Moovers Indoor Positioning System

Supervised by: Dr.Sameh Salem, Eng.Radwa Samy, Eng.Huda Eltouny

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1 Introduction

1.1 Purpose of this document

The purpose of this software specication document is to outline the requirements for IPS: detection of user position in an indoor place. It will consist of one mobile application accessible by any android phone and a web application independent and accessible with any standard compliant browser. This system will introduce the benefit of using Bluetooth beacon lowest average error and to enhance it by making use of the known indoor positions to make use of them in different fields.

1.2 Scope of this document

This document targets both users and business owners that would integrate their systems with the IPS system. It also may be helpful for designers and developers that may work on the IPS system in the future in many sectors.

1.3 Overview

There has been an upward trend in the requirement of indoor positioning systems as people spend a lot of time in indoor places, its a concern now for people and service providers to get exact indoor positioning information.Nowadays location predicated techniques are utilized in various fields such as traffic navigation, map accommodations, health-care ,manufacturing, and airports.There are many technologies to get indoor location information like Wifi,Bluetooth,Radio Frequency Identification.Regardless the importance of IPS there is no a standard principle for IPS techniques.Thus,this proposed project will focus on improving the performance of indoor positioning systems by enhancing its accuracy. This document introduces "Movers a mobile application that supports indoor localization which will help users to find their desired places faster and also find the shortest path to it. Movers will be focusing on improving the indoor localization by using both Wifi access points and Bluetooth beacons in order to achieve better accuracy that will be reflected to the customer while navigating.

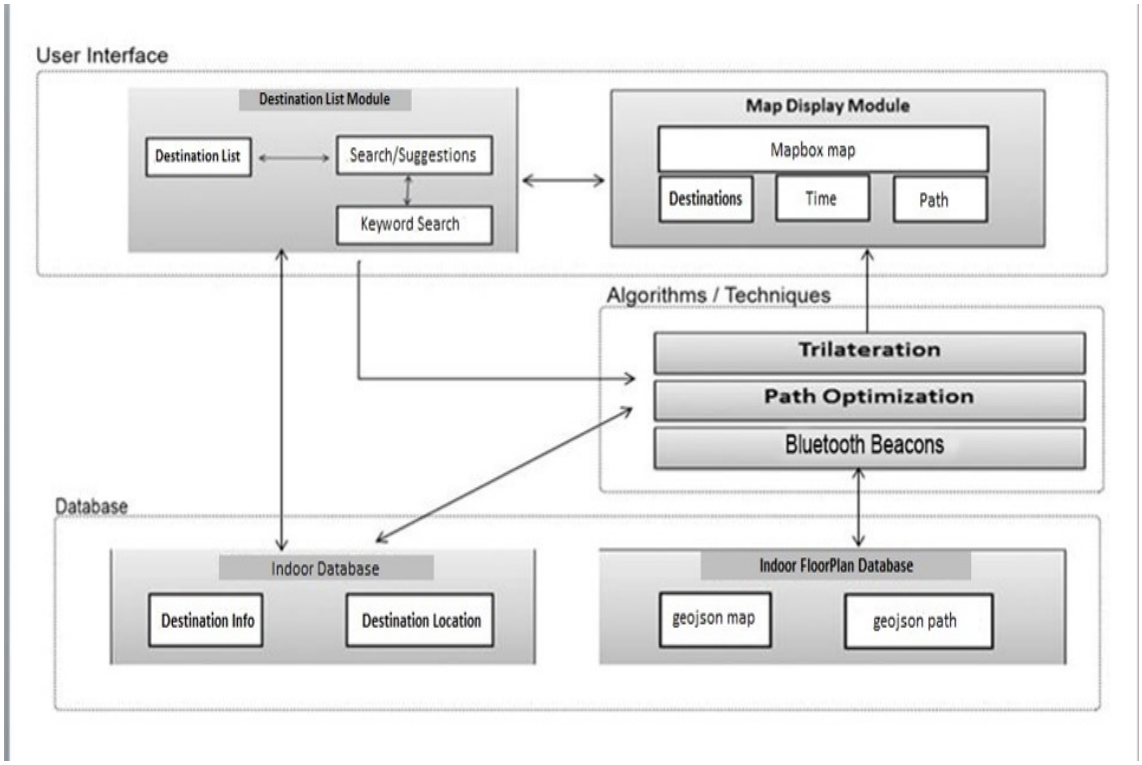


Figure 1: System Over View

Our system consists of three components:
The user interface,algorithms, techniques, and database. The user interface consists of a destination list module and a map module which allows the user to input or search for his desired destinations and view the map respectively.The search results access the trilateration technique in order to locate the user indoor location then allow him to put his desired destination and this data is processed by path optimization algorithms in order to give a shortest path to the user from his indoor location to the destination. The database component contains destination information and Indoor floor plan modules. The saved info modules interact with the keyword search by gathering the destination information and their respective location. The Indoor floor plan modules provide information to the path optimization algorithm to generate maps and locations of products.

1.4 Business Context

There has been an upward trend in the requirement of indoor positioning[2] systems as people spend a lot of time in indoor places, its a concern now for people and service providers to get exact indoor positioning information.Nowadays location predicated techniques are utilized in various fields such as traffic navigation, map accommodations, health-care ,manufacturing, and airports.There are many technologies to get indoor location information like Wifi,Bluetooth,Radio Frequency Identification. Regardless the importance of IPS there is no a standard principle for IPS techniques.Thus,this proposed project will focus on improving the performance of indoor positioning systems by enhancing its accuracy and which can be integrated with many various fields that are mentioned above.

