

Real-Time Indoor Localization System Using WiFi Scanning



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Abstract

Location tracking is an important part of many ubiquitous computing applications. Unfortunately, global positioning systems (GPS) only provide sufficient tracking coverage in an outdoor setting, unavailable to many users in an indoor setting. With the popularity of wireless access points, and WiFi-capable mobile devices, the use of this wireless infrastructure can become a viable option for instant and portable indoor tracking. We investigate and propose deploying a quick real-time indoor location system that accounts for obstacles and wireless instability for mobile devices without fingerprinting locations. We discuss the actual performance and accuracy of tracking both stationary and moving targets in a structure by incorporating common mobile device tracking features, and applying predictive heuristics to account for inaccuracies such as structural boundaries.

Provided with only a passive based collection of WiFi based signal strength indications (RSSI), this system relies on achieving accuracy by using the built-in orientation features present in many existing mobile devices, and does not rely on any costly additional sensor/external feedback. By using the collected signal graph, a positioning map is formulated and used with both predictive and deterministic algorithms to derive the estimated location of the WiFi node. We compare the performance of the algorithm with several other approaches, including fingerprinting approaches. Our real life walkthroughs collecting data samples indicate that once a indoor structure is passively scanned, our system is sufficient enough to derive accurate location estimates of nodes with decent accuracy. With such information easily obtainable, a scalable context-aware mobility framework was developed to demonstrate a context-dependent multimedia interactive application.

Objectives

Accuracy

- Predictive location algorithm (given obstacles, direction, and scan information)

Convenience

- Passive (non-automatic) collection of flagged location information
- Requires no knowledge about the source of the access points

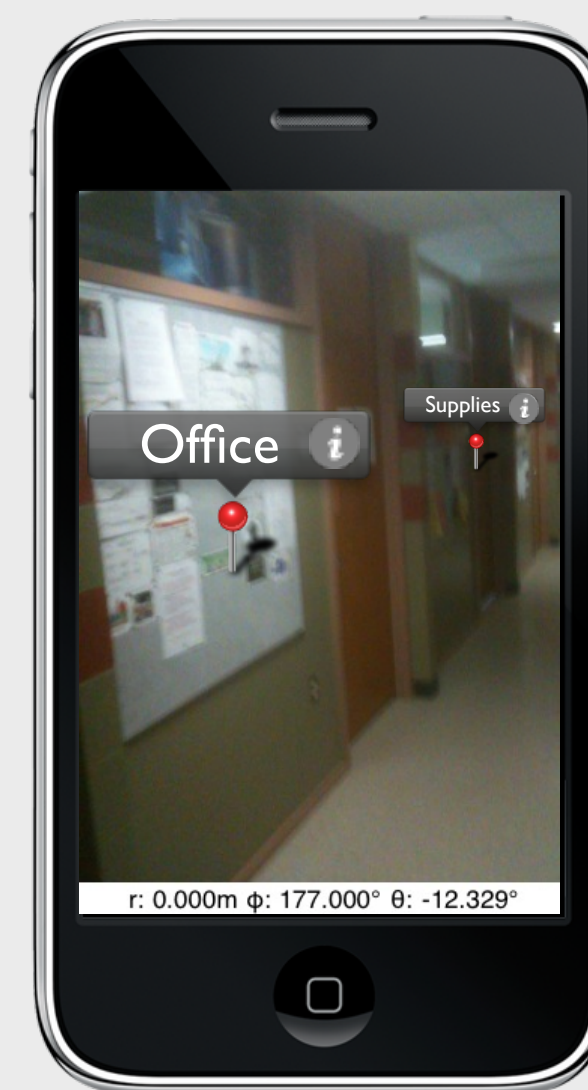
Portability

- Only uses publicly available access point information
- Deployable on mobile handheld devices

Affordability

- Uses existing established WLAN/WI-FI standards
- Ability to run on any mobile platform without additional sensor feedback

Develop a context-aware mobility framework that supports context-dependent, multimedia interactive application (e.g. augmented reality viewer).



A handheld augmented reality application that overlays location specific points through a camera. Navigation is done by tilting or directing the phone's camera to a new view.

