ShopAssist - A Unified, Interactive, Location-Aware System for Shopping

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Abstract—Being able to locate customers in shopping malls allows them to appreciate features such as indoor navigation, product localization and enjoy location-based offers. Business owners may also benefit from it through the produced analytics, increased revenue and customer engagement. In this document we survey the available technologies that make this possible and present a system which is capable of providing indoor localization services, relying on small Bluetooth devices – called Beacons. The existing systems are highly individual, solely designed for a specific place. Therefore, we developed a generic mobile application which dynamically locates users indoors, regardless of the location. Moreover, a Content Management System was also developed to abstract Business Owners of the complexity to deploy an indoor localization system and to provide an interface for controlling the media content to be displayed on the Digital Signage. Towards validating our prototype, we performed accuracy tests in different scenarios to evaluate the accurateness of the system. Likewise, load tests were carried out to assess the performance of our server, as well as user tests to measure the usefulness of the system.

I. Introduction

Nowadays, we spend most of our time indoors, either at home, at the office or shopping. Over the course of time, given the broad range of products available, large retail spaces have essentially turned into the primary “go-to” place to buy everything. In contrast, small traditional commerce is losing its faithful customers. In this type of proximity commerce, shop assistants usually know their customers and are able to perform a personalized marketing by recommending them the products they are likely to need or buy. The same is true for online commerce, where massive databases of consumers habits can be mined for recommendation and targeted promotions, as Amazon does with the recommendation algorithms. However, the same does not apply for large brick and mortar stores, where thousands of individuals cross the entrance doors per day. And in today’s society where time is at a premium, customers are looking for an efficient shopping, avoiding wasting time searching for goods.

Retail spaces only have access to information about the customer at the time of payment, when he finally identifies himself and makes his presence known, just right before he leaves the store! All shopping done by the customer is considered blind, thus preventing targeted recommendations to the shopper. Large companies try to circumvent this by deploying loyalty programs, where customers are regularly contacted (by mail, email or SMS) about global or specifically tailored promotions. Nonetheless, time spent in the store, browsing products, is a wasted chance for personalized marketing.

Today, there are technologies that may provide a leap forward in this context. As almost every person carries a mobile phone, these technologies are available for companies to take advantage of.

As we spend most of our time indoors, either working or shopping, eating, and having in mind that GPS performs poorly inside buildings, a problem emerges. Thus, we come up with the following question:

How can we identify and locate customers inside stores, in a reliable and non-intrusive fashion?

Currently, there are technologies that aid to overcome the problem of indoor positioning, and several systems have already been developed in this scope. However, none of them is completely reliable, as all the underlying technologies have their own drawbacks.

Retail spaces can benefit from indoor positioning technologies that enable them to trigger contextual actions designed by business owners. Pushing unique and highly individualized promotions to the customer and collecting detailed metrics and analytics (heatmaps and dwell time maps) are some examples that can improve a business’s operation and revenue. Customers can also benefit from these technologies to enhance their shopping experience: indoor navigation will facilitate and expedite their visits to large stores; augmented reality or contextualized information display will provide easy access to more information about the products that interest them, such as photos, videos and reviews. Some large retail spaces have begun to implement indoor localization technologies and provide their own mobile apps so that their customers can experience some of these benefits. However, each application is designed for a specific context, for a particular place, requiring customers to install a specific app for each store, thereby leading to the following question:

In what way can we overcome the need of one application per place, aiming a deployment in multiple places?

Taking into account the aforementioned problems and challenges, the main goal of this thesis is to develop a system in which the customer shopping experience is enriched, bringing added value for both sides (businesses and shoppers). Our solution aims to solve the previously
stated problem of individuality, as currently each different space requires a different application. To enable indoor navigation, the map of the building is required. It is intended that new locations can be integrated in our application by supplying the corresponding location data by business owners and desired media content.

II. Indoor Localization

Significant work has already been done in the area of indoor localization. The technologies, methodologies and solutions already in use have been surveyed.

A very popular approach for localization is the Global Positioning System (GPS). Some attempts to use GPS indoors have been done, namely using high-sensitivity GPS receivers [1] or using Assisted-GPS [2]. GPS performs poorly indoors because buildings block GPS signals, not achieving satisfactory results. Some experiments have been using Global System for Mobile Communications (GSM) for indoor localization [3] [4], but none of them could provide an error margin smaller than 5 meters. Wireless Local Area Network (WLAN) could be a good choice due to its widespread deployment, eliminating the need for installing extra-hardware, even though it was not designed with the purpose of localization. Li et al. [5] stated some problems concerning using WLAN for indoor localization, namely the penetration losses through walls, the interference from other sources, and the effects of signal reflections. Many attempts of using Bluetooth for indoor positioning took place [6] [8] [7]. The latter two used Bluetooth Low-Energy (BLE) – the 4th version of the Bluetooth Protocol, deployed in 2011 – which eases and increases localization accuracy by including the default RSSI value in the advertisement packet, allowing to achieve an average accuracy of 1.5 meters. Short-range technologies such as Radio-Frequency Identification (RFID) and Infrared (IR) have also been surveyed [9] [10], but still not fitting our purpose. Inertial Navigation Systems have the cumulative error problem [11], which is a major drawback. Visual Light Communication Systems suffer from multipath effects, interferences from other lamps and require a Line-of-Sight to the light source [12] [13].

