Localization with Wi-Fi Fingerprinting: towards Indoor Navigation on Smartphones

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Summary: *Wi-Fi fingerprinting is used as an alternative positioning method, which utilizes signal strength information from various access points (Wi-Fi routers). By comparing the received data with the recorded signal strengths in a later stage, locations can be returned. As signal strengths fluctuate in time and space, exact positioning is challenging.*

By only selecting locations that are useful for navigation, and by providing the user with descriptive information, a sparse method of localization seems to be a promising solution towards the first steps of indoor navigation.

Introduction

In the indoor environment, exact positioning by GPS has its limitations. One possible positioning technique to counter this is fingerprinting, which assumes that each position has a unique set of signal strengths, the so-called fingerprint. By retrieving previously recorded fingerprints, a location can be returned (Kolodziej & Hjelm, 2006; Manodham et al., 2008).

Due to the fluctuating nature of Wi-Fi signals, exact pinpointing of a location is challenging. However, many researches have attempted to improve exact positioning with the fundamentals of Wi-Fi fingerprinting, including the applications of various filters (Chiou et al., 2009; Jan et al, 2010; Yim et al., 2010). Commercial systems utilizes existing Wi-Fi networks, i.e. the Ekahau Real Time Location System (Ekahau, 2012).

It is plausible why one would need to know an exact position in an indoor context. Returned information in the form of a position called “(X,Y,Z)” can be considered doubtful, since a user usually does not know its physical location in terms of coordinates in the outdoor world, let alone the indoor environment.

Relative location descriptions such as “in the lobby near entrance A” is more meaningful, since it is not of importance to know whether the user finds himself 5 metres away from that spot, or 3 metres from that spot. The only thing that matters, is that descriptive parameters are made available, and can be used to confirm a physical location. As such, a localization approach with Wi-Fi fingerprinting is more feasible and realistic for indoor navigation.

Modelling the environment

Fingerprinting assumes that each position has a unique set of signal strength information. However, fingerprints that are close to each other might resemble too much and since Wi-Fi signal strengths fluctuate over time and space caused by multipath (the scattering of signals due to present objects), the idea of localization prevails over positioning. It means that only a select amount of fingerprints (locations) in an indoor environment are suitable for navigation. From here, a simple navigable graph can be constructed. Each fingerprint can be identified as a location, and each fingerprint is connected with another fingerprint (figure 1). Each fingerprint is given a unique ID, which shall be translated as a concrete description (such as “in the lobby near the exit” – or in the figure below ID 1002).

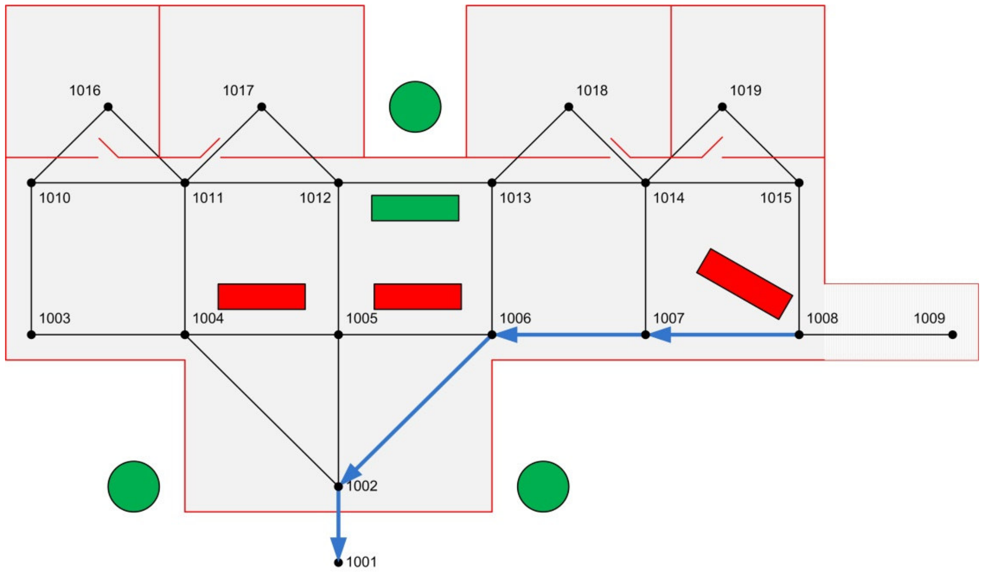

Fig. 1: fingerprints as a navigable, node-edge model

Towards navigation

On a smartphone, a database with the fingerprints, paths and locational information can be stored, so it can be incorporated into a navigation client. As soon as a user enables the Wi-Fi functionality, the device will look-up which stored fingerprint (location) resembles most, depending on the matching algorithm, such as least sum of squares (Shum et al., 2011) or a within-range comparison (Stook, 2011). From here, further steps towards navigation can be undertaken, including monitoring current and future locations and various routing options (Kolodziej & Hjelm, 2006). Simple text based navigation can be sufficient ("walk towards the stairs while you see a painting on the right. You are on track if you see the room numbers adding up."), but also more advanced, map-based navigation can be deployed.

Non-usage of geometry

Unlike the outdoor navigation, data on indoor locations is not widely available. Not all companies are willing to provide floor plans for public use, or even if there is a provision, it might be possible that not everything is covered to keep it secret. This might cause less accuracy, or missing data, although this might change in the future.