Localization Techniques

Sample #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Adhoc	-87	-50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UWEC/Chadwick	-89	-50	0	-47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UWEC/Chadwick	0	0	0	-99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UWEC/Chadwick	0	0	0	-43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UWEC/Chadwick	0	0	0	-29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UWEC/Chadwick	0	0	0	-30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UWEC/Chadwick	0	0	0	-31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UWEC/Chadwick	0	0	0	-25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UWEC/Chadwick	0	0	0	-31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UWEC/Chadwick	0	0	0	-40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UWEC/Chadwick	0	0	0	-42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UWEC/Chadwick	0	0	0	-52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UWEC/Chadwick	0	0	0	-52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UWEC/Chadwick	0	0	0	-56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UWEC/Chadwick	0	0	0	0	0	0	0	-52	0	0	0	0	0	0	0	0	0	0	0
UWEC/Chadwick	0	0	0	0	0	0	0	-47	0	0	0	0	0	0	0	0	0	0	0
UWEC/Chadwick	0	0	0	0	0	0	0	-48	0	0	0	0	0	0	0	0	0	0	0
UWEC/Chadwick	0	0	0	0	0	0	0	-47	0	0	0	0	0	0	0	0	0	0	0

Pass 1 - Non-Filtered Signal Map

Collection

Models are generated by the initial user taking passive scans of a given floor, marking periodic location based flags (start and end positions) within the map to ensure signal values are contiguous so a lookup can be performed. Points of interests could also be simultaneously mapped, to establish well defined lookup points for users. Maps are able to contain all identifying information about the WLAN access point as well as the contiguous signal strength RSSI values.

