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A Framework for detecting Movement Indoors

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Abstract*: The ability to track the real-time location and movement of items or people offers a broad range of useful applications in areas such as safety, security and the supply chain. Many systems that track subjects in real-time outdoors such as GPS and mobile phone triangulation have severe limitations when tracking individuals in a smaller area, such as a room, building or garden. GPS devices require line of sight with satellites to be tracked correctly, meaning devices cannot be tracked indoors or in some areas surrounded by tall buildings. The degree of accuracy to which GPS provides location information is also inadequate for applications that monitor areas with specific boundaries between where an individual is allowed and where they are not. Mobile phone tracking is expensive and works only in more developed areas in the range of multiple cell towers. Position estimation, to within an average of fifty metres, is much too inaccurate to track subjects over a small area. Implementing a location determination system using received-signal-strength (RSS) has the advantage that the system can work indoors, however the cost of implementation is rather high and the complex network infrastructure may need constant maintenance. Radio Frequency Identification (RFID) is an automatic identification technology which has seen increasingly prominent use in tracking, however problems also exist here with regards accurate tag location determination. WLAN fingerprinting is arguably the most successfully used technique in systems on the market now. We provide here an overview of common techniques & commercial products used in tracking people and objects within indoor environments and outline the Locator framework which allows the tracking of people indoors using active and passive indoor localisation techniques.*

Keywords**:** *Movement Detection, Device Free Passive Localisation, Presence Detection, smart phone activity detection*

1. Introduction

There is a substantial amount of work in determining the location or activity of an individual over time inside a building with wireless. Movement detection is important for many scenarios such as asset tracking, health care, games, manufacturing, logistics, shopping, security and tour guides [1]. Indoor localisation systems can be classified into active and passive systems. Using Wireless signals is an attractive and reasonably affordable option to deal with the currently unsolved problem of widespread tracking in an indoor environment. Location estimation has become an important component in many applications. Various implementations of location estimation systems which can estimate/track the position of people or objects exist [2]. A localisation system is chosen based on the accuracy and precision required for a specific application. Indoor location estimation systems are classified into active and passive systems. Active localisation requires the tracked people participate actively, while passive localisation is based on monitoring changes of characteristics dependent on human presence in an indoor environment. Active participation means that a person is required to carry electronic devices or tags which send information to a localisation system that infers that person's position. In many cases the devices/tags used by the localisation systems can also process recorded data. The results are sent to an application server running the localisation algorithms for further processing. Passive localisation estimates the position based on the variance of a location dependent measured signal or video process. Thus, the system is not using any electronic devices to infer the person's location. Device Free Passive Localisation (DfPL) approaches can identify human presence by monitoring variances of the signal strength in wireless networks. This is since human body contains about 70% water and it is known that waters resonance frequency is 2.4 GHz. Most common wireless networks use the 2.4GHZ frequency, thus the human body behaves as an absorber attenuating the wireless signal. The use of indoor location determination technology could be utilised in several applications namely:

- **Prisoner Monitoring -** A system using tamper-proof Wi-Fi tags can be worn by prisoners for instance to restrict prisoners to certain areas of the prison by notifying prison wardens if prisoners enter restricted areas.
- **Child Safety -** A Wi-Fi based system could be used by which could activate if they were distressed or in need of help and notify the nearest teacher, carer or park staff about the issue.
- **Indoor gaming -** A large scale version of Pac-man could be played with people equipped with tags playing the roles of video game characters.
- **Security –** Here valuable equipment being moved could activate an alarm for the security staff and allow them to act.
- **Healthcare -** Patients could wear wristband tags that allow them to be tracked throughout the hospital. This would be particularly useful for patients suffering from dementia or Alzheimer's disease.

We next outline common implementations of active and passive indoor location tracking technologies.

2. The Technology behind Pinpointing Users Indoors

Received Signal Strength Indicator (RSSI) is the most crucial parameter in the localization of WLAN devices. At the laptop, it shows the signal strength received from an access point, where the stronger signal received by the WLAN card, the closer the position of the card to the access point. This corroborates a natural observation that there is a dependence between RSSI and the distance from the source of the signal, though the actual relation is not needed in the non-parametric localization algorithm used in this project. For localization purposes, the RSSI parameter must be measured between the device of interest and many APs. One of the most important factors in the measurement of RSSI is the power attenuation due to distance; however, absorption gradient also affects the RSSI measurement. Sudden changes in signal absorption, due to walls for example, introduce discontinuities into the dependence between RSSI and distance which is normally considered a smooth function [3]. In addition to walls, the presence of humans, the direction of the antenna, and the types of WLAN cards influence the absorption of the RF signal energy. The RSSI values can be reported by the device driver as a non-dimensional number or percentage and sometimes is converted to dBm through some nonlinear mapping process [4]. However, the means of conversion are different from one WLAN card to the other. Although there is a formula for each specific card, some cards like Cisco cards follow a table for conversion with higher granularity, and some like Atheros cards use lower resolution [5] Since the RSSI measurements are dependent on different laptop / antenna positioning (e.g., height of the mobile card), antenna orientations were controlled. The average of all data in all directions was used to create the vector for the measurement point. We found that the antenna orientation could cause a variation in RSS level of up to 10 dBm. This effect cannot be ignored when considering the impact different orientations have on RSSI measurements reliability and eventually on the localization accuracy documented here. Another source of error for localization is the presence of humans in the environment. The frequency used by 802.11b, g standards is 2.4 GHz and the resonance frequency of water is at the same frequency. Therefore, water and anything containing water can be problematic because it absorbs RF signal and attenuates it significantly. Since the human body consists of 70% water, the received signal strength is absorbed when the user obstructs the signal path and causes an extra attenuation. The deployment of different wireless NICs during the training phase and the actual localization phase, can also cause discrepancies in measurements. Also, the collected RSSI data on laptops are percentage-based while at Access Points they are in dBm. Since the conversion methods and their accuracy depend on the type of WLAN cards, the actual RSSI readings in the localization algorithm may be interpreted in erroneous ways, resulting in different RSSI data for the exact same environment. The error caused by different types of WLAN cards can be around 20% which is a considerable error value. What follows is a summary of some of the primary active indoor location tracking technologies.