2 General Description

2.1 Product Functions

Indoor Positioning System (IPS) will be used by a lot of sectors more than particular individuals[4]; it will be used in:

1. Hospitals and medical sector:
    - for patients including indoor navigation, reminders and services.
    - for visitors including the building navigation and map of the place.
    - tracking of mobile medical devices
    - integration into hospital information system
2. Trade fairs and congresses:
    - Details about exhibitors, products and events based on navigation.
    - Inter-modal and parking information.
    - location exhibition stand staff.

3. Office:
    - For access control.
    - visitor and invitation management.
    - Asset tracking.
    - Support a facility of management.
    - It may support theft protection.
4. Parking:
    - optimization of occupancy rate through user navigation and reservation.
    - Car finder.
    - preparation for future changes in parking sector (autonomous mobility).
    - people will find free parking space faster.
5. Super markets and malls:
    - 2D/3D maps including shops,products,..etc.
    - Sales promotion at the POS (point of sale); (couponing, location based ads,push notifications).
6. Transportation:
    - passengers app including inter-modal traffic routing,delay alarm.
    - security relevant tracking, including alerts.
    - Location based marketing.
7. Industry:
    - Asset tracking (forklift,goods,robots,..)
    - Personal tracking.
    - Definable alerts.
    - Integration into existing ERP systems (enterprise resources planning Erp software).

2.2 Similar System Information

- Any place (Launched on the app store) [3].
- Hybrid Indoor Positioning With Wi-Fi and Bluetooth: Architecture and Performance.

2.3 User Characteristics

User: Must have basic knowledge in using Android mobile devices.

Admin: Must have good knowledge in using web applications to control the system and using android mobiles.

2.4 User Problem Statement

Enhancing the accuracy of Indoor localization that can be integrated with many market applications such as retail supermarkets to offer several services to world-wide clients and users.

2.5 User Objectives

The user objective is to have a guidance to make the user find his targeted destination in an optimal time. The application will have a user interface that contains a database with search suggestions that allow users to input destinations they want to reach. A map, with an optimal path and suggested time required to traverse path, will be displayed to guide the customer to retrieve their required destination.

1. Real time detection of indoor location.
2. Classifying the indoor position.
3. Interesting Pop up messages to view notifications.
4. Tracking users and recommending them.

2.6 General Constraints

1. Google Maps.
2. IPS accuracy (Real time update).
3. Easy navigation.
4. Business owners may provide their buildings with beacons.
5. Mobile application applicable for android mobile devices only.

3 Functional Requirements

3.1 User - class 1

3.1.1 FR1

-Title: Locate GPS.
-Description: The user locates himself globally and sees building location on map.
-Input: User's latitude and longitude
-Output: The user location on Google maps.
-Pre-conditions: None
-Post-condition: Screen updated with current user global position.
-Dependencies: None.

3.1.2 FR2

-Title: Search for building
-Description: user search for a certain building on Google maps.
-Action: Retrieves information about the building registered in the system from the database.
-Input: Building name
-Output: The building location on Google maps.
-Pre-conditions: Building registered in the system by the admin.
-Post-condition: Desired building shown on Google maps.
-Dependencies: FR15.

3.1.3 FR3

-Title: Load Floor plan
-Description: Load the floor plan of a desired building and load it to the user's screen.
-Action: Retrieves the building's floor plan registered in the system from the database.
-Input: Building location
-Output: View the floor plan
-Pre-conditions: Building registered and its respective floor plan uploaded by admin
-Post-condition: Desired Floor plan is loaded to the user from the database.
-Dependencies: FR1, FR19.

3.1.4 FR4

-Title: List Buildings
-DESC: List all Buildings that were added by the admin in the system.

-Input: Added building name.
-Action: Retrieves all added buildings in database.
-Output: view all added buildings.
-Pre-Condition: admin add building to the database.
-Post-Condition: list all building available.
-DEP: FR15.

3.1.5 FR5

-Title: Locate Indoor Position.
-DESC: Determines the user's current indoor location in the building on the floor plan.
-Input: Sensors Readings.
-Action: Retrieves sensor's readings registered in the system from the database.
-Output: Real-time estimated indoor position of user on floor plan as a point.
-Pre-condition: Floor plan loaded and sensors readings are recorded previously.
-Post-Condition: An indication on floor plan to current user position.
-DEP: FR1, FR3, FR9.

3.1.6 FR6

-Title: Start navigation
-DESC: Generate a route on floor plan between two POIs.
-Action: Two routes will be drawn between the starting point and the end point
-Input: POI1 (Start point) , POI2 (End Point).
-Output: Navigation starts and a guided route is drawn, and updated.
-Pre-condition: Building Floor plan saved in database with POIs added and sensors already available.
-Post-condition: generate a path route to the user from his indoor location or starting POI to his destination.
-DEP: FR5, FR19.

3.1.7 FR7

-Title: Search for destinations
-DESC: Search for the user's destinations.
-Input: Name.
-Action: Views all rooms in the building.
-Output: List all rooms
-Pre-Condition: rooms saved and marked in the building
-Post-Condition: None.
-DEP: FR19.

3.1.8 FR8

-Title: Show notification
-DESC: Shows specific notification according to the specific user indoor location
-Action: Check Database for location and shows respective notification if available and notifies user.
-Input: User Position
-Output: A dialog is previewed to show notification.
-Pre-Condition: Notification setupped .
-Post-Condition: The screen is updated to the user to see notification.
-DEP: FR3.