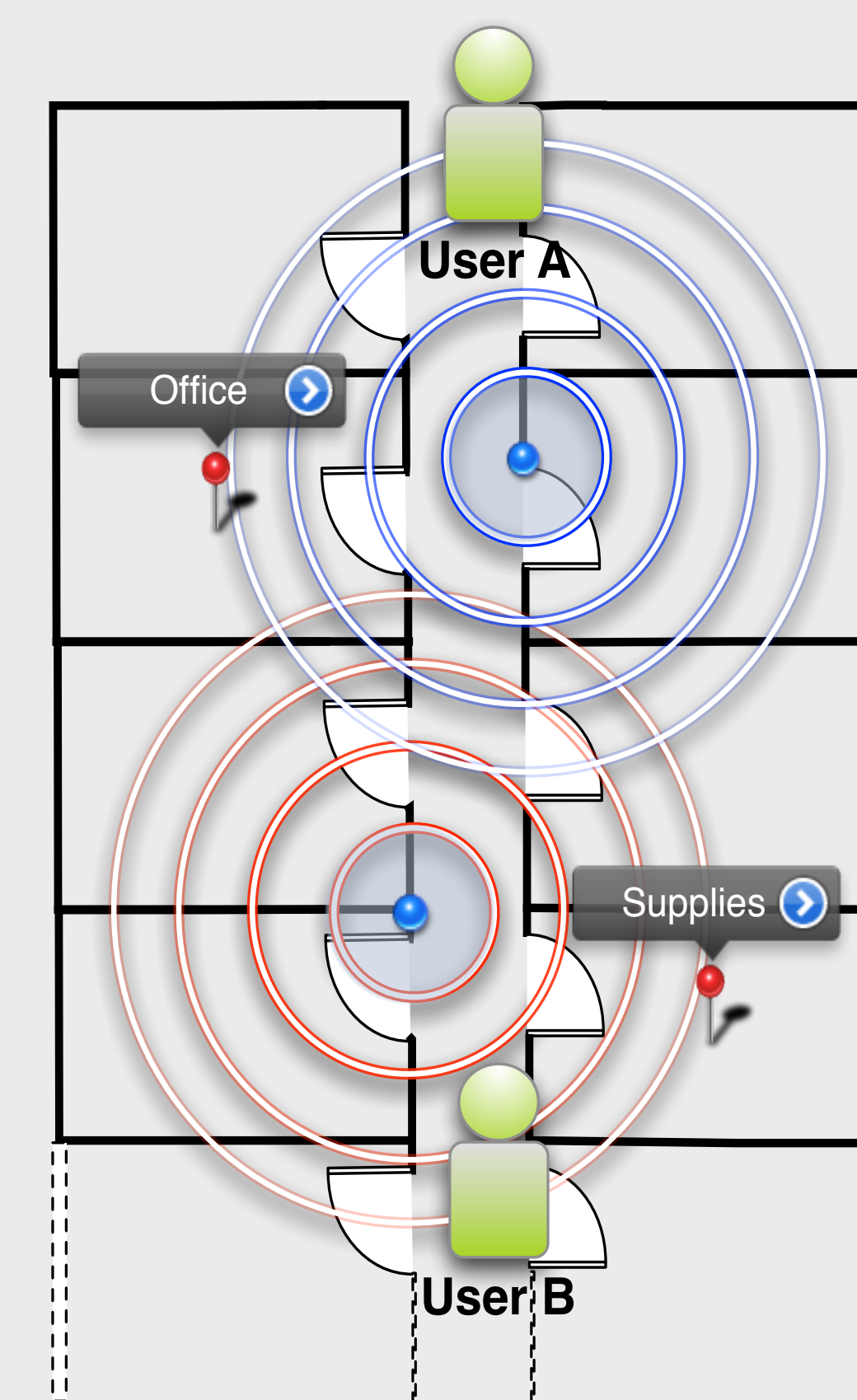
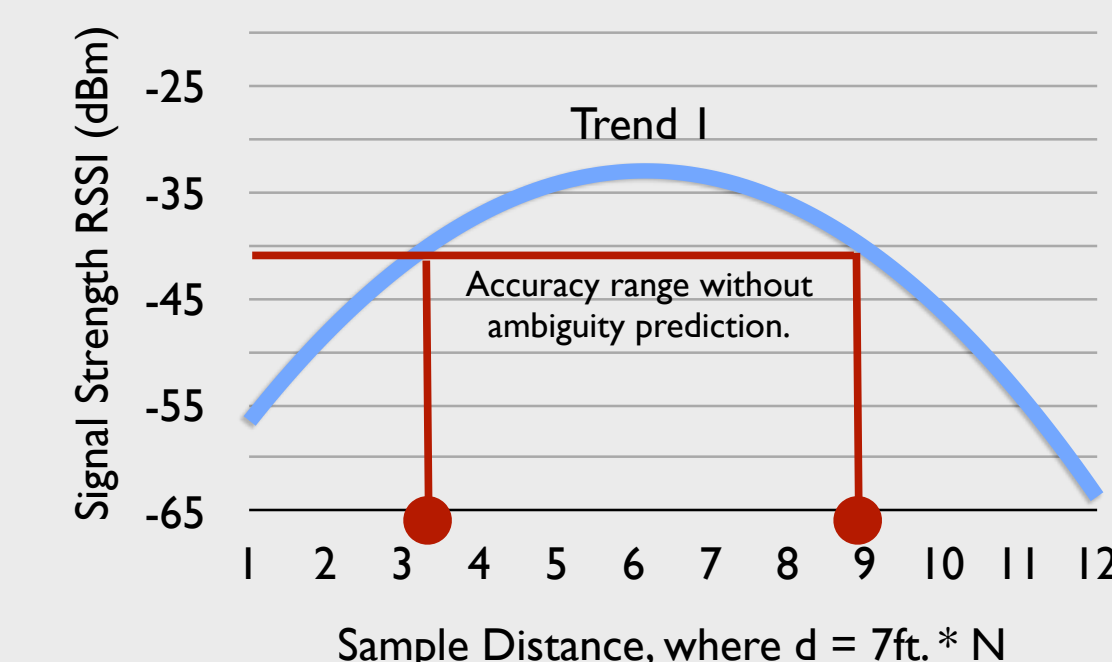
Behavior Filtering

Sampling errors can occur during the scan in which a simple filter needs to be applied to the map to achieve the highest possible accuracy signal graph of a given floor. RSSI values beyond -70 (where 0 is the theoretical best signal obtainable), are simply thrown out. These outlying RSSI values result from out-of-reach ad-hoc computer networks.