2.1 RFID Tracking

Radio Frequency Identification (RFID) is a technology which is in widespread use in areas like asset management and stock control. Radio signals are transmitted between a reader and a tag. An RFID tag consists of an antenna, a transceiver and a small amount of memory. An RFID reader has more functionality than a tag and in addition to an antenna and a transceiver it also contains a power supply, a processor and an interface to connect to a network. The tags may be either active or passive. The passive tags have no power supply and are activated by the signals scanning them [6]. The active tags have a small power supply and this enables them to have a range of several meters when compared to less than 1 meter for most passive tags. RFID tags enable positioning by placing the readers at doorways or other such points of human movement. The network can then track people when the tag they are carrying, passes through a doorway. This information can be sent by the reader to a central server which can display the tag's location graphically. Active RFID tags have a much higher signal strength, as opposed to passive tags with a low signal strength that are depending on the RFID readers to power them. Active tags for a project tracking people could be set to have a range of approximately 20-30 meters which should give room level visitor information. An active RFID tag has a unique identifier which can be continuously tracked with approximately 1 update per second as long as its signal reaches an RFID reader. The range of an active RFID tag is up to 200 meters. In order to save battery life and reduce the number of updates sent to the system, tags that only broadcast when moved can be used. Active tags however cost significantly more than passive tags. Therefore RFID tags must be handed out and linked to individuals or otherwise be available to for example, the shoppers and collected again when leaving the centre. This requires shoppers as well as the centre to take action for the system to work, thereby lowering the penetration of the system.

Communications from active tags to readers is typically much more reliable than from passive tags due to the ability of active tags to conduct a "session" with a reader. Active tags, due to their on board power supply, also may transmit at higher power levels than passive tags, allowing them to be more robust in "RF challenged" environments with humidity and spray or with dampening targets (including humans, which contain mostly water), reflective targets from metal (shipping containers, vehicles), or at longer distances: generating strong responses from weak reception is a sound approach to success. In turn, active tags are generally bigger, caused by battery volume, and more expensive to manufacture. Many active tags today have operational ranges of hundreds of meters, and a battery life of up to 10 years. Active tags may include larger memories than passive tags, and may include the ability to store additional information received from the reader. Semi-passive tags, also called semi-active tags, are similar to active tags in that they have their own power source, but the battery only powers the microchip and does not power the broadcasting of a signal. The response is usually powered by means of backscattering the RF energy from the reader, where energy is reflected back to the reader as with passive tags. An additional application for the battery is to power data storage. Semi-passive tags have greater sensitivity than passive tags, possess a longer battery powered life cycle than active tags and can perform active functions (such as temperature logging) under its own power, even when no reader is present for powering the circuitry. Whereas in passive tags the power level to power up the circuitry must be 100 times stronger than with active or semi-active tags, also the time consumption for collecting the energy is omitted and the response comes with shorter latency time. *The battery-assisted* reception circuitry of semi-passive tags leads to greater sensitivity than passive tags, typically 100 times more. They have the ability to extend the read range of standard passive technologies, to read around challenging materials such as metal, to withstand outdoor environments, to store an on-tag database, to be able to capture sensor data, and to act as a communications mechanism for external devices.