3.1.9 FR9

-Title: load beacon map
-DESC: Load the beacon map of a desired room and load it to the user's screen.
-Input: User indoor Location.
-Action: Retrieves the beacon map registered in the system from the database.
-Output:view beacon map of a certain room.
-Pre-Condition: the beacon map is loaded to the user .
-Post-Condition: Desired beacon map is loaded to the user from the database.
-DEP: FR10.

3.2 Admin - Class 2

3.2.1 FR10

-Title: Register Beacons.
-DESC: admin will register beacons to the room.
-Input: Beacon UUID.
-Action: Add beacon details.
-Output: Beacons Details added to database.
-Pre-Condition: Scan for Beacons.
-Post-Condition: Beacons are registered successfully and saved in database and assigned to a building.
-DEP: None.

3.2.2 FR11

-Title: Add notification
-DESC: Assigns notifications to the users or guests to the business site.
-Input: Name, Description, image, Mark on floor Plan (X and Y points on floor plan).

-Action: X and Y points on floor plan searched in database and respective notifications are retrieved.
-Output: Confirmation message or error message if something went wrong upon assigning the notification.
-Pre-Condition: the floor plan is loaded to the business owner.
-Post-Condition: Database is updated with new notification based on X and Y points on floor plan.
-DEP: FR20.

3.2.3 FR12

-Title: Delete notification
-DESC: delete notifications to the users or guests from the business site.
-Input: Name, Description, image, Mark on floor Plan (X and Y points on floor plan).
-Action: X and Y points on floor plan searched in database and respective notifications are deleted.
-Output: Confirmation message or error message if something went wrong upon deleting the notification.
-Pre-Condition: the floor plan is loaded.
-Post-Condition: Database is updated with new notification based on X and Y points on floor plan.
-DEP: FR11.

3.2.4 FR13

-Title: Edit notification
-DESC: Edit notifications of the users or guests from the business site.
-Input: Name, Description, image, Mark on floor Plan (X and Y points on floor plan).
-Action: X and Y points on floor plan searched in database and respective notifications are retrieved and edited.
-Output: Confirmation message or error message if something went wrong upon assigning the notification.
-Pre-Condition: the floor plan is loaded to the business owner.
-Post-Condition: Database is updated with new notification based on X and Y points on floor plan.
-DEP: FR11.

3.2.5 FR14

-Title: Locate GPS
-Description: The user locates himself and determine the building location.

-action: Retrieve latitude and longitude location from GPS and show it on Google maps.
-Input: Latitude, Longitude.
-Output: The user location on the GPS
Pre-conditions: None
-Post-condition: Get user GPS location on Google map.
-Dependencies: None

3.2.6 FR15

-Title: Add building.
-Description: Marks a building on Google map.
-action: Save building's latitude and longitude on Google map.
-Input: Code, Name, Description, publicity, geojson file
-Output: Confirmation message or error message if something went wrong upon adding the building on the system.
-Pre-conditions: None.
-Post-condition: Building saved in database.
-Dependencies: None.

3.2.7 FR16

-Title: Delete building
-Description: Deletes a building on Google map.
-action: Deletes building's latitude and longitude on Google map.
-Input: Building Name.
-Output: Confirmation message or error message if something went wrong upon deleting the building on the system.
-Pre-conditions: At least one building is registered in the database.
-Post-condition: changes are saved in database and on Google maps.
-Dependencies: FR15.

3.2.8 FR17

-Title: Edit building
-Description: Edit certain building on Google map.
-action: Edit building's information such as: name, code, description or publicity.
-Input: Building Name.
-Output: Confirmation message or error message if something went wrong upon editing the building on the system.
-Pre-conditions: At least one building is registered in the database.
-Post-condition: changes are saved in the database.

-Dependencies: FR15.

3.2.9 FR18

-Title: List buildings
-Description: Shows all or a certain building on Google map.
-action: Retrieves information about the building registered in the system from the database.
-Input: Building Name. -Output: All buildings registered in the system and their information is previewed.
-Pre-conditions: At least one building is registered in the database.
-Post-condition: None.
-Dependencies: FR15.

3.2.10 FR19

-Title: Upload building Floor plan.
-Description: Upload floor plan for certain building for indoor localization.
-action: Save Floor plans of buildings that registered in the system to the database.
-Input: geojson file.
-Output: Confirmation message or error message if something went wrong upon uploading the floor plan of the building from the system.
-Pre-conditions: At least one building is registered in the database.
-Post-condition: Database updated with new building's information.
-Dependencies: FR15.