In fact, the geometry does not necessarily have to be used in order to deploy the navigation service. Indoor, a user only needs to know whether he is still on route, going from A to B. Going on route, there are significant recognizable objects present, such as plants, pillars, postal boxes or paintings, which provides help to confirm the user is in the right direction. For this, only fingerprints are an absolute necessity. The requirement is that the fingerprints should be distinguishable from each other and attached to POIs. Those fingerprints can be stored in a database and can be coupled with attributes (recognizable objects) about what is present at that place and organized in the graph. These attributes can be displayed on the screen in text or image. If the user can see those objects, as the screen tells them, the user can be certain he is at the right place. If the user reaches a node where a vertical movement can be made, information about possible stair climbing can be returned as well. This whole process is illustrated in Figure 2..

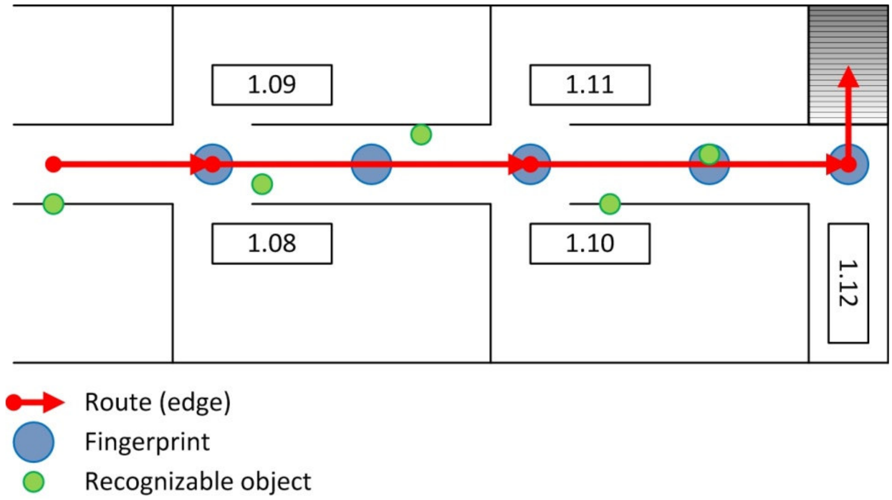

Fig. 2: fingerprints as a navigable, node-edge model

The above implies that there is no geometry necessary, but this means that topology is indispensable. As indoor pedestrian navigation has the opportunity to recognize the space in multiple ways through present objects, it is not necessary to plot the entire floor plan: a fingerprint is sufficient. The only information the pedestrian can have, is how to go from one end to another.

Cartography of text

The well-known outdoor large points of interests in the form of buildings do not apply to the indoor context. Instead, smaller points of interests are present. Simple room destinations can be translated to concrete goals and information. For example, room 1.001 can be an information point for administration, and room 1.002 contains a copy machine. However, as a result of not using the geometry for the modelling, no maps can be displayed. It is possible to provide the user with a graph or with simple listed text to direct the user, instead. The necessity of a map thus disappears, although this assumes there is a significant amount of recognizable objects present. The presentation of the service could be as follows:

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1. Keep straight as you pass a copy machine
2. Keep straight as you pass inboxes
3. Keep straight as you pass room 1.011 to your left.
4. Move up one floor.
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The advantage of no cartography (maps) means that time and effort can be saved for deploying the application on a larger scale, as one only needs to determine the fingerprints. Text usually takes longer to process for the user, which can be considered as a disadvantage. Ideally, the text should be as short as possible, and supported by icons. The sub sections below will discuss the underlying principles of text usage and text visualization as a whole.

Generating navigation guidance

When no maps are preserved, it is challenging to determine orientation aspects. Upon travelling from node A to C via B, it is hard to tell from solely a graph whether one has to turn left, right or keep straight, as one can flip the graph, for instance. It is then important to assign orientation aspects to a connectivity database, when nodes (the fingerprints) and edges (connectivity information between fingerprints) can be stored. It is then important that the application should take the current and predicted positions into account.

Indoor Wi-Fi Navigation testing

The navigation, with the Wi-Fi fingerprints as location check, is the core of the application. The user has planned a journey, and the position is being monitored with the Wi-Fi fingerprints. The user has to follow the rules and directives provided and should receive a message whether the user is on or off route.

Routes are being calculated with the graph and Dijkstra algorithm. Neutral directions are provided, along with the node numbers. If the device picks up the signals and translates that into a node ID, this is being compared with the list of nodes in the calculated route. If this ID is within the list, the message “on route” is being displayed, if not, “off route” is being displayed.

Conclusions and recommendations

Wi-Fi fingerprinting for indoor navigation is possible, keeping in mind localization prevails over positioning due to the nature of Wi-Fi signals. Naturally, the performance of the localization depends on factors such as the (1) inclusion of Wi-Fi access points in fingerprints, (2) refinement of matching methods and (3) dependency on recording versus actual fingerprints (matching of high/low-end recordings with the smartphone, also questioning how large a database needs to be).

At the navigation end, it is important to acknowledge that not every single location needs to be covered. As with the level of detail surrounding a user, a simple text list is considered sufficient, as long as it includes information about recognizable objects. However, a weakness is that there is no clear direction or orientation (left/right) possible, since there is no geometry. Instead, neutral descriptions in combination with recognizable objects have to be provided.

Further investigations on how this principle works can be made with (4) subselecting fingerprints based on current matches instead of full, complete scans and (5) applying/deploying advanced navigation.

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