2.2 WiFi Tracking Solutions

802.11 Wi-Fi networks are available in most public buildings. The signals transmitted by the Access Points (APs) provide a readily available network of signals which may be used for positioning. The wide availability of existing Wi-Fi networks and of Wi-Fi enabled mobile devices makes WLAN positioning an attractive option due to the low roll-out and operational costs. The majority of systems in use today rely on measurements of RSS, Signal to Noise (SnR) ratio and Proximity Sensing. Each beacon (AP) sends out periodic broadcasts on the up or down link [7]. Measurements are taken at the terminal device for RSS and SnR. Passive scanning is used to listen for the signals from the beacons. This is normally used to select the best signal for data communication. Each beacon emitted from an AP contains some information about the AP. For positioning purposes, one of the interesting properties is the Basic Service Set Identifier (BSSI) which acts like an individual name for the beacon. These beacons are emitted periodically and the time delay can be configured but is usually in the order of a few milliseconds. With the information gained from these beacons a number of positioning methods may be implemented. The AP with the strongest signal is considered to be the location of the mobile device. If the Base Station's (BS) coordinates are known to be (x, y), then with proximity sensing, the Mobile Device's coordinates are also considered to be (x, y). WLAN fingerprinting is the most successfully used method in commercial systems available today [7]. It is used in both the Ekahau system and the LA200 systems from Trapeze networks. There are two separate stages in the fingerprinting process, the offline and online stages. The offline stage involves calibrating the area where positioning is to be conducted. This can be a time consuming process and involves manually walking around a building with a Wi-Fi enabled device which is constantly taking "RSS snapshots" of the signals that it can detect at each location from all the detectable APs. This must be done every few meters or so and at each location a full 360 degree rotation must be carried out as there can be a large variation in RSS values depending on orientation. This information is then stored in a database with the coordinates of each location corresponding to a different pattern of RSS values. Systems such as Ekahau display areas where calibration has been conducted with their RSS values denoted by the different colours graphically on a map. The online phase involves actually getting a position fix from a mobile Wi-Fi device at an unknown location in the test area. Several approaches can be followed with either terminal, network or terminal–assisted being used [4]. The detected RSS values at a particular location are compared with those in the database. The closest matching pattern with its corresponding location coordinates are given as the previously unknown coordinates of the mobile device. A number of different methods may be used for find which of these patterns is the closest as there will very rarely be an exact match. Disadvantages of this method include a time consuming calibration/training process. In addition, if some of the APs are moved then partial calibration needs to be redone.

2.3 Bluetooth Tracking Solutions

There are a number of technologies available that use both Bluetooth to augment Local Positioning Systems [8]. Most Bluetooth systems similar to WiFi and active RFID systems are made up of three major components the positioning server, the access points and the tags. The tags can be either special vendor specific Bluetooth tags or any Bluetooth equipped device such as a mobile phone. Some systems claim up to ninety five percent reliability accuracy to around two meters. Bluetooth tags are detected by several methods namely, using RSSI to triangulate the location, putting an access point in every room and using the nearest AP to the tag to indicate its location.

2.4 Indoor Map Based Systems

Several indoor solutions based on cell-tower triangulation or Wi-Fi network databases have appeared in recent years, the newest being one from Point Inside. By combining a proprietary location solution with indoor maps of major malls and airports, these systems offer guidance in places where Google Maps and others simply cannot. It is a rapidly growing area of localisation. Google, Yahoo, Microsoft, Nokia and a few standalone portable navigation device makers are well-entrenched with their efforts to dominate the indoor navigation space. An overview is provided here of the recent offerings in creating indoor maps for large public spaces. Some of these systems use existing WiFi infrastructures to triangulate position. The key difference between these systems and standard wifi based solutions are that you are reliant on the company or other users in having mapped the location beforehand. They are however very powerful and cheaper to utilise although there will be licensing costs to build your own apps with integrate with their API. Google and Apple are both in the positioning game and have both recently come into the news for collecting our personal data to improve their location abilities. They are gathering location information to build massive databases capable of pinpointing people’s locations via their mobile phones. Generally, when companies have collected data from users it has been from personal computers. The data gathered through this medium can be tied only to a city or area code. The rise of internet-enabled mobile phones allows the collection of user data that is much more personal and can be tied to locations on a more granular scale.

2.5 Ultra-wideband

Ultra wideband is precisely timed short bursts of RF energy to provide accurate triangulation of the position of the transmitting tag. Ultra-wideband (UWB) is a radio technology which can be used at very low power levels for short-range high-bandwidth communications (>500 MHz) by using a large portion of the radio spectrum [9]. UWB transmissions send information by generating radio energy at specific time instants and occupying large bandwidth thus enabling a pulse-position or time-modulation. The information can also be modulated on UWB pulses by encoding the polarity of the pulse, its amplitude, and/or by using orthogonal pulses. Unlike conventional RFID systems, which operate on single bands of the radio spectrum, UWB transmits a signal over multiple bands simultaneously, from 3.1 GHz to 10.6 GHz. In a UWB location system, small active tags are attached to the objects to be located, or are carried by personnel. The signals emitted by these tags are detected by a network of receivers surrounding the area. By detecting the signal at two or more receivers, the 3D position of the tag can be found. It is worth noting that two algorithms are employed. One calculates the time difference of arrival of a signal at two different readers and the other calculates the angle of arrival of the signal. Ultra wide band systems work well indoors as the short bursts of radio pulses emitted from UWB tags are easier to filter from multipath reflections than conventional RF signals, however metallic and liquid materials still cause some signal interference.