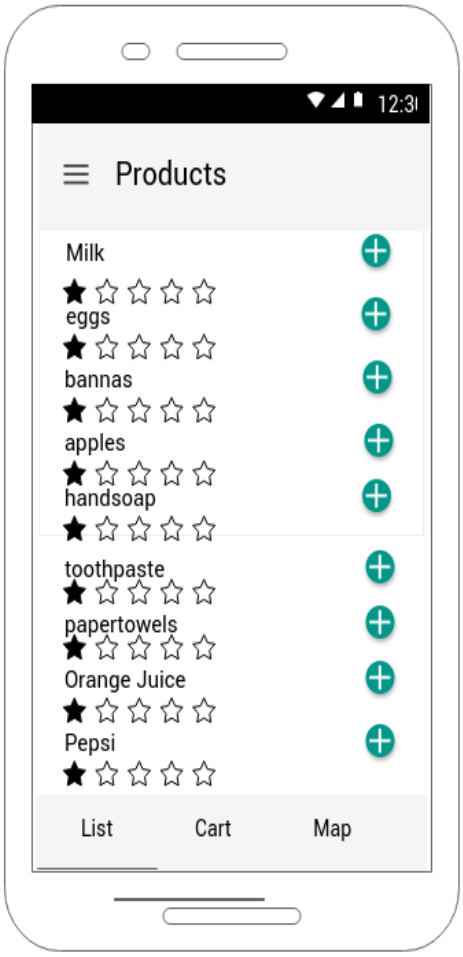
3.2.11 FR20

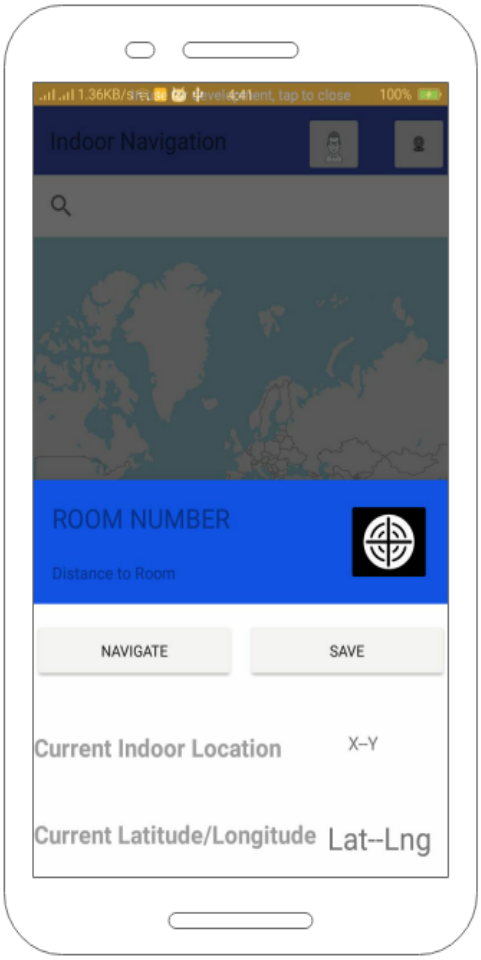
-Title: Upload beacon map .
-Description: Upload beacon map for certain room for indoor localization.
-action: Save Floor plans of buildings that registered in the system to the database.
-Input: geojson file.
-Output: Confirmation message or error message if something went wrong upon uploading the floor plan of the building from the system.
-Pre-conditions: At least one building is registered in the database.
-Post-condition: Database updated with new building's information.
-Dependencies: FR15, FR10.

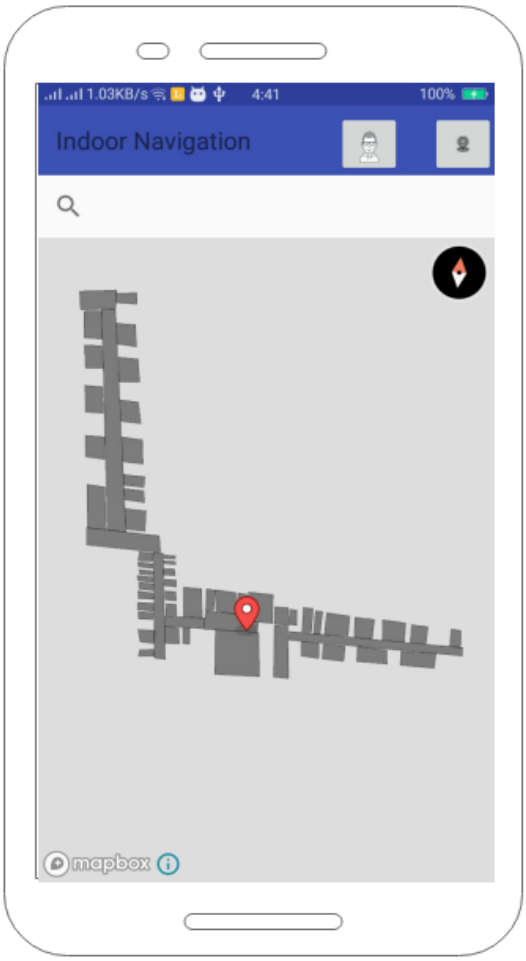
4 Interface Requirements

4.1 User Interfaces

4.1.1 GUI




Indoor Navigation
ROOM NUMBER
Distance to Room
NAVIGATE
SAVE
Current Indoor Location
X--Y
Current Latitude/Longitude
Lat--Lng



4.1.2 API

1. Google Maps API
2. Estimote SDK

4.1.3 Diagnostics or ROM

Estimote Location Beacons:

1. Identification (Hardware revision):
    - F3.3
2. MCU:
    - Bluetooth® SoC
    - ARM® Cortex®-M4 32-bit processor with FPU
    - 64 MHz Core speed
    - 512 kB Flash memory
    - 64 kB RAM memory
3. Radio: 2.4 GHz transceiver:
    - Bluetooth® 4.2 LE standard
    - Range: up to 200 meters (650 feet)
    - Output Power: -20 to +4 dBm in 4 dB steps, “Whisper mode” -40 dBm, ”Long range mode” +10 dBm
4. Sensitivity:
    - -96 dBm
    - Frequency range: 2400 MHz to 2483.5 MHz
    - No. of channels: 40
    - Adjacent channel separation: 2 MHz
    - Modulation: GFSK (FHSS)
    - Antenna: PCB Meander, Monopole
    - Antenna Gain: 0 dBi Over-the-air data rate: 1 Mbps (2 Mbps supported)
5. Sensors:
    - Motion sensor (3-axis)
    - Temperature sensor
    - Ambient Light sensor
    - Magnetometer (3-axis)
    - Pressure sensor
    - EEPROM Memory 1 Mb
    - RTC clock
6. Additional features: GPIO NFC
7. Power Supply:

- 4 x CR2477 – 3.0V lithium primary cell battery (replaceable)
- High efficient Step-Down DC-DC converter

8. Environmental Specification: Operating Temperature:
   - 0C to 60C (32F to 140F)
   - Storage Temperature (recommended): 15C to 30C (59F to 86F)
   - Relative Humidity (operating): 20
   - Relative Humidity (storage): 10
9. Materials:
   - non-ammable
   - enclosure: silicone
   - adhesive layer: double-sided adhesive tape
10. Size and Weight:
    - Length: 62.7 mm (2.47 inches)
    - Width: 41.2 mm (1.62 inches)
    - Height: 23.6 mm (0.93 inches)
    - Weight: 67g (2.36 ounces)

Signal characteristics and the way beacons communicate with mobile devices (received data [signals] from beacons): [1]

1. Broadcasting Power: Broadcasting Power (or Transmit Power) is the power with which the beacon broadcasts its signal. In Estimote Beacons, you can change it with the Estimote SDK, the Cloud interface, or the app. The value ranges from -40 dBm to +4 dBm.
2. Advertising Interval: Beacons do not broadcast constantly. They 'blink' instead. Advertising Interval describes the time between each blink. Just as with Broadcasting Power, Advertising Interval on beacons can be adjusted with Estimote SDK, Cloud, and the app.
3. RSSI: RSSI stands for Received Signal Strength Indicator. It is the strength of the beacon's signal as seen on the receiving device, e.g. a smartphone. The signal strength depends on distance and Broadcasting Power value. At maximum Broadcasting Power (+4 dBm) the RSSI ranges from -26 (a few inches) to -100 (40-50 m distance).
4. Measured Power: Measured Power is a factory-calibrated, read-only constant which indicates what's the expected RSSI at a distance of 1 meter to the beacon. Combined with RSSI, it allows you to estimate the distance between the device and the beacon.
5. Proximity zones: allows you to establish your own proximity zones with a code and enable interactions when a user enters or leaves each zone.

4.2 Hardware Interfaces

1. Wifi Router

2. Estimote Location Beacons.
   A small location-based technology device that transmits a signal using Bluetooth Low Energy (range of up to 70 meters).

4.3 Communications Interfaces

5 Performance Requirements

- The system must be capabl of collecting different sensors readings (wifi and beacons)

-send and updates the indoor position

- The actual average error should be less than 1.5 meters.

6 Design Constraints

6.1 Standards Compliance

- Mobile smart phone that should be connected to Wi-Fi or Bluetooth to connect with beacons
- Wireless Ethernet IEEE 802.11 (Wi-Fi)
- BLE based technology using Estimote beacon devices

6.2 Hardware Limitations

- Wifi Routers should be used.
- Beacons may be used.
- Mobile phone should be android based.
- Mobile phone should support Bluetooth feature.
- Mobile phone must be connected on WIFI.
- Mobile phone may have inertial motion sensors.

7 Other non-functional attributes

7.1 Accuracy

-The whole system work is depended on accuracy. The system should provide high accuracy. It will determine the exact indoor location of the user, tracking employees in a system and start navigation between two points in a building.
-FR Dependent on this: FR5, FR6, FR7, FR29, FR10, FR11, FR18, FR34.

7.2 Performance and Speed:

-Description: The IPS must be interactive. Data sent such as user's location needs to be sent with very high speed as it must be updated on real-time. Also it's needed in order to upload the floor-plan of the building for the wanted building, show notifications to the user, and allow the business owner to track his employees with no delay. .
-FR Dependent on this: FR4, FR6, FR45, FR34, FR5, FR8, FR18, FR11, FR4, FR2, FR3, FR7, FR14,FR18, FR22, FR39, FR44,FR41,FR45.