Localization Lookup

Once a user has tagged a particular location, they'll send a request for a lookup to be performed. There are several cases of how a lookup is executed. The worse case, will always be a single strength value associated with a BSSID (access point identifier); in which multiple matched locations may result. The best case is when two or more access points overlap each other, thus having multiple RSSI values to compare against.

Basic Localization with Polynomial Interpolated Curve

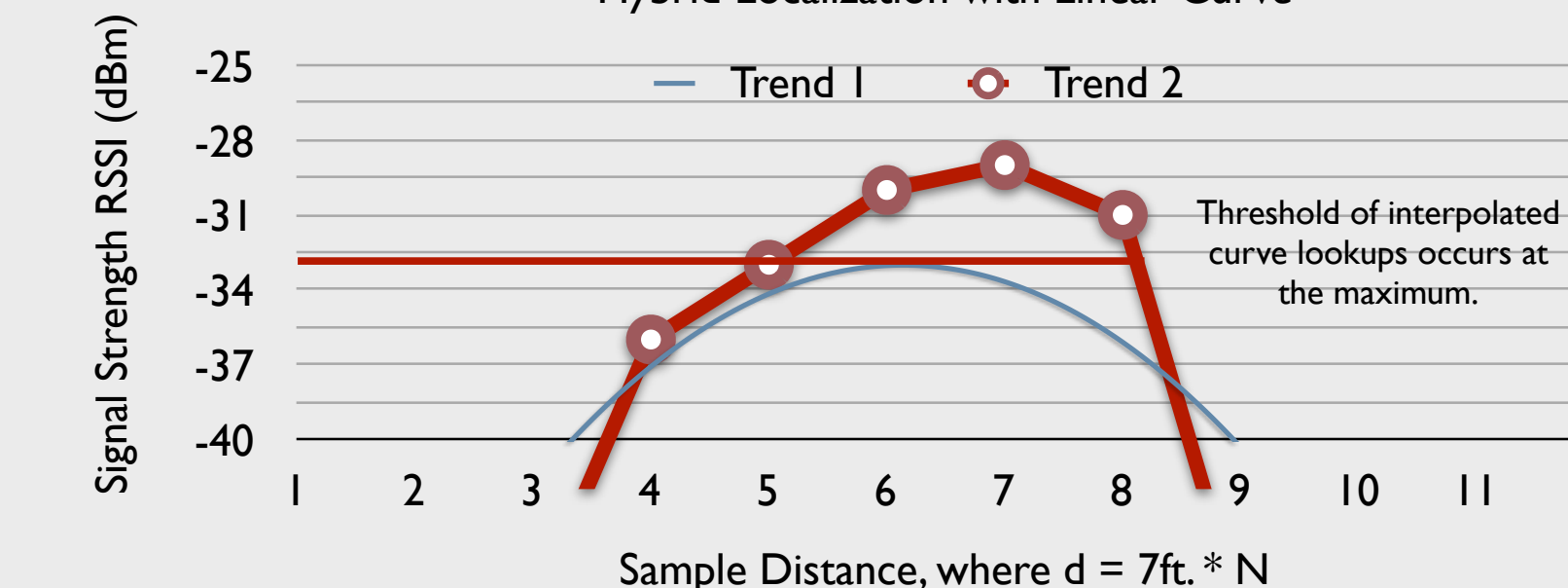


Visual representation of a scanned hallway map

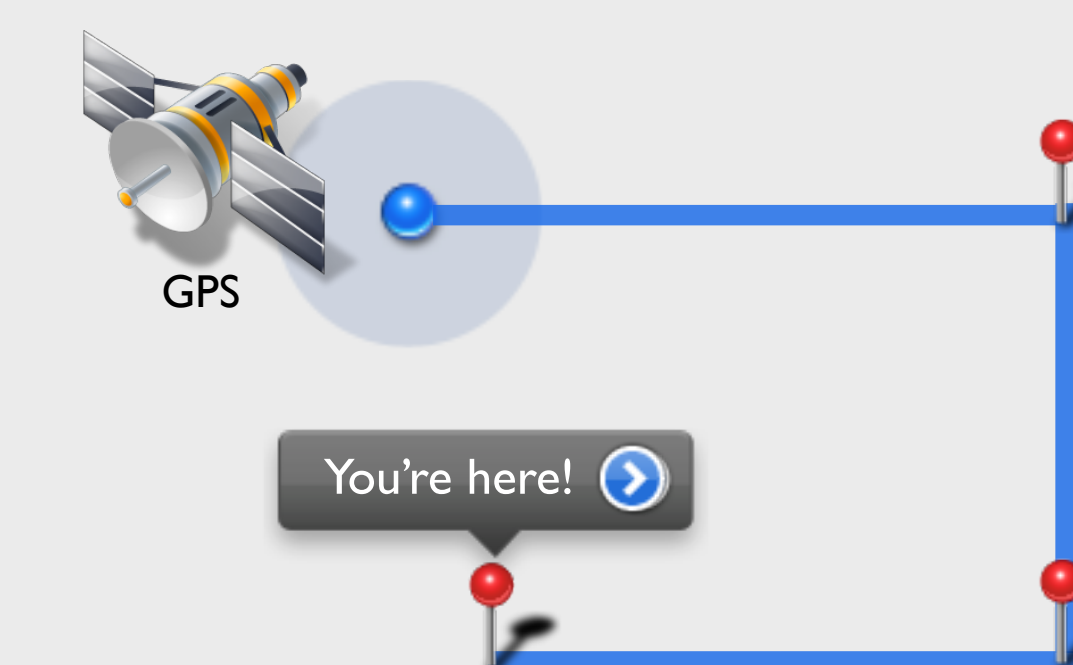
Resolving Ambiguity

A high strength signal lookup would result into the respective closest-distance model sample(s) for the given RSSI that rests above the interpolated curve maximum. A low strength signal lookup would result into the two closest model sample points in the interpolated curve. Once multiple positions are determined a selection algorithm needs to take place to predict the position or provide the radius of selection of error.