2.6 Wireless Sensor Networks – Zigbee

Sensors are commonly used as a means of detecting an environmental or physical condition such as sound, light, pressure or temperature. When a large number of sensors are connected together for means of communication via RF a Wireless Sensor Network (WSN) is formed. Zigbee is a technology standard based on 802.15.4 which allows for control and communication in WSNs [10]. Each sensor in the network is called a node. The nodes form a mesh network and due to the self-forming and self-healing architecture of WSNs it may be used as an infrastructure for positioning. A Zigbee tag may be localised upon entering the network by taking advantage of the way the network operates. Zigbee routers and tags, periodically or on demand, take TOA values from the signals received from one another. This information may be used by a Zigbee positioning engine to calculate the position of the mobile Zigbee device, given that the positions of the other Zigbee nodes (including routers) have already been calculated relative to one another. Many of the advantages of using Zigbee are similar to those of UWB systems as the underlying technology is the same [6]. However, their best feature, which is unique to WSNs, is their high fault tolerance. If a network node fails, the network reconfigures and works without it in much the same way the internet does. Despite this significant strength however WSNs suffer from the same weaknesses that all RF technologies do like interference and security issues. The range is short and many nodes are required to give decent accuracy levels. Similarly to many of these proprietary technologies, the installation of a new RF network is unlikely to be popular with I.T. staff and leads to large roll out costs. Also, these new networks need to be troubleshot and maintained by a member of staff. These are costs that may not be apparent when first deploying an RTLS.

2.7 Camera Based

By far the best localisation method used by humans is using vision. By simply directing our eyes at a target (within LOS) we can instantly work out where it is and can make a fairly good estimate of the distance from ourselves to the target. Despite the high quality video technology and the powerful computers available today these operations, in general, cannot be performed with the same ease by an artificial vision system. Nevertheless, vision based positioning systems are very powerful if certain criteria are met. By using one or more cameras trained on an area, it is possible to track the location of a person or thing if (a) the computer knows what to look for, (b) conditions for viewing are suitable and (c) the computing engine has enough processing power to perform the complex analysis required for identification and tracking [11]. A problem scenario would be trying to get a computer to spot a previously known person in a crowd who had changed their appearance somewhat. A beard or dyed hair, substantially changes the look of a person in the computers eyes, whereas for humans, the same person would be easily recognizable. Despite these difficulties, vision based RTLS are rapidly evolving and improving thanks to artificial intelligence techniques and more powerful computing engines. One of the greatest benefits of vision systems is that no tag is necessary. In this way localisation of a person or object doesn’t require their cooperation. Locating engines look for specific patterns and can monitor an object in LOS over a large area and over a long timescale given enough processing power. The United Kingdom is reported as having the highest per capita number of surveillance cameras of any nation in the world and is using vision based positioning systems to do it. Setting up an accurate vision based RTLS can be expensive, at least one camera is required per room (preferably more). High network bandwidth is required to transfer a stream of high resolution video between the network of cameras and the positioning engine, which must be a high end computer. These requirements mean that vision based positioning is not a viable solution where affordable ubiquitous localisation is required. If reductions in cost of vision systems can be made, then their readily understandable output and the fact that they do not require tags, could make vision based RTLS a very attractive option. Some of the more recent camera based systems are included here simply for completeness.

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3. Locator Framework

This section provides an overview of an indoor location tracking extensible architecture including the web application and the mobile app which we have developed which builds on our previous work [12]. This framework allows the use of different indoor tracking technologies to be plugged in and it also allows the use of passive and active tracking technologies.

3.1 Architecture

The web application is implemented in Java and supports interaction with the system by a range of different types of clients. The web application offers content in a RESTful way. Access to the web portal is via JSP pages which are compiled into HTML mark-up with Ajax used as the primary means of transferring data. Data transfer is based on a commonly used data interchange format (i.e. JSON) to permit reuse of functionality by the mobile application. Figure 1 shows the communication procedure with the web application. The request and response may or may not contain JSON data.

