Accurate Real-time Indoor Navigation
# Table of Content

1. Overview ................................................................. 3
2. Market............................................................................. 3
3. Indoor Localisation Technologies........................................ 4
   3.1 GPS/Assisted GPS................................................. 4
   3.2 Wi-Fi Trilateration – Low Accuracy........................... 5
   3.3 Hardware based solutions..................................... 6
   3.4 Fingerprinting....................................................... 6
   3.5 Intertial navigation/dead reckoning......................... 7
4. The indoo.rs Solution......................................................... 7
   4.1 Advantages of the indoo.rs solution............................ 7
      4.1.1 Accuracy......................................................... 7
      4.1.2 Memory, Power and Performance..................... 8
   4.2 What our product offers?.......................................... 8
      4.2.1 Real-time navigation........................................ 8
      4.2.2 Quick accurate indoor mapping......................... 9
      4.2.3 Infrastructure & messaging management........... 9
      4.2.4 Quick overview............................................. 9
   4.3 Underlying technology............................................ 9
      4.3.1 Post-process filtering...................................... 9
      4.3.2 Predictive algorithms...................................... 10
   4.4 How does the integration work?................................. 10
      4.4.1 Integration steps........................................... 10
4. Use Cases..................................................................... 11
5. Professional Services.................................................... 12
6. Contact.......................................................................... 13
1 Overview

Human beings spend more than 90% of their time indoors. While innovations in GPS mean the great outdoors is almost entirely mapped, indoors still remains a mystery. With a touch of a button interactive maps are available outdoors, but GPS’ indoor limitations means that indoor navigation relies on paper maps. Indoor navigation providers face an array of technical hurdles determined by confined, dynamic spaces and structural interference.

indoors uses dead-reckoning/inertial positioning, both radio and electromagnetic fingerprinting, and a custom Kalman filter. Combining multiple technologies gives the most accurate reading inside a building. Additionally, indoors provides real-time positioning while preserving the battery life of the mobile device.

indoors is a core technology with significant advantages over competitors: accuracy, battery life, and availability across all leading mobile devices. indoors is optimized per device type and works with the broadest range of map data, and provides an SDK for application developers. All maps are available offline and the positioning calculations are done on a mobile device.

2 Market

“Overall, by 2018, around $10 billion in spending to be touched or directly affected by indoor location.” Opus Research predicts

In 2015, 2.6 billion Wi-Fi/Bluetooth-capable devices will be in circulation and 42% of all delivered mobile devices will be Wi-Fi/Bluetooth-capable. Users will spend 80-90% of their time indoors and 80% of all data connections are initiated indoors.

“Smartphones, now at critical mass, are bridging the digital and physical worlds. Public Wi-Fi networks and new indoor-location technologies are enabling better location awareness indoors: in office buildings, entertainment venues, retail stores and other commercial environments.”

Opus research, mapping the indoor marketing opportunity
Indoor navigation and the seamless handover to outdoors is at the core of the indoors product, likely moving to chip-based solutions on the device, as retail, travel, hospitality, amusement park and conference customers increasingly adopt integrated solutions that can deliver customers to aisle or kiosk level accuracy without any additional hardware on site.

3 Indoor Localisation Technologies

Currently, there is a broad range of technical approaches to the complex problem of indoor navigation. Application providers, hardware and semiconductor manufacturers and traditional LBS (location based services) and mapping data providers are widely invested in developing indoor navigation technology. The IP landscape is very heterogeneous, and 2013-2014 saw a refinement of R&D in this space. Currently, solutions are nearly all based on a hybrid approach of 2 or more technologies, with Wi-Fi fingerprinting forming the cornerstone technology of the leading platforms today. A ‘best of breed’ solution, one that will form a seamless, indoor/outdoor navigation platform, embedded on native hardware and likely to ship in volume within 4 years, will almost certainly comprise an integration of the following technologies.

3.1 GPS/Assisted GPS

The Global Positioning System (GPS) is a satellite based navigation system that provides location information anywhere on earth, where there is an unobstructed line of sight to four or more GPS satellites.

"Standalone" or "autonomous" GPS operation uses radio signals from satellites alone. A-GPS (Assisted Global Positioning System) additionally uses network resources to locate and use the satellites in poor signal conditions. In very poor signal conditions, for example in a city, these signals may suffer multipath propagation where signals bounce off buildings, or are weakened by passing through atmospheric conditions, walls, or tree cover. A-GPS can address these problems and provide better accuracy.
GPS/A-GPS services like Google Maps provide information on your whereabouts. They help you to localise and navigate outdoors on the streets. But where there are streets, there are buildings. And it is inside those building's walls where GPS services are no longer useful.

GPS signals cannot penetrate buildings, therefore alternative technologies have to be used once the user moves indoors.

3.2 Wi-Fi Trilateration – Low Accuracy

Wi-Fi trilateration (measuring distance to three known points to get a location) can compute the user’s location on the fly from the signal strength data and known positions of the Wi-Fi signal transmitters, also known as Access Points (APs).