7.3 Re-usability

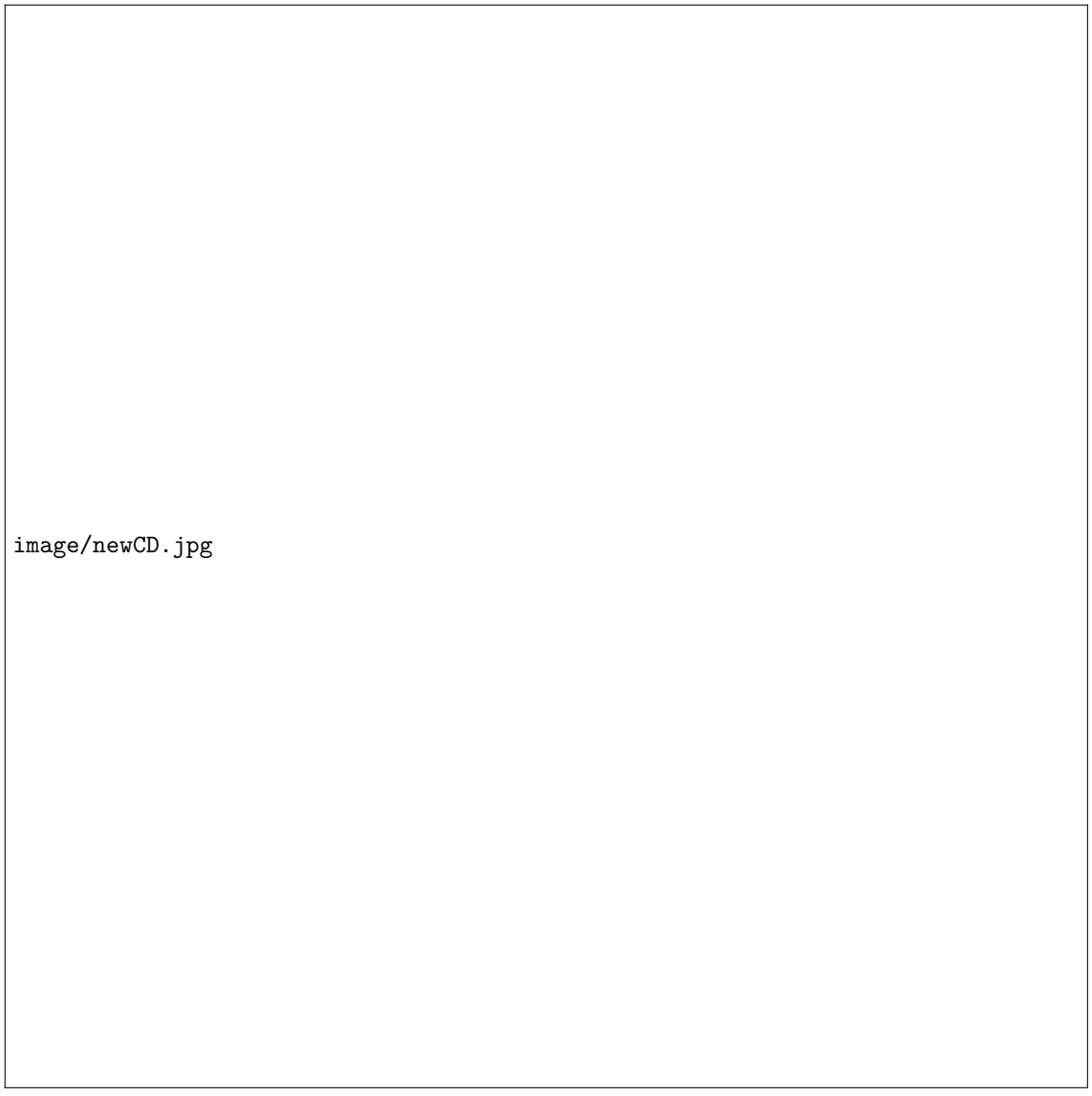
-Description: The system is designed as component packages, that existing components could be reused in new applications. In the prepossessing the system can scan the signals of the Wi-Fi/beacons, the signal is added to filters to improve its accuracy to return RSS values to determine the user's location; the system uses the GPS to locate the building location and to view the floor plan if exists.
-FR Dependent on this: FR1, FR3, FR5, FR34, FR41, FR36, FR15, FR19, FR24, FR29, FR8, FR11.

7.4 Maintainability

-Description: The system is designed in MVC design Pattern in order to make the least effort if any changes appeared in the future. As the MVC divides the system into three inter connected parts. This is done to separate internal representations of information from the ways information is presented to, and accepted from, the user. It allows for efficient code reuse and parallel development.
FR Dependent on this: FR2, FR4, FR7, FR15, FR16, FR17, FR19, FR20, FR21, FR22, FR23, FR24, FR25, FR26, FR27, FR28, FR29, FR30, FR31, FR32, FR33, FR37, FR38,FR39,FR41,FR42,FR43,FR44.

8 Preliminary Object-Oriented Domain Analysis

8.1 Inheritance Relationships



8.2 Class descriptions

8.2.1 Class name

Building

Admin

sensors

Workers

8.2.2 List of Sub classes

Beacons

Floor

Indoor position

POI

8.2.3 interfaces

Isubject

8.2.4 Purpose

Building: Handles buildings info.

Admin: Handles all business owners and buildings in the system.

Sensors: Handles signals detection and classification to classify the indoor position.

Workers: handles all the attributes and extends the common function between business owners, employees and the admin.

Beacons: Handles beacons information and notifications.

Floor: Handles the floor-plan images of the building.