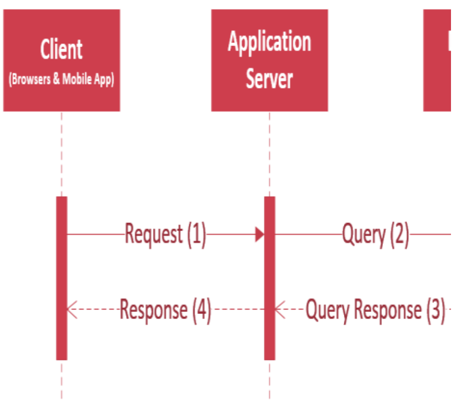

Figure 1: Web app communication

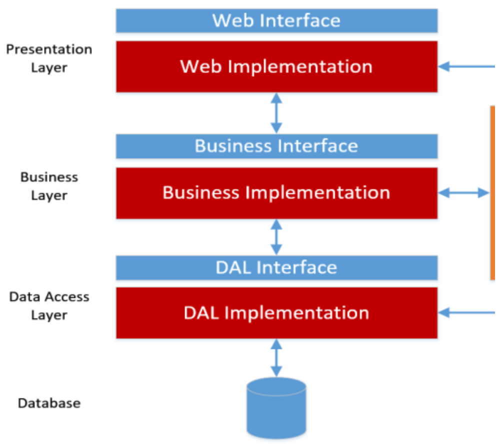

Figure 2: Web app architecture

The web application is modular and loosely coupled allowing functionality to easily be reused or replaced entirely if required. A three tiered system is used to achieve this. The three distinct tiers or layers are composed of a data access layer, a business layer and a presentation layer. Each layer has a clearly defined role; the data access layer or DAL is used exclusively for communication with the database, the business layer holds any application specific logic while the presentation layer contains user display/interaction logic as well as offering an endpoint for client communication. The presentation layer communicates with the business layer while the business layer communicates with the DAL layer which communicates with the database. As a result program flow of control is easily followed and traced. The presentation layer makes use of the model view controller architectural pattern to further separate display logic from interaction logic helping to keep the system maintainable and easily changed in the future. In order to transfer data between layers, data transfer objects (DTOs) were created to model application data (e.g. a BeaconDTO contains all beacon information). Web application layers are shown in Figure 2. All layers of the web application make use of the open source Spring framework. Spring is an application and inversion of control container for Java web applications which relies heavily on the use of interfaces and XML wiring to inject dependencies (or configurable properties) into other classes. The use of dependency injection is one of the most effective ways of reducing a class' dependency on another class and greatly aides in keeping classes loosely coupled, reusable, extensible and highly testable. A number of software design patterns were used for the implementation, most noticeably the business layer which uses the command design pattern to encapsulate particular pieces of functionality such as saving a user's location. A business command performs some specific high level business functionality and interacts with the database by using the DAL services mentioned previously to persist or retrieve data (e.g. a location service which contains references to a position DAO and beacon DAO used to determine location). The presentation layer uses the Spring framework's Java annotations to specify web request (URIs) mapping with specific Java functionality in classes known as controllers. Each controller contains a collection of URI mappings with Java methods offering similar aspects of functionality e.g. a beacon controller only contains functionality related to beacons. In keeping with the system structure, controller methods will always execute a business command.

3.2 Mobile Application

The mobile application uses the Android beacon library to communicate with nearby beacons to retrieve their Eddystone-UID (i.e. namespace id and instance id). The Android beacon library has been chosen as it is an open source library with a large support base and is regularly updated for bug fixes and support for new features. Once retrieved the Eddystone-UID communicates to the server which determines and stores the user's current position. The mobile app is used by most of the users of the system and the initial start page of the mobile application allows users to login with the username/password combination if they already registered. If no registration has been done previously, then new users can to navigate to the registration page to create a new account.

3.2.1 Registration

Figure 3 shows the register page which allows new user to create a new user account to collect reward points with. New users must enter a username (which must be unique), a first and last name as well as a suitably complex password with at least four alphanumeric characters. The new password must be re-entered to confirm it is what the user expected. Users can opt to cancel and return to the previous page or use the back button (available on all pages). Informative feedback messages are displayed to the user after successfully creating an account or duplicate username errors. Input validation errors result in similar errors icons to those shown on the login page.

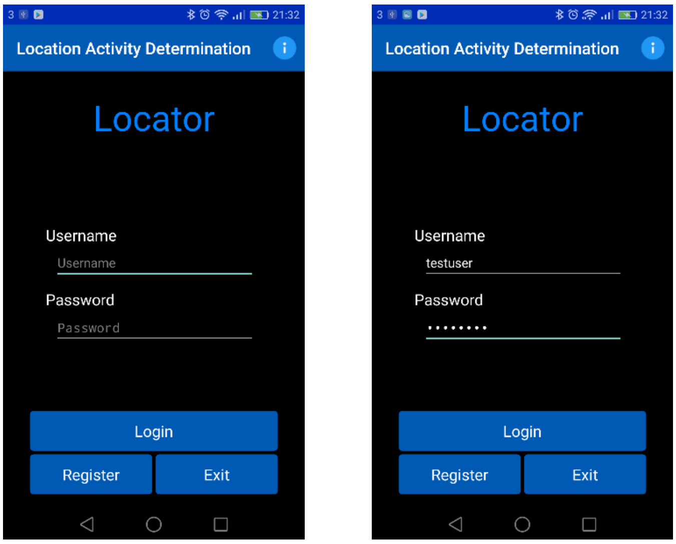

Figure 3: Register page with (left) and without (right) input

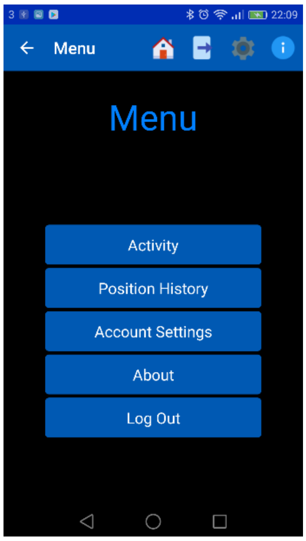

Figure 4: Main Menu

3.2.2 Menu

The menu page shown to users after login allows the user to navigate between application pages. The menu bar includes access to all pages via icons or an overflow icon (three dots on the right with text shown on selection) if there is limited space. At any time, the user may exit the application which displays a confirmation dialog beforehand. The menu bar is shown on all pages to allow quick navigation to any page from any page.

