Abstracting Positions for Indoor Location Based Services

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ABSTRACT
Indoor localization is a key enabler for dual and mixed reality applications in real world smart spaces. Currently WiFi positioning is one of the most widely used indoor localization techniques thanks to its ability to provide reasonable position accuracy withour excessive investments in additional infrastructure. However, the accuracy of WiFi positioning tends to vary signficantly and, while the average accuracy is typically within few meters of the actual position, sudden jumps in the estimated positions are possible. This position paper discusses potential solutions for abstracting location information in order to alleviate the influence of positioning errors on location-based services.

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Positioning, WiFi, Location based services

ACM Classification Keywords
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PROBLEM STATEMENT
Indoor positioning is fraught with distorting factors, not the least of which is noise and interference in the measuring devices. Whereas an outdoor positioning technology like GPS can function well under accuracies of 10 meters or more, such an uncertainty in indoor environments is unfeasible for many location-based services. A popular choice is then to use the signal strength measurements from several WiFi access points to model the target environment and infer positions. Since the WiFi standard operates in the 2.4 GHz frequency spectrum, however, it is easily interfered with by a range of modern electronic devices. In addition to direct crowding by technologies like Bluetooth, ordinary household appliances such as microwave ovens leak into this frequency range. The human body is also made up of up to 70% water, which absorbs this frequency. Due to the wave nature of the signal it is also easily deflected and attenuated by infrastructure. This results in the *multi-path problem*, where a signal can appear stronger than it should based on the distance. Conversely, attenuation weakens the signal, in the worst case blocking it entirely when out of line-of-sight. For a positioning paradigm that is based on the signal strengths decaying smoothly and exhibiting distinctive profiles in separate locations in the environment, this invariably leads to a decrease in localization accuracy.

Simply increasing the amount of access points does not work properly as overlapping channels interfere with each other. Increasing the range of channels used on the other hand puts more stress on the positioning device, since it has a wider range of frequency to scan for signals. This is mostly exhibited by a decrease in battery life. Since most location based services are designed for the mobile user, this constitutes a problem if the positioning is to be ubiquitous.

TOWARDS A SOLUTION
The situation can be eased somewhat by concrete measures employed before the environment is calibrated. By strategic placement of the WiFi access points (where this configuration of positioning infrastructure is possible), some of the issues can be alleviated. WiFi positioning works best when the signal is constrained by obstacles. One can thus direct the access point down a hallway, for instance, to block external signals and distinctly profile the area.

Even in the optimum case we are still left with accuracies of two to three meters, one meter even in the best cases. The solution here, then, is to move away from trying to achieve pinpoint accuracy and instead reduce the positioning problem into one of classification. By decreasing the granularity and letting signal strength measurements represent a wider area of interest, the robustness of the positioning can be increased while maintaining context. In an office building, for instance, the positions can be constrained to rooms or specific hallways without losing interesting information. This abstraction also facilitates the quite expensive calibration process [2]. Positioning approaches have traditionally defined a somewhat arbitrary distribution of calibration points, where the individual points themselves carry little to no context. A smarter structure focuses on interesting locations for measurements while encompassing the entire positioning environment.

A grid-based representation of the positioning environment can increase robustness by abstracting positions to *cells* in a *grid*. These cells can represent interesting areas in the environment and facilitate mapping between positions and

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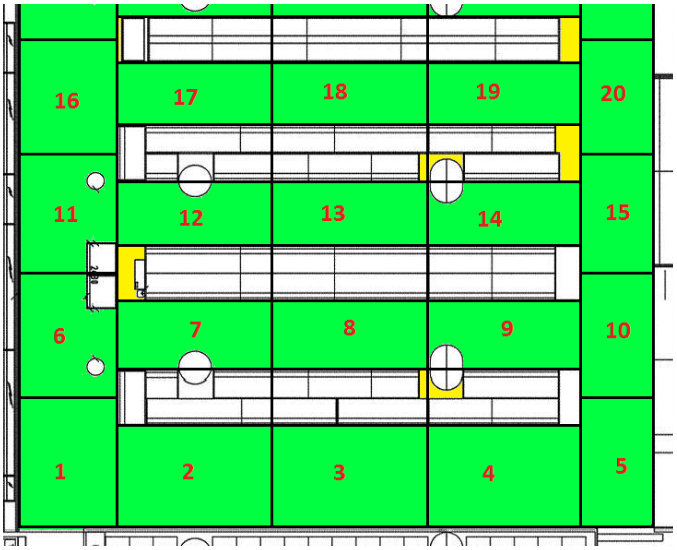

Figure 1. Section of the grid representation of the retail environment.

real-world information, and help to balance between accuracy and radio map size [1, 3]. This grid structure also lends itself well to a graph representation, which means cell *neighborhoods* can easily be defined and taken into account in the estimation phase. Finally, the grid structure facilitates modeling uncertainty in position estimates. The estimation of errors on a grid level is easier than constructing an accurate metric or probabilistic error model. Moreover, grid errors are often more intuitive from an application perspective.

EVALUATION

As an example of the use of grid-based representation and error modeling in indoor positioning, we have deployed an indoor navigation system in a retail setting called MONSTRE (*Mobile Navigation System for Retail Environments*) [4]. To facilitate the mapping of products and alleviate the uncertainty of the positioning, the environment was divided into a set of cells in a grid (Fig 1). MONSTRE uses the grid representation to resolve the shortest path that is used in navigation and an error model is used to ensure that instructions are played at correct time despite localization inaccuracies.

Instead of focusing on the target cell, the navigation was able to survey the neighboring cells when judging when to output navigation instructions. Specifically, an *extended neighborhood* was defined for each cell. In the example section in Fig 1, the extended neighborhood of cell 13 would be its *direct neighbors* 12 and 14, as well as its *shelf neighbors* 8 and 18. Furthermore, the neighbors of direct neighbors were considered as well. This structure was designed around empirical observations of the positioning quality. Namely, in most cases the position erred within these boundaries; $\pm$ 1 shelf or $\pm$ 2 grid cells. Finally, we also embedded location information in each cell, which essentially meant giving them labels based on their locations in the store. This representation was built around the established positioning, meaning estimated points were placed in a cell depending on their coordinates. A future endeavour would optimally train the positioning model to this cell abstraction from the start.

In the study MONSTRE relied on the Ekahau Real-Time Location System[1] for its position information. Since the system was deployed in a retail environment, it was beset by all the problems inherent to WiFi positioning. Electrical appliances such as freezers and ovens might leak into the 2.4GHz spectrum. Calibration also necessitated a delicate balance between trying to find a quiet moment in the store and avoiding early hours when employees restocked the shelves with the help of large metallic containers. In addition, though a large section of the store was divided into shelves and the aisles between them, some open areas remained. Maintaining sufficient accuracy in these sections proved difficult.

The issues mentioned above were combatted with the use of the grid structure. Even though positions occasionally strayed to the wrong end of an aisle or to the wrong aisle entirely, navigation instructions were timely due to the consideration of the extended neighborhood. Using the location information of the cells also facilitated the navigation effort, since it was essentially reduced to guiding the user to the next landmark location. These landmark instructions could easily be extracted from the labels stored with each cell.

CONCLUSIONS

By abstracting the concept of positions to that of locations, we can create a robust positioning system that is sufficient for location based services. We presented an example setup of a grid divided into cells with neighborhoods. This abstraction not only lends itself well to a graph representation, it also increases the robustness of the positioning as well as maintains a manageable radio map size. We also discussed how error models that are based on empirical observations can be incorporated into location-based services to reduce the influence of positioning inaccuracies.

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[1] `http://www.ekahau.com/`