Indoor Classroom Location: A Survey and Case Study

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With the advent of new low-energy wireless standards like BLE, affordable indoor location is becoming finally feasible. With the aim of using such location in our research to provide spatial and pedagogical "orchestration maps", I have surveyed different technologies for indoor location, and I have tested one specific brand of BLE beacons. The main conclusion of our tests with Estimote beacons is that accuracy . . . . Feasible alternatives on the market include . . .

Introduction

- Indoor location, Indoor positioning systems (IPS), also known by the name of "microlocation" are technological solutions to locate objects or people inside a building (where other methods like GPS cannot operate)
- Typical uses of these systems include augmented reality applications such as guided museum or city tours, store or warehouse or airport navigation, targeted advertising, sports, etc.
- A variety of technologies have been used to implement these systems, with varying degrees of success and accuracy: radiofrequency, infra-red (IR), acoustic signals, inertial measurements and even Earth's magnetic field
- Our plan is to perform experiments with school teachers, where we provide them with a map of their movements in the classroom, so that they can reflect on the patterns that they observe
- Thus, we need an IPS solution that can track the teacher with enough accuracy to provide meaningful patterns/insights (e.g., <1m error)
- This document summarizes a) a survey of the IPS field (both research and commercial solutions) to find an accurate-enouough solution we can use in a classroom, as well as b) the results of our first experiments with BLE beacons in our lab's meeting room

Survey on Indoor Location Methods

Performance Metrics

- The most commonly used is *accuracy or location error* (mean distance error between the detected and the real position)
- Other metrics include *precision* (either robustness of the positioning, e.g., standard deviation of the location error, or its distribu-

tion, e.g., 90% within 2.3m), *complexity* (hardware, software, operational – often indicated by the location rate or lag), *robustness* (to the unavailability of certain signals/units), *scalability* (how large can the indoor location grow, and whether location is 2D or 3D), and of course, *cost* (including energy consumption too).

- Given our aim of measuring positions in a classroom, we will mainly use *accuracy* and *precision* as the main metrics, with an eye on cost, complexity and robustness

Systems and Solutions

- The resolution/accuracy of methods depends largely on the wireless technology being used (Fig. 1). We see that, for accuracies <1m, RF hybrid methods or UWB/microwave seem the best bet

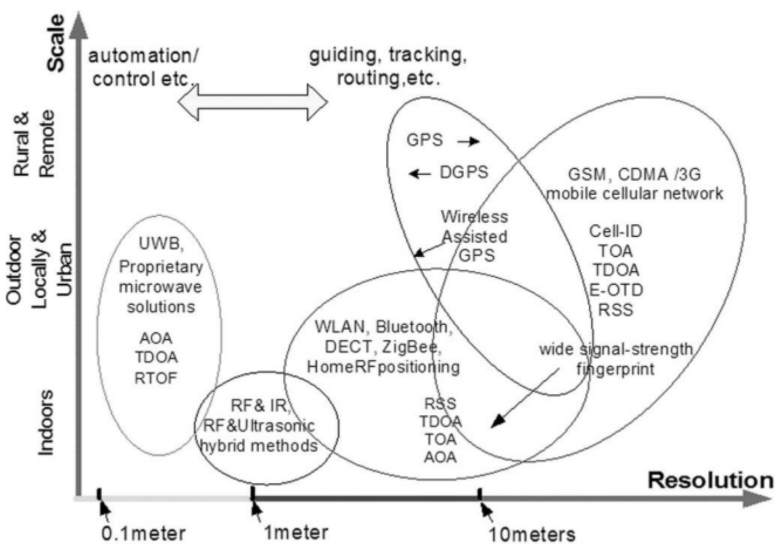

Figure 1: Wireless technologies used in indoor location and their typical accuracies

- Ultrasound systems seem to have very high accuracies up to a few centimeters... but as noted by [1], these systems often require synchronized nodes, a dense grid of receptors (difficult to install in a school) and/or are prone to interference by ultrasound noise
- Looking into several reviews of the field [2] [3] [4], we find several methods and systems with <1m accuracy: Ekahau (WLAN/Wifi), Ubisense (UWB), Sappire Dart (WLAN+ultrasound), SmartLOCUS (IR+UHF), EIRIS, Pinpoint 3D-ID (UHF), Active badge (IR), Active bat (ultrasound), Cricket (ultrasound), Dolphin (RF+ultrasound), UWB, or computer vision methods
- One of the most prominent recent contenders are Bluetooth-based (especially, BLE and the iBeacon technology promoted by Apple),

[1] Ijaz, F., Yang, H. K., Ahmad, A. W., & Lee, C. (2013, January). Indoor positioning: A review of indoor ultrasonic positioning systems. In *Advanced Communication Technology (ICACT), 2013 15th International Conference on* (pp. 1146-1150). IEEE.

[2] Liu, H., Darabi, H., Banerjee, P., & Liu, J. (2007). Survey of wireless indoor positioning techniques and systems. *Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on, 37*(6), 1067-1080.

[3] Koyuncu, H., & Yang, S. H. (2010). A survey of indoor positioning and object locating systems. *IJCSNS International Journal of Computer Science and Network Security, 10*(5), 121-128.