How Trilateration works:
- A line of sight is required to work; the human holding the device can dampen the dB, which biases position.
- It needs exactly three visible beacons (if there are more they must be ignored)

Problems with Trilateration:
- Signals are reflected (multipath), absorbed, and refracted (change direction) these all affect trilateration.
- The exact beacon positions must be known in advance.

Ideal conditions are needed for Wi-Fi Trilateration to offer accurate positioning. This is not easy to find indoors with the amount of interference, due to building structural features and materials, and equipment within the building.

Two more methods are:
- Triangulation differs from Trilateration as it measures angles not distance, not increasing the accuracy.
- Multilateration measures distances to three or more points and gets the location.
3.3 Hardware based solutions

Hardware based solutions like RFID (Radio-frequency identification) are an accurate way to determine indoor positioning.

However, hardware based solutions require the acquisition of hardware transmitters or tags. In addition to these hardware costs, specially trained personnel are required to install and maintain the hardware, which in turn may lead to very high costs.

Furthermore RFID is only supported by a minority of smartphones. The short range of high frequency radio signals generates the need for high concentration of transmitters/tags to cover even a small area. QR codes employ a similar solution to RFID but are not very commonly used/scanned, as they require a scanning software to be installed. Fingerprinting

Fingerprinting is a standard component of the most successful indoor location platforms designed for broad consumer usage. This is because it does not require the user to know the following

- Building Materials,
- Do signal modelling, or
- Beacon Locations

Fingerprinting involves two phases: the training (calibration) phase, and the positioning phase.

In the first training phase, the location signature (i.e. the signal strength data from nearby access points (APs)) is recorded and stored in the database along with the location details of that point within building. Actual signals at various points are recorded, and this signal information includes interference and multipath patterns of radio frequency (RF) signal data in the indoor environment. Thus, fingerprinting allows for accurate differentiation between two spatially close points separated by walls, a feat unachievable via trilateration.

In the second positioning or localisation phase, the signals obtained at the user’s location are matched back to the training data. The location corresponding to the best match using a location estimation algorithm is the estimated position of the user.
3.4 Intertial navigation/dead reckoning

An **inertial navigation system** uses motion sensors and rotation sensors. A starting point is needed here and on a mobile device quality degrades with distance travelled. This means another reference point (dead reckoning) is needed every 20m or so to maintain the quality. Without the dead reckoning the position, orientation, and velocity is not possible to be accurately followed.

4 The indoo.rs Solution

**indoo.rs is a core technology** with significant **advantages** over competitors; providing real-time positioning while preserving the battery life of the mobile device. It is possible to integrate the solution on multiple hardware environments and to implement it for multiple use cases.

The indoo.rs navigation solution is developed by signal processing and navigation experts to offer clear benefits over competitors, and best practice in a fast developing technology field.

The indoo.rs proximity marketing solution is built off of the already existing navigation and location technology. Due to the level of exactness of the location, augmenting the shoppers experience and collecting analytical data has been made possible.

4.1 Advantages of the indoo.rs solution

4.1.1 Accuracy

The indoo.rs solution uses **dead-reckoning/inertial positioning**, both **radio and electromagnetic fingerprinting**, and a **custom Kalman filter**. Combining multiple technologies gives the most accurate reading inside a building. This creates the most precise navigation, location and proximity marketing tool on the market.
indoors is also researching the use of 3G frequencies where Wi-Fi/Bluetooth is not available. Furthermore, the indoors team uses structural and materials data to enhance predictive positioning accuracy. The indoors solution is able to provide accuracy of between 2-5 meters.

4.1.2 Memory, Power and Performance

To minimize power consumption indoors is active only when needed. The RAM requirements have been reduced by optimizing the data storage, buffering and algorithms for mobile devices. The maps and location data are compressed and saved on the client device. Data can be deployed from the server to indoors enabled handsets incrementally, as needed, thus saving power and bandwidth. indoors can be used as a library, configured to run as an independent process encapsulated independently from any application. indoors can use code and process sharing between apps, and can also benefit from heavy caching. Maps are stored in the cloud and transferred in a well-documented REST interface over a compressed and securely AES encrypted interface. Maps can be transferred directly to the cloud without any intermediate steps and become available to mobile devices on demand.

The indoors solution supports both iPhone and Android platforms and indoors offers professional services for embedded and native chip set applications.

4.2 What our product offers?

4.2.1 Real-time navigation

The indoors solution accesses raw signal data directly from sensors, taking device profile (antenna characteristics, etc.) into consideration. The processing quality is thus very high, and very fast. indoors is able to process Wi-Fi/BLE data on the lowest bit-for-bit data level and can communicate directly with the Wi-Fi device. indoors does so by interfacing with hardware.
drivers directly and automatically selects the best low level driver access for each platform: WINAPI (windows), libpcap, libnl80211/ WEXT (Linux) and Android. indoo.rs uses custom, patented algorithms for quick, accurate calibration of device location.

4.2.2 Quick accurate indoor mapping

To increase the ease and the speed of implementing an indoor navigation and location solution, the indoo.rs team created the SLAM (simultaneous localization and mapping) Engine. This decrease the time it takes to radio map a location by between 10-20x.