Hybrid Localization with Linear Curve

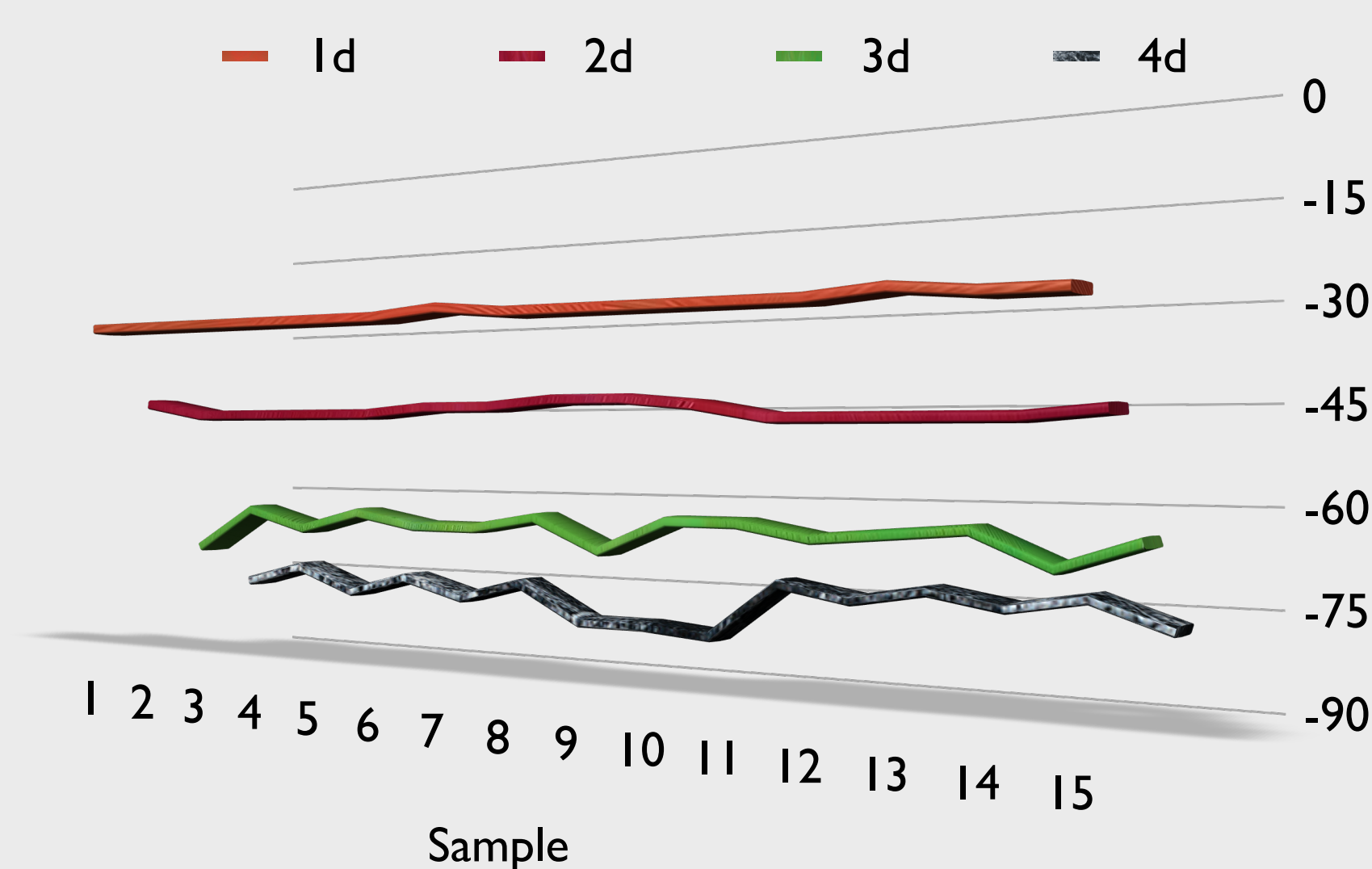


Making a decision on how to select between multiple locations can be predicted with the help of GPS. If floor entry points are mapped in conjunction with a continuous scan of the floor (for both the user and the initial scan), we can determine the direction of which "hallway" the user is most likely in. However, this sometimes relies on the fact that the user must be periodically checked for location.