3.2.3 Beacon Scanning

The beacon scanning screen allows a user to enable scanning for beacons with a prompt shown if Bluetooth is not already enabled (See Figure 6). Once scanning is enabled, the scanning functionality of the mobile application lets beacons be scanned for every ten seconds. If a beacon (closer than the ranging distance threshold) is found, then its Eddystone-UID details are sent to the web application which saves a new position history with the current timestamp. While remaining within range of the same beacon, new position histories are saved every 60 seconds. If multiple beacons are scanned, then the closest beacon is used. Once beacon scanning is enabled it will continue to run in the background even if the user closes the application completely. We choose this because beacon scanning is performed in a custom background service which the application communicates with. This becomes problematic however when attempting to get the current status of the background service after restarting the application as Android does not provide a clear way of checking if a service is running or not. Nevertheless, if the application does restart, the state of the

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background service is correctly shown by the state of the buttons. Although the normal scan cooldown time results in very little additional battery consumption, a power saving mode has been included which increases the scanning cooldown to thirty seconds. This reduces the time it takes to discover new beacons although user locations are still saved often enough to be considered accurate.

3.2.4 Position History

The position history page allows a user to view all their own position histories in a list shown in Figure 5. When a position history is selected, specific details are shown including the time and date they visited each position. This page automatically updates each time a new position history is saved (if beacon scanning is enabled) allowing the user to see in real time which location they are in.

Figure 5: Position histories

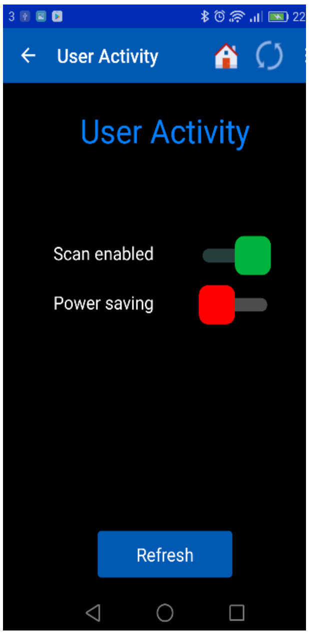

Figure 6: User Activity

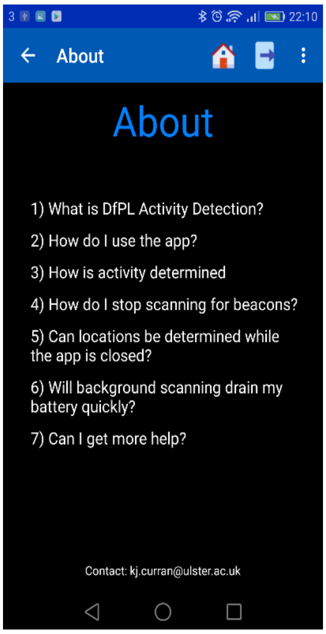

Figure 7: FAQ screen

3.2.5 Account Settings

The account settings page allows users to manage their account details such as name and password. The user account id and username are also shown (to use if admin support is required) and validation errors result in icons like those on the login and registration pages. The URL that the application uses can be changed here. The reset button allows a user to reset any changes they have made. Figure 7 shows the About page.

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3.3 Web Application

Since the web portal is only accessible by admin users, the main page displays a login form in which users must enter valid administrative credentials to gain access to the management section of the web portal. The index page includes a download button from which a user can download the mobile application and install it. Once Eddystone-URLs gain widespread native support by mobile browsers, the download functionality could be simply offered to users (without any knowledge of the system) by configuring beacons to broadcast this download URL.

3.3.1 Manage User Accounts

The manage user accounts page displays all information relating to existing user accounts such as usernames, user account types and full names. From this page an administrative user can create, update or delete user accounts.

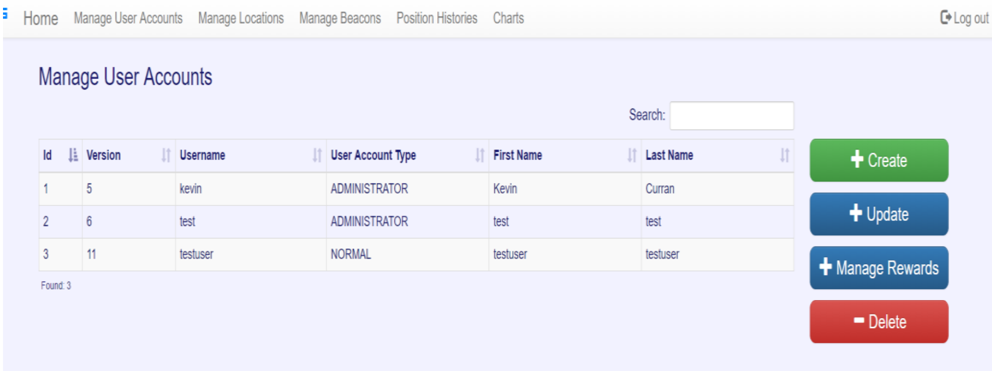

Figure 8: Manage user accounts page

A sample of some of the dialogs produced because of various actions on this page are shown in *Figure 9* including the delete and create user account dialog which is also used for updating user accounts.

