carry a “bulky” smartphone while playing soccer.
  3. Large size of a soccer field requires too many beacons to be placed.
- First two can be dealt with, but the third one is a major obstacle…

Applying it to a soccer field…?

- Typical soccer field's dimension is 100m x 60m
- Considering 5m distance between beacons and 3m margins around them, we need 240 beacons to cover this soccer field.
- It will cost easily more than $1000 even with the cheapest beacons available.
- Very impractical costwise!

Applying it to a soccer field…?

- However, apart from the cost, this project clearly showed that the beacons can be used to track outdoor movements.
- Feasible…? **YES!**
- Practical…? **NOT YET!**
- Hopefully, beacons technology improve in the future so that it also becomes “practical” to apply this project to a soccer field.

Future Works

1. Automatic calibration of beacons
2. Ability to stream tracking information to a separate device or a server
3. Replace a smartphone with a small, custom Bluetooth receiver.
4. More sophisticated algorithm for determining a location
5. Ability to save and replay tracking data