[4] Bastos, A. S., Vieira, V., & Apolinário Jr, A. L. (2015). Indoor location systems in emergency scenarios-A Survey.

although experts say that it is more aimed at indoor *proximity* (activate something when very close to a beacon), not indoor *location* (determining distance to one or more beacons)
- However, this sector is moving fast, there are a number of startups working at this problem that might have interesting results soon [5]

[5] https://angel.co/indoor-positioning

The Bottom Line: Most Likely Options

- A quite complete and recent review/thesis [6] has found and categorized systems belonging to 13 different technologies, and concludes that <1m accuracy is really hard to find, with reasonable cost/infrastructure
- From that list, and Microsoft's latest "IPS competition" [7], some of the most promising options, that are available commercially or might be made available to us are:
  - ABATEC [8]: Tracking for sports events, apparently centimeter precision. **Contacted by email, awaiting response**
  - UbiSense [9]: claims to achieve 15cm accuracy, and has some kind of "location kit" for research use. **Contacted them, their solution would have more likely an accuracy of 0.3m, the price tag is 12500 euro (!)**
  - Cricket [10]: dates from 2005, but still claims high accuracy and it is an open architecture/product (now sold by stores like [11]). **Contacted by email, awaiting response**

[6] http://e-collection.library.ethz.ch/eserv/eth:5659/eth-5659-01.pdf

[7] http://research.microsoft.com/en-us/events/indoorloccompetition2015/

[8] https://www.abatec-ag.com/en/inmotiotec/lpm-team/motiotrac-wireless-team/operating-principle-motiotrac-wireless-team-wirele

[9] http://ubisense.net/en/information/resources

[10] http://cricket.csail.mit.edu/

[11] http://www.willow.co.uk/html/mcs410-_mcs_cricket_series.php

The Case of BLE Beacons (Estimote)

- As a first approximation to this idea of a teacher location map, we bought (cheap) Estimote [12] BLE beacons, and did some experiments with its indoor location mechanisms

[12] http://estimote.com/

Initial Test Runs

- As an initial test of the technology, I did a "calibration walk" in our meeting room, in which the true location is known (for every second), with the hope of adjusting the signals of each beacon and get more accurate results
- Then, results were tested on a second "test walk", in which the true position is also known in advance
- As we can see in Fig. 1, results are not very accurate: using our most accurate method (see the red triangles in Fig. 1), the mean error was of 1.5460022 meters (and it looks like this is because the method keeps the positions always near the center of the room!)

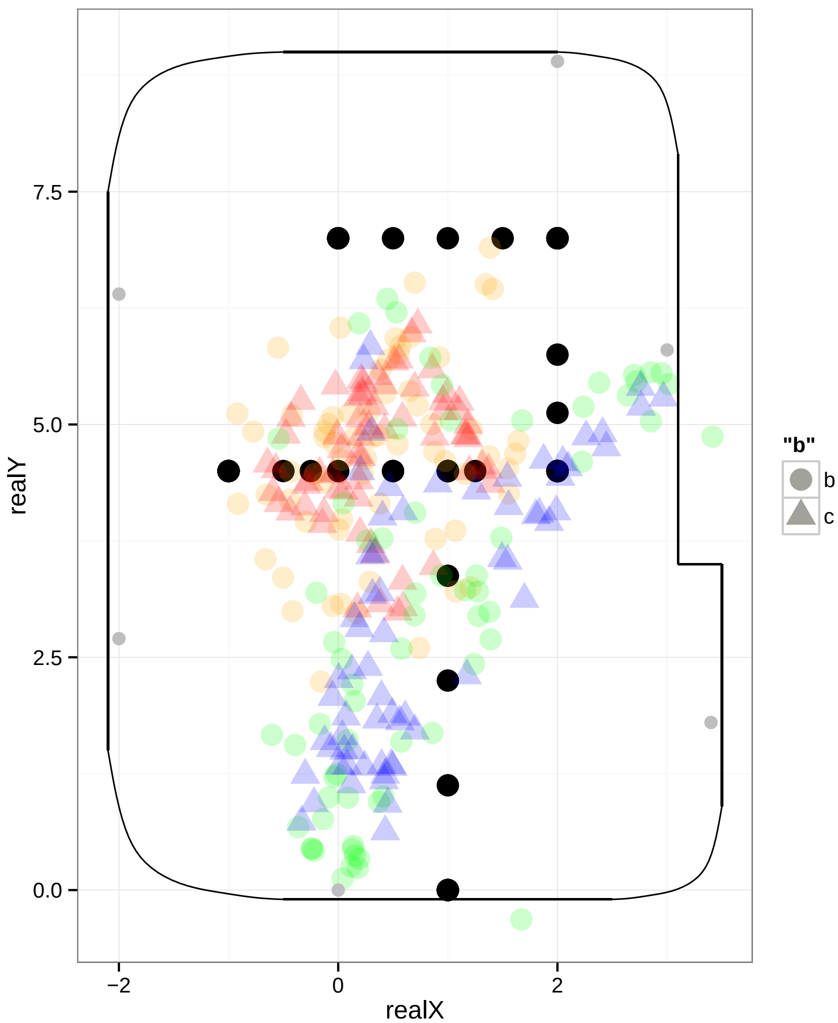

Figure 2: Real and estimated positions during the (short) test walk. In black, the true positions. The other colors represent different methods for estimating the position from the beacon signals.

A Real Case: Journee des Classes 2015

- Using this kind of position estimation for the data data gathered during the JdC2015 experiment...

Discussion: What Are Our Alternatives?

- Use one of the options provided in the survey
- Use 2m-accuracy beacons (might be good for longer periods of time)
- Change our strategy to something using proximity (a symbolic map of the class?), similar to Slotta & Moher's "embedded phenomena" [13]

[13] Moher, T., Slotta, J., Acosta, A., Cober, R., Dasgupta, C., Fong, C., ... & Peppler, K. Knowledge Construction in the Instrumented Classroom: Supporting Student Investigations of Their Physical Learning Environment. *Proceedings of the CSCL 2015 Conference*.