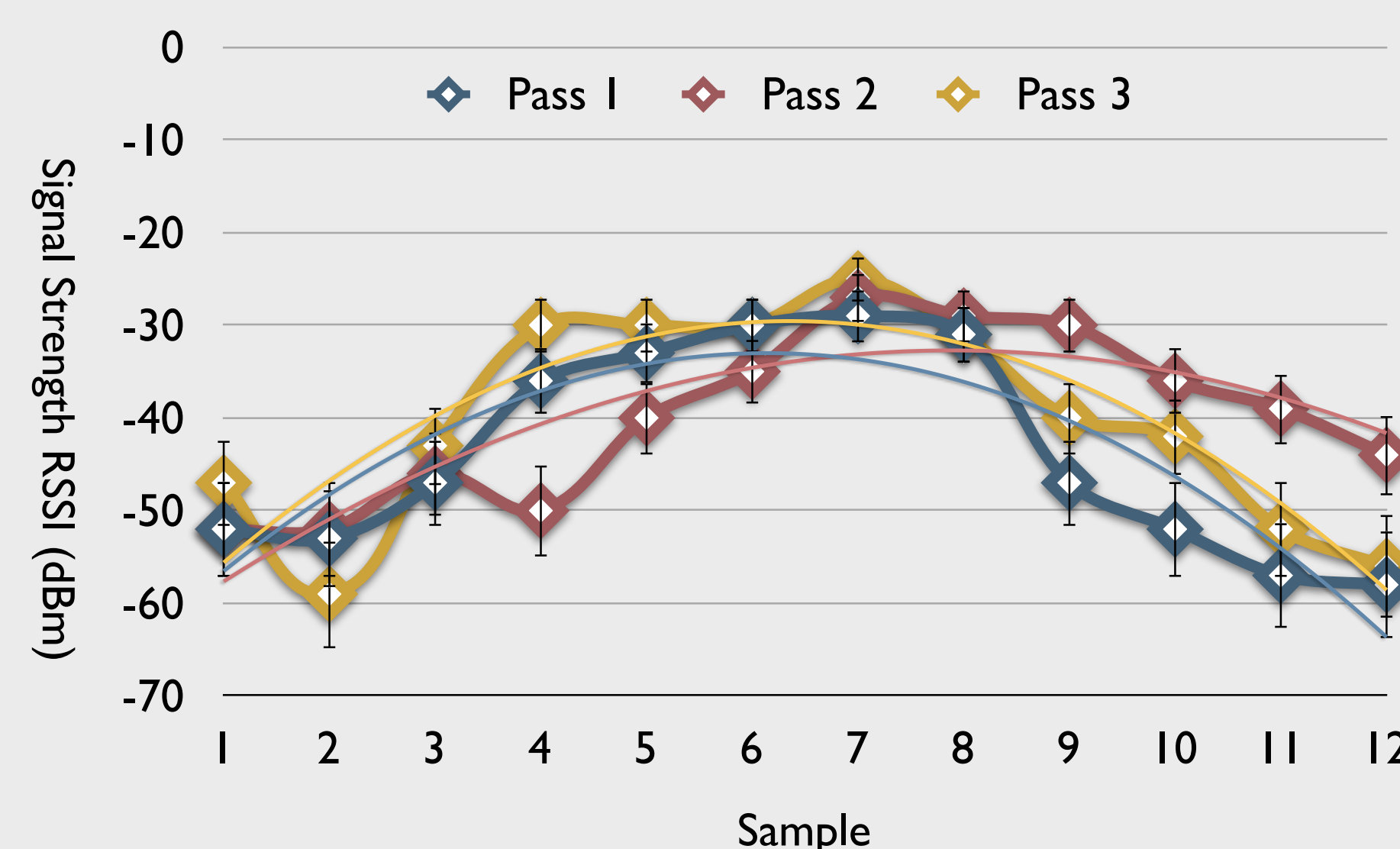


Method

Signal Consistency from Controlled Stationary Access Point

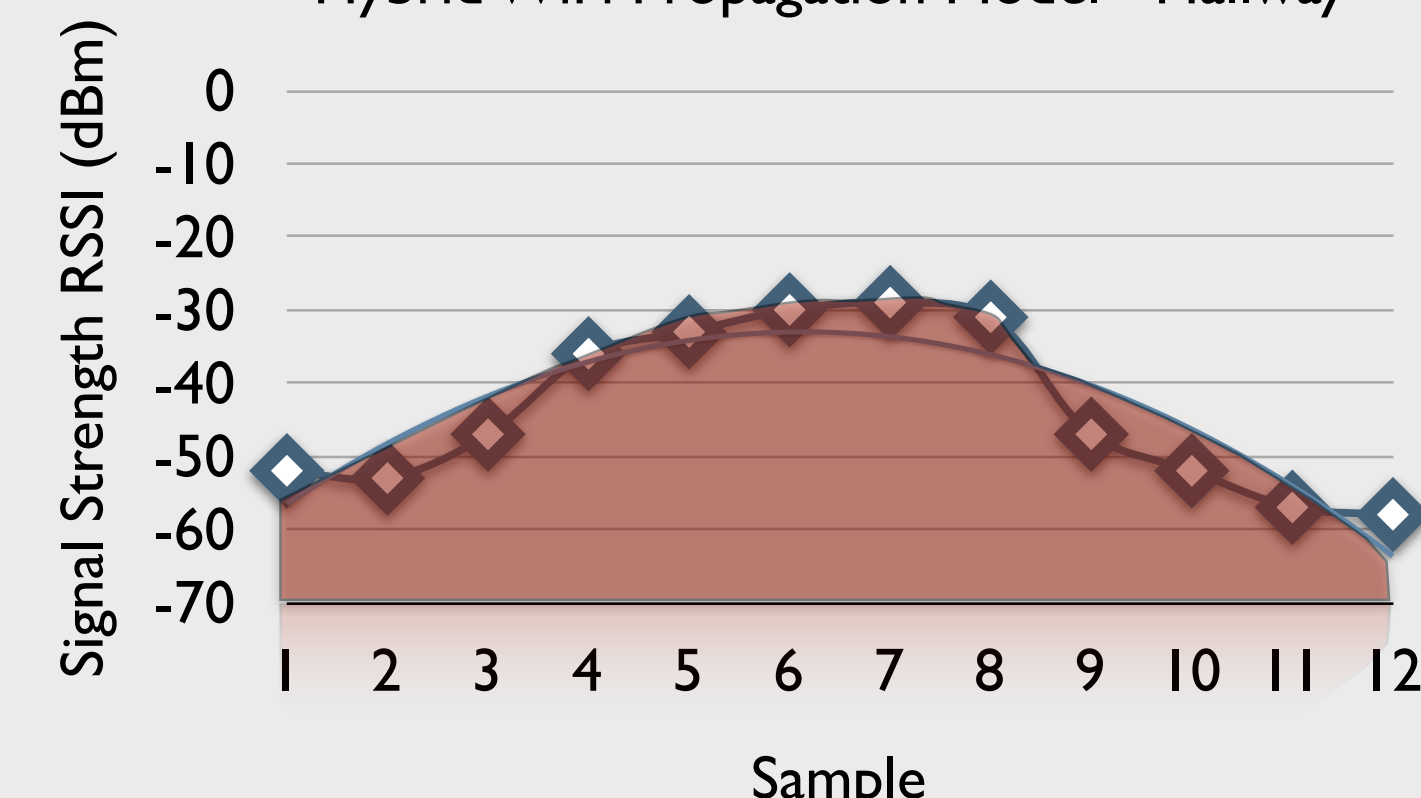


Triple Pass Signal Propagation Variations - Hallway



It is often the case that indoor localization trackers are unaware of the access points. Rather than construct a model of the existing wave propagation and tracing the source, develop a model that follows the existing signal trend per access point and takes into account both new mobile tracking technologies (accelerometers, GPS), and signal inconsistencies that would question the accuracies of other wireless models. Tracking targets in real-time involves complexities such as moving obstructions, variations in readings, and other signal discrepancies.

Hybrid WiFi Propagation Model - Hallway



A signal's propagation behavior that's generated from a IEEE 802.11 WLAN access point in free space has a well-known signal model. However, the fluctuation of signal strengths values (RSSI) in indoor environments demonstrates that even an adjusted free-space path loss (FSPL) signal curve is still insufficient in compensating for obstructions for location tracking.

The Hybrid WiFi Propagation Model takes these considerations into account. The red area represents the trackable area in which higher signal strengths remained preserved, while lower signal strengths follow the FSPL model of a second order polynomial.

A minimum of 3 samples are needed to formulate this curve, while a desirable higher sample count will achieve higher accuracy to correct any signal inconsistencies during sampling itself.