In conclusion, Bluetooth was the chosen underlying indoor location technology, as its 4th version made indoor localization systems cheaper and easier to procure. Despite the fact radio signal propagation indoors is not regular, it has a reasonable accuracy. Therefore, we chose the Estimote platform to provide indoor localization services. This company sells beacons which use Bluetooth Low-energy to provide indoor localization, together with a fully documented Software Development Kit (SDK).

There are several methods to estimate a user’s position indoors that can be used with the above technologies, namely Trilateration and Triangulation, Fingerprinting, Dead-Reckoning and Proximity-based techniques. Some of the analysed technologies can be used with several of these methods, while others are only suited to a particular one.

III. A Location-Aware System for Shopping

We propose a unified, interactive, location-aware system for Shopping. The key idea is to take advantage of the fact that almost every person carries a mobile phone, by providing customers a context-aware application for their devices, while at the same time providing business owners a way to engage customers and increase revenue. Therefore, our platform is composed by three parts: the Server, the Client and the Digital Signage. We opted for a client-server architecture due to the need of centralization of information and because we wanted to provide a unique place for statistic data gathering.

Hence, we developed a modular architecture, in order to facilitate the extension of the functionalities or their updates. Figure 1 presents a detailed view of the architecture in the form of a block diagram of the entire system.

A. ShopAssist Server

The ShopAssist Server is the core of our system. It is responsible for coordinating the inputs from clients, process them and act accordingly (e.g., by sending content to the Digital Signage display). The Server is also responsible for managing the unique identification of the customers, as they can be registered on different stores. It was implemented using the Play Framework and uses a MySQL database to store all locations data.

Whenever the user device senses a beacon, the Server is sent the username and BeaconID (Major & Minor values of a beacon). This information is processed and matched to a known location. After this, Location Data is sent to the client, containing all the coordinates of the map, beacons position, location of products, windows and doors. Furthermore, this information from the client is combined with media content previously stored in the Database, and sent to the Digital Signage in order for targeted advertisement to be displayed.
Our system offers a unified interface where business owners are able to manage all the information about customers, locations and media content. The CMS is the module responsible for this. Therein lies the place where business owners can manage or add new locations, administer content to be displayed on the digital signage and consult gathered analytics. It uses a database to store this information in a persistent manner. The CMS exposes a Web interface with the following functionalities:

- **Location Manager** - In our platform, a Location is considered a store. Our Location Manager allows the Business Owners to have many stores associated. It allows the creation of new locations from scratch, or modification of already existing ones. In here, business owners can build up the map of his space, add beacons, windows and doors (to provide better accuracy, as claimed by Estimote).

- **Content Manager** - Allows assigning media content (images) to each digital signage present on the corresponding location. Furthermore, it allows to aggregate customers within user profiles, to associate advertising campaigns to them.

- **Position Log** - This feature displays the history of user recorded positions of any location belonging to him. It is possible to see on the map where users have been, filtering it by time interval. It is also possible to filter by user. This allows the business owner to analyse the most popular spots and dead zones of his store, being able to take actions accordingly, such as the rearrangement of the store’s disposition.

The Positioning Engine handles inputs and processes it accordingly, either querying the database, sending the data to the presentation module of the digital signage or to the client. It exposes a RESTful Application Programming Interface (API) for the client and the digital signage to use.

**B. Client**

The client runs our mobile application on his smartphone, which provides indoor positioning and allows customers to browse for products within the current location. It displays a list of products or product sections (whichever the Business Owner defines) in the main screen. The selected product is then marked in the map, enabling customers to guide themselves to the destination. The application also notifies the presence of the user in the store, causing the Digital Signage to be activated.

The client acquires Bluetooth data (RSSI and BeaconID) through the Bluetooth Module and passes it to the location module. The BeaconID consists of a pair of numbers (Major and Minor) which uniquely identify each beacon within a location. The Location Module is a wrapper around the Indoor Positioning System from Estimote, which provides positioning within a space. The Presentation Module displays a map of the location where the user is located.

Regarding the interactions, the Client (mobile application) queries the Server through a REST API to perform the user authentication. In case of a successful authentication, the application starts a loop listening for beacons, displaying a message on the mobile screen saying 'Waiting for a beacon'. Once a beacon is sensed, the loop ends and the beacon’s major and minor ID along with the logged username are sent to the server. Then, the server return a JSON message containing all the location data (its points, windows, doors, and so on). This data is used setup the location object for further indoor positioning in the mobile application.

Then, the positioning loop begins, where the user's position is calculated by Estimote framework. These