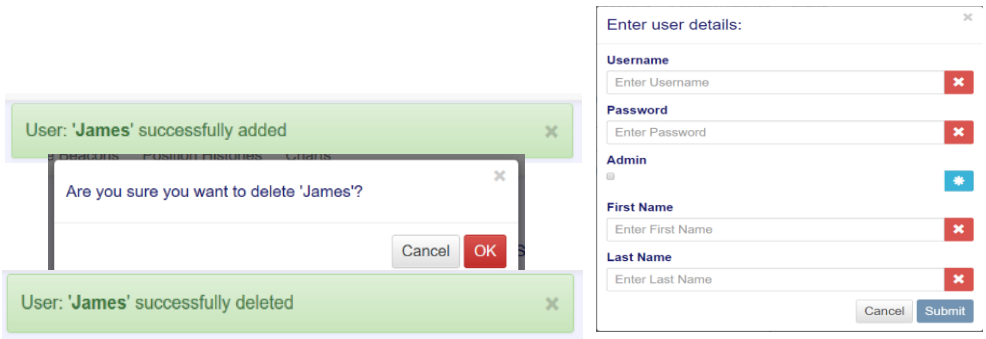

Figure 9: User account page dialogs

3.3.2 Manage Locations

In order to assign beacons to positions there must be locations which the positions are associated with. The manage locations page (see Figure 10) allows administrative users to manage locations including the ability to create, update and delete location data. Deleting a location also deletes any positions which are assigned to that location, with the user made aware of this while confirming deletion.

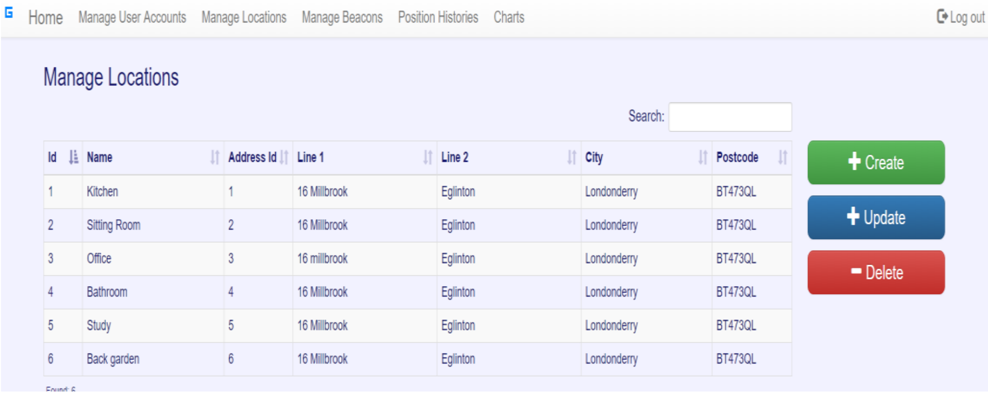

Figure 10: Manage locations page

3.3.3 Manage Beacons

Managing beacons is one of the key features of the web portal and the manage beacon page allows admins to do this. Beacons can be created, modified and deleted from this page as shown in Figure 11. During creation or modification, beacons can be optionally assigned to a location via a dropdown which is populated with locations saved through the manage locations page. If a beacon is assigned a location, then a position name must be entered.

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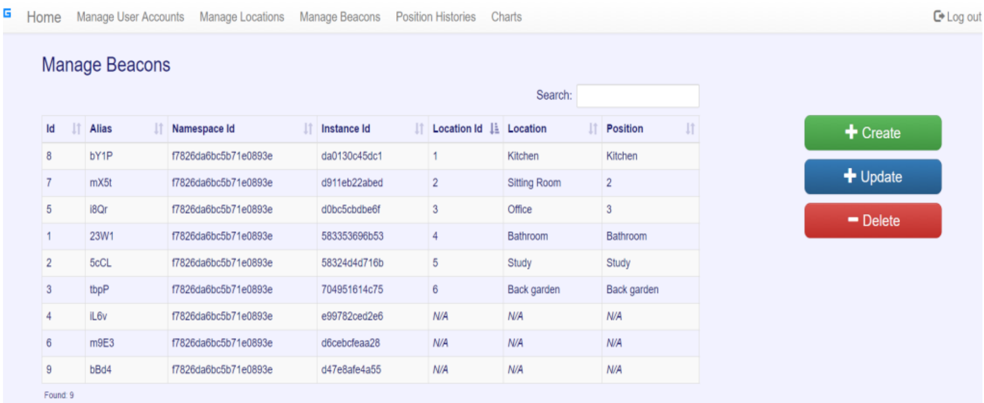
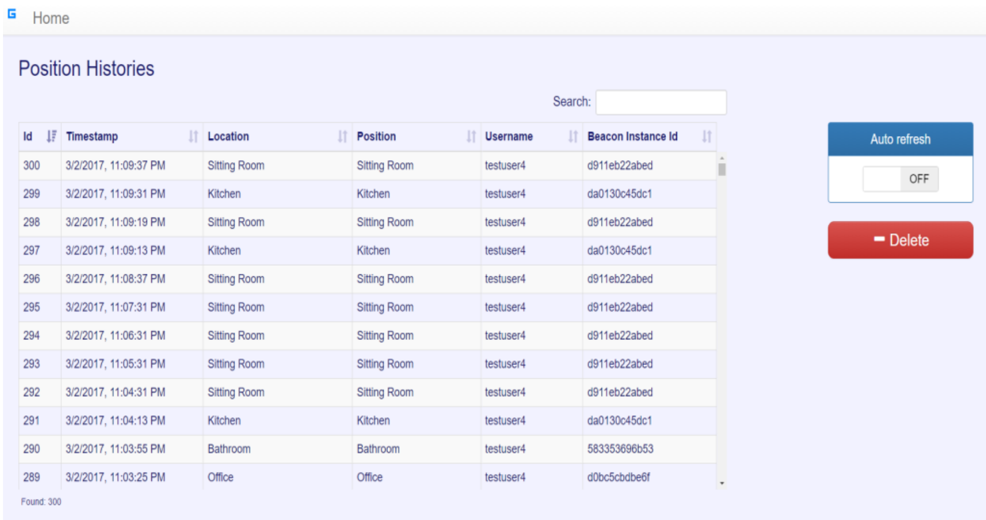