As indoor locations are constantly being changed, renovated, repaired, re-purposed; the maps that are created are valid, in general, between 6-12 months before a remapping needs to be carried out. The indoo.rs solution works with crowd sources paths, allowing the maps to be regularly updated.

4.2.3 Infrastructure & messaging management

An indoor navigation & proximity marketing solution is only as good as the health of the iBeacons. To this avail, the indoo.rs solution enables the entire network of installed iBeacons and the messages they transmit to be managed from one platform.

Beacon health checks and battery levels, can be monitored and geo-fences, either small, medium, or large can be set. Messages can be tailored to specific situations.

4.2.4 Quick overview

- SDK for localization and navigation,
- Infrastructure management,
- Notification management, and
- Analytics

4.3 Underlying technology

4.3.1 Post-process filtering

The result of the radio localization strategy is improved using an Extended Kalman filter that fuses the radio location with the output of the step detection.
The output of the filter is smoother and has lower latency than the raw radio locations.
4.3.2 Predictive algorithms

Indoo.rs takes the wall and zone and portal data to create a routing graph, in the measurement tool. They then save this data into the map. This makes looking up the route faster on a mobile device. Rather than loading the entire reference radio map in memory at once, indoo.rs loads a selection of fingerprint points based on what signals currently is available.

4.4 How does the integration work?

4.4.1 Integration steps

1. Integrate SDK,
2. Mount beacons,
3. floor plan management (MMT),
4. in-doo.rs cloud, and
5. fingerprinting or SLAM in the future

The indoo.rs solution supports ‘out of the box’ integration with third party software and systems. indoo.rs provides an easy-to-use SDK for applications that require accurate, efficient location information.

indoo.rs works with any Wi-Fi or BLE network. Simply extend an application by adding the indoo.rs library, then walk through the mapped indoor area with a measuring device (client device or laptop with positioning sensors) and a digital location grid of the area is automatically created. An overview map (e.g. an image file, such as JPEG) of your location is all that’s required.
The measurement process itself works in real time. You do not need to stand still at every measurement-point for 10 seconds, as with other providers.

indoors tells your application the current position (as X,Y,Z coordinates) every second. X and Y coordinates are your position on the current floor. The coordinate origin is the top-left corner in the building map. Units are millimetre. Z coordinates are the ID of the floor (e.g. -1=Sub1, 0=Ground, 1=Floor1, etc.) For example, if x=1500, y=10000, z=2 you are on the second floor and 1.5m from the leftmost and 10m from the top-most corner in the building map.

indoors notifies the application when the user enters or leaves a building. The notification also contains information about the building that the user recently entered or exited.

5 Use Cases

The goal of current solutions is to provide aisle level accuracy, while eliminating (or at least minimizing) requirements for on-site hardware. indoors achieves this to within a target of 15 feet (5 meters), and can substantially improve on this resolution with additionally placed Wi-Fi access points and Bluetooth Low Energy beacons – resulting in an accuracy of approximately 8 feet (2-3 meters). indoors works with hardware manufacturers, application providers and map providers to build applications to support the widest range of use cases, requiring the most accurate, real-time indoor navigation capability.

- Travel - indoors partners with public transport operators to provide a showcase navigation application. Travellers at airports, subway- or railway stations will receive a mobile assistant, which navigates them to the right place within the terminal structure.
  In mid-2014, indoors engaged in a project with San Francisco Airport (SFO) to enable effortless navigation for visually impaired people around terminal 2. Projects with Lufthansa and KLM Royal Dutch Airlines followed.

- Retail - shopping malls can guide customers to specific shops and combine the navigation feature with a check-in or couponing system. Customers in hardware stores or supermarkets receive information on products and special offers, when in proximity of a specific product or product range.
Trade fairs and events help visitors find specific exhibitors or food courts like at eDAY:14 (eday.at/app) or Life Ball 2014 (app.lifeball.org) and VieVinum (http://www.unserwein.at/vievinum-2014/app/). indoo.rs also engaged in a number of further great events like Leiden Culinair festival, London’s Pure autumn fair etc.

Enterprise – Save time searching for the next available meeting room by finding and booking it more efficiently with indoo.rs. Share your location with your colleagues, for efficient hotdesking, and easily guide them to the conference room.

Navigation for visually impaired – enabling people with visual disabilities not just to be guided from A to B but also giving them spatial awareness. This enables them to take advantage of their surroundings better, know when a restaurant is on their left or a power outlet is in their right.

Hospitals and other medical facilities can determine and survey the position of staff members, patients and appliances.

Museums are able to provide information to their visitors about exhibits and customized tours.

Public safety - police, fire brigade and emergency medical services are able to locate themselves and their colleagues inside buildings.

6 Professional Services

The indoo.rs team provides support and training for developers using the indoo.rs SDK for application development. Additionally, the indoo.rs team provides consultancy and professional services for embedded system development, and can provide customization and porting for a number of native chip-sets.
7 Contact

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