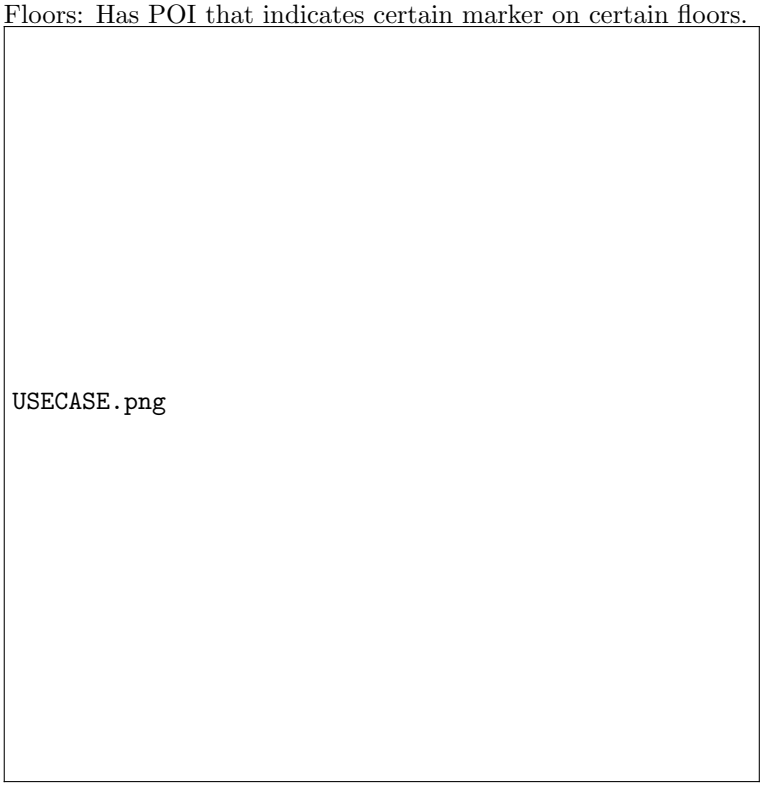
POI: A unique marker on the floor plan to indicate point of interests on certain indoor locations.

8.2.5 Collaborations

Sensors: is used by class buildings in order to indicate that each building has different sensors and is composed of indoor position class to indicate that each sensor has a specific indoor location.

Admin: Uses business controller and buildings controller in order to control the business owners and buildings in a system.

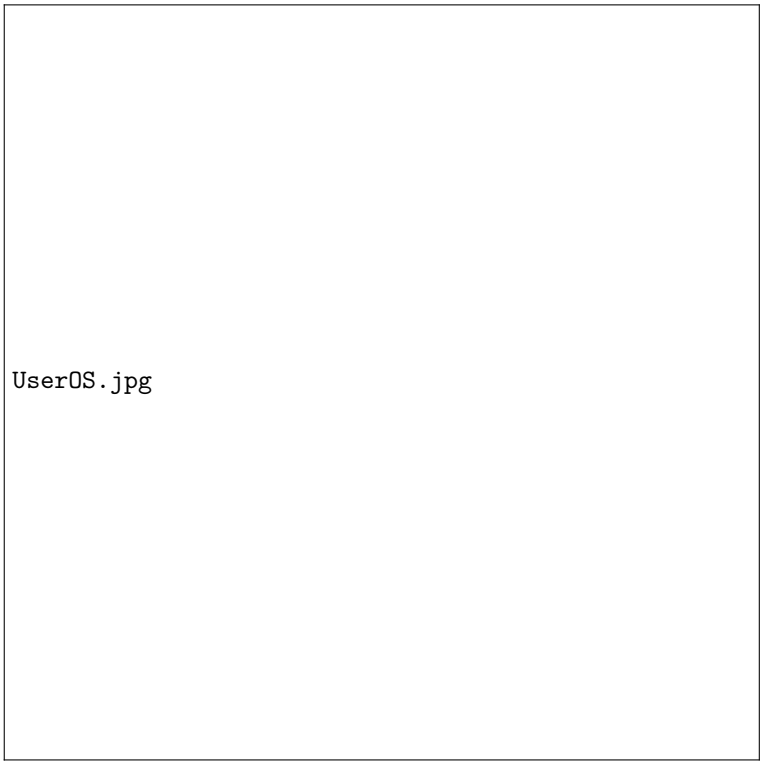
Floors: Has POI that indicates certain marker on certain floors.



8.3 Scenarios

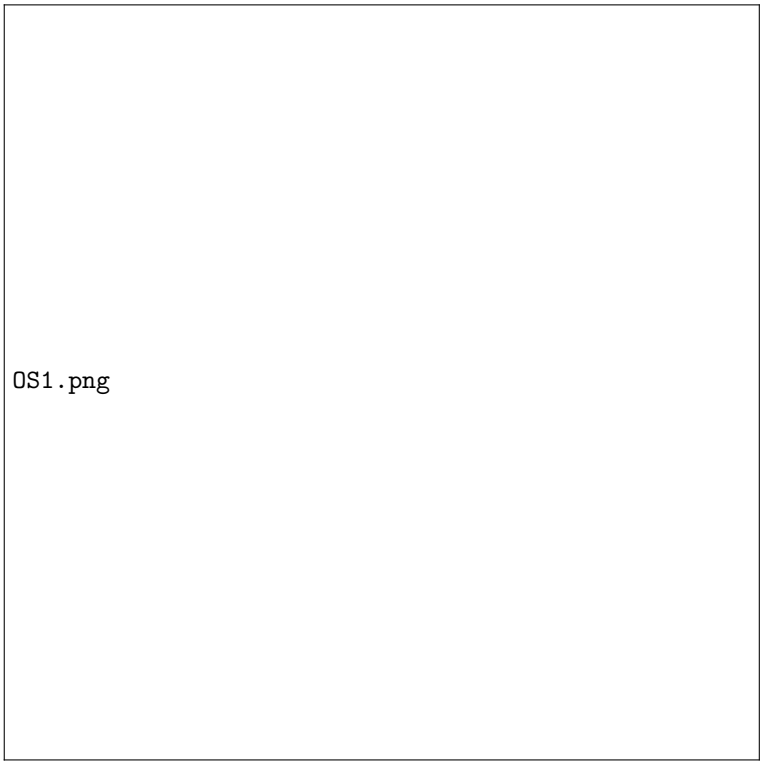
Here will be illustrated some of the scenarios that are shown in the system's use case diagram.