Results

Sample d	RSSI	Model d	Δd	Error feet
2	-59	0.73 or 11.6	1.3	9.1
4	-30	6.0 or 7.8	2.0	14.0
7	-25	7.0	0.0	0.0
8	-31	5.8 or 8.3	0.3	2.1
10	-42	9.4	0.6	4.2

Error table using Pass 3 signal strengths for lookup

Model d is composed with both the traditional signal curve (in blue), and the hybrid linear curve (in red). The ambiguity problem is evident with the multiple possible model d values. Where a selection can be resolved by GPS or overlapping wireless signals.

From this lookup chart, the error distance heavily depends on signal accuracy of both the model and the point of interest. One solution to prevent these inaccuracies is to increase the amount of samples and average the values over the given interval within the sample distance.

References / Acknowledgments

Damayanti Gupta, "WLAN Signal Characteristics In an Indoor Environment - An Analytical Model And Experiments." 2005.

Thanks to the UWEC Computer Science Department and IBM Cambridge Research for inspiring me to take on such a challenge.

Conclusions

-A hybrid model approach that adjusts for high-accuracy WiFi signals can be a good choice in several cases to achieve both sufficient accuracy and speed.

-Using device directional indicators (compass GPS, accelerometers) can aid the ambiguity problem of returning multiple possible locations.

-More approachable to scale when multiple users can be tracked on a collected single map of N hallways, with M samples.