Id	Alias	Namespace Id	Instance Id	Location Id	Location	Position
8	bY1P	f7826da6bc5b71e0893e	da0130c45dc1	1	Kitchen	Kitchen
7	mX5t	f7826da6bc5b71e0893e	d911eb22abed	2	Sitting Room	2
5	i8Qr	f7826da6bc5b71e0893e	d0bc5cbdbe6f	3	Office	3
1	23W1	f7826da6bc5b71e0893e	583353696b53	4	Bathroom	Bathroom
2	5cCL	f7826da6bc5b71e0893e	58324d4d716b	5	Study	Study
3	tbpP	f7826da6bc5b71e0893e	704951614c75	6	Back garden	Back garden
4	iL6v	f7826da6bc5b71e0893e	e99782ced2e6	N/A	N/A	N/A
6	m9E3	f7826da6bc5b71e0893e	d6cebcfeaa28	N/A	N/A	N/A
9	bBd4	f7826da6bc5b71e0893e	d47e8afe4a55	N/A	N/A	N/A

Figure 11: Manage beacons page

3.3.4 View Position Histories

The view position histories page can be used by admins to view position histories for all users within the system (see Figure 12). The admin can also elect to auto refresh this page meaning table data will automatically update every few seconds, displaying any new position histories which may have been saved.



Id	Timestamp	Location	Position	Username	Beacon Instance Id
300	3/2/2017, 11:09:37 PM	Sitting Room	Sitting Room	testuser4	d911eb22abed
299	3/2/2017, 11:09:31 PM	Kitchen	Kitchen	testuser4	da0130c45dc1
298	3/2/2017, 11:09:19 PM	Sitting Room	Sitting Room	testuser4	d911eb22abed
297	3/2/2017, 11:09:13 PM	Kitchen	Kitchen	testuser4	da0130c45dc1
296	3/2/2017, 11:08:37 PM	Sitting Room	Sitting Room	testuser4	d911eb22abed
295	3/2/2017, 11:07:31 PM	Sitting Room	Sitting Room	testuser4	d911eb22abed
294	3/2/2017, 11:06:31 PM	Sitting Room	Sitting Room	testuser4	d911eb22abed
293	3/2/2017, 11:05:31 PM	Sitting Room	Sitting Room	testuser4	d911eb22abed
292	3/2/2017, 11:04:31 PM	Sitting Room	Sitting Room	testuser4	d911eb22abed
291	3/2/2017, 11:04:13 PM	Kitchen	Kitchen	testuser4	da0130c45dc1
290	3/2/2017, 11:03:55 PM	Bathroom	Bathroom	testuser4	583353696b53
289	3/2/2017, 11:03:25 PM	Office	Office	testuser4	d0bc5cbdbe6f

Figure 12: View position histories page

This page includes search functionality (also offered on all other management pages), which allows the information displayed to be searched allowing an admin user to filter these results by a username, date, location or position.

3.3.5 View Charts

Viewing charts allows an admin user to see various statistics about the system including the most popular locations by total linger time, most visited positions for a location by location linger time, average linger time for a location, and the overall top system users by reward points. Linger time and session times are calculated based on the amount of continuous time each user spends at a position, referred to as a position history session. All position history sessions are first determined to produce the chart data displayed on this page. This page also has auto refresh functionality which can be enabled or disabled to view a snapshot or real time statistics for the system whereby all chart data automatically updates every few seconds. An admin user can hover over each chart which displays additional detail about the targeted data in a grey popup. A user can select locations on this chart which updates the other charts with data specifically for the chosen location.

4. Conclusion

This paper has provided an overview of an extensible indoor location determination framework. It utilizes Bluetooth beacons for active positioning which can determine location of individuals alongside device free passive localisation techniques for determination of activities performed in each location. The Bluetooth active localisation hardware can easily be substituted with another active technology such as WiFi. The framework allows the easy updating of new locations, beacons and activities. Charts are accessible which allow the determination of linger times in various locations in addition to activities classified at each location. Future plans include the integration of Channel State Information (CSI) in order to more accurately classify activities using device free passive localisation.

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