8.3.1 Scenario 1: User Locating Indoor position and Shopping



The user included this scenario is a normal user to the system. This scenario will allow the user to log in and then locate him self on Google maps using GPS location to find a respective indoor place near his global position,then accordingly the map of the indoor place will be loaded from the server and the indoor position will be updated on the map.The user then can start choosing his destinations and the system will optimize the shortest route for him to navigate inside the indoor place to assist him. The user may get notification shown on his device.Moreover when the user reaches his destination a beacon map will open if exists to allow the user to locate himself inside a room to enhance the accuracy.

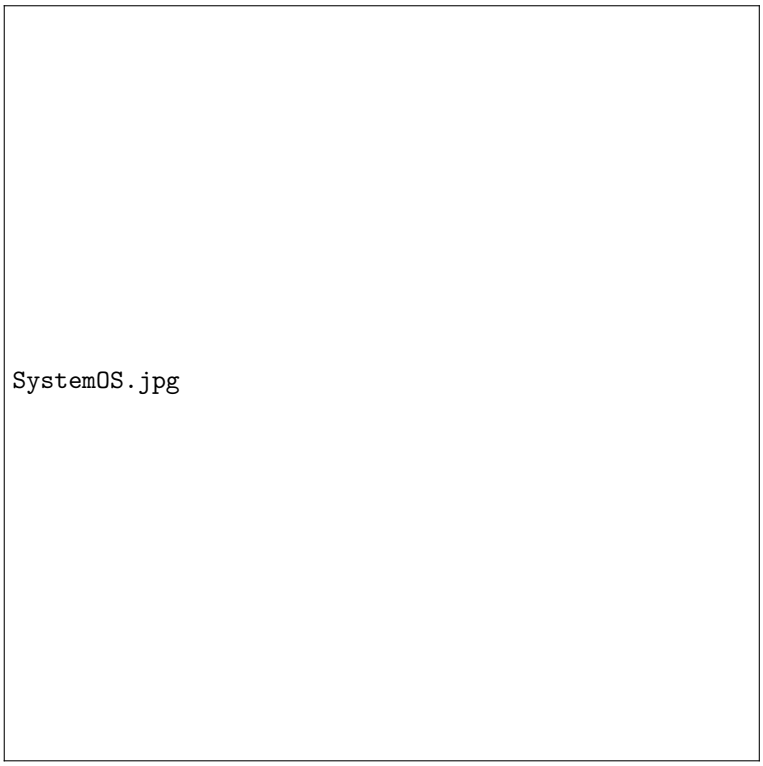
8.3.2 Scenario 2: Admin Controlling the system



The user included in this scenario is the admin. The admin is the one who controls the whole system, as he is going to do the following:

1. Add,edit,delete and list all the floor plan maps.
2. Managing the rooms position which will be placed on the nodes.
3. Add,edit,delete and list the stores.
4. Uploading at least one map for each indoor .
5. Add,edit,delete and list notifications that will be shown to the users.
6. Add,edit,delete,search and list all used beacons

8.3.3 Scenario 3 - Detecting and Classifying sensors reading to generate an indoor position



The system will detect the user indoor position by trilateration approach. This position will be displayed on the map that is visible to the user. As the user reaches a place has a beacon map the system will open the map and locate the user inside it that will enhance the accuracy. Moreover, the list of destinations that the user chooses will be optimized by an optimized shortest route that the user must follow in order to navigate reach his destinations. The proposed system will support the orientation of the user using IMU sensors.

9 Preliminary Schedule Adjusted

Time plan Table.
Gant chart.

10 Preliminary Budget Adjusted

- COST: 4493 LE

11 Appendices

11.1 Definitions, Acronyms, Abbreviations

-Definitions:

- Bluetooth beacons: are hardware transmitters - a class of Bluetooth low energy (BLE) devices that broadcast their identifier to nearby portable electronic devices. The technology enables smartphones, tablets and other devices to perform actions when in close proximity to a beacon.
- is about your apps detecting they're near areas of interest.
- Indoor Location: a navigation system used inside venues such as airports, museums, shopping malls and hospitals. An indoor positioning system (IPS) is the indoor counterpart to the global positioning system.
- Android Studio: an integrated development environment (IDE) for Android platform development.

-Acronyms:

- IPS: indoor positioning system.
- RSSI: Received Signal Strength Indicator.

- UUID: Short for Universally Unique IDentifier, UUID is a 128-bit value used for identification used in software construction.
- MVC: Model View Controller Design Pattern.
- SDK: Software Development Kit.
- FR: functional Requirement.
- POI: point of interests.

11.2 Collected material

References

[1] Estimote. *Bluetooth Estimote Beacons*.

[2] Chunyan Liu Jian Wang Andong Hu and Xin Li. "A Floor-Map-Aided WiFi/Pseudo-Odometry Integration Algorithm for an Indoor Positioning System Körper. (China) [On IBEACONS and indoor positoning systems]". In: *ISSN* (2015).

[3] Christos Laoudias‡ Lambros Petrou§ Georgios Chatzimilioudis Kyriakos Georgiou Timotheos Constambeys and Demetrios Zeinalipour-Yazti. "Anyplace: A Crowdsourced Indoor Information Service Körper. (California) [On Indoor Positioning system]". In: ().

[4] ALSHIHRI SAAD JuHo Kim SungIl Kim SunHwa Ha. "Indoor Positioning System Techniques and Security Körper. (Seoul, Korea) [On IPS and security]". In: (2015).