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

- What is indoor location, microlocation [1].
- Typical uses
- Technologies
- Our purpose with this investigation
- Structure of the document

[1] `https://code.google.com/p/tufte-latex/`

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 (robustness of the positioning, e.g., standard deviation of the location error, or its distribution, 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 accuracy <1m, RF hybrid methods or UWB/microwave seem the best bet
- In a 2007 review[2], we see a list of systems and methods. The ones

[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.

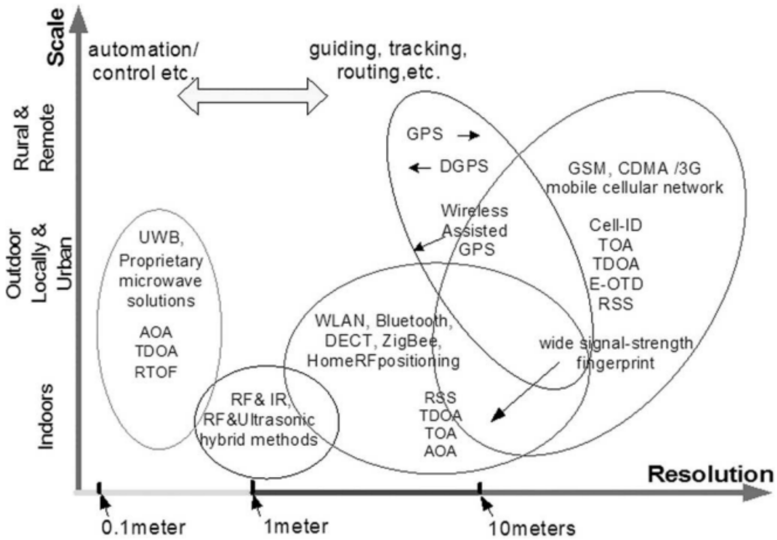

Figure 1: Wireless technologies used in indoor location and their typical accuracies

with <1m accuracy are: Ekahau, Ubisense, Sappire Dart, SmartLOCUS, EIRIS, Pinpoint 3D-ID

  - Based on WLAN/Wifi, UWB, WLAN+ultrasound, IR+UHF, UHF

- Another review[3] also mentions several systems that achieve <1m accuracy: Active badge (IR), Active bat (ultrasound), Cricket (ultrasound), Dolphin (RF+ultrasound), UWB, or computer vision methods

  - However, IR and ultrasound seem to require a dense layout of receivers in the ceiling, which can be hard to install in a school

- A more recent review [4] also puts the emphasis on RF and UWB solutions, and mentions a lack of studies about BLE (a recently emerged technology)

  - For example, there are RF systems[5] that put (quite conspicuous) antennas outside the building, and achieve 0.7m accuracy (probably better if the antennas were inside?)

- Ultrasound systems seem to have very high accuracies up to a few centimeters... but as noted by [6], these systems often require synchronized nodes and/or are prone to interference by ultrasound noise
- There exist also systems based on existing WiFi infrastructure, such as [7], however the accuracy seems to be around 2m

[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.

[5] Duckworth, J., Cyganski, D., Makarov, S., Michalson, W., Orr, J., Amendolare, V., ... & Woodacre, B. (2007). WPI precision personnel locator system–evaluation by first responders. *Proceedings of ION GNSS*, (Fort Worth, Texas).

[6] 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.

[7] `http://anyplace.cs.ucy.ac.cy/`

- One of the most prominent recent contenders is Bluetooth (especially, BLE and iBeacon promoted by Apple), although experts say that it is more aimed at indoor *proximity*, not indoor location
- Another good source for systems and algorithms is Microsoft's yearly indoor location competition[8],
- Startups in the area[9] include Estimote

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

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

Commercially Available Systems

- A quite complete and recent review/thesis[10] 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 challenge, some of the most promising options, that are available commercially:
  - ABATEC[11]: Tracking for sports events, apparently centimeter precision
  - UbiSense[12]: claims to achieve 15cm accuracy, and has some kind of "research kit"
  - Cricket[13]: dates from 2005, but still has very high accuracy and it is an open architecture/product
  - NorthStar[14]: based on infrared light, is said to achieve 10cm accuracy
  - ALPS[15]: based on a combination of BLE+ultrasound, uses a normal mobile phone as receiver and seems to achieve 0.4m accuracy

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

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

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

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

[14] https://en.wikipedia.org/wiki/Evolution_Robotics

[15] http://research.microsoft.com/en-US/events/indoorloccompetition2015/ipsn_lazik.pdf

The Case of BLE Beacons (Estimote)

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

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

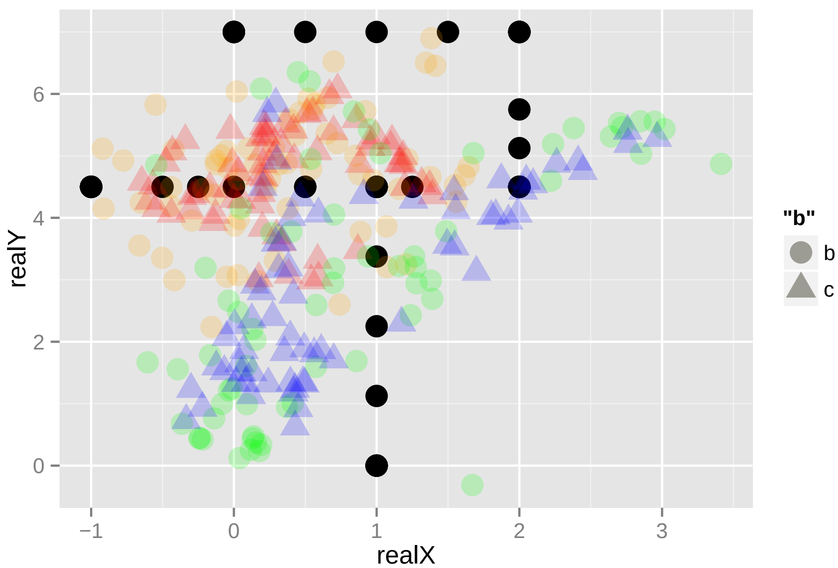

Figure 2: Real and estimated positions during the test walk. In black, the true positions. The other colors represent different methods for estimating the position from the beacon signals.

- 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!)

A Real Case: Journee des Classes 2015

- As a more real estimation of accuracy in real settings (as furniture and people can interfere with the beacon positioning), we compared the beacon positioning with a "real position" (also estimated, but from the video feed of the eyetracker and chilitags placed in the walls)

Conclusions: What Are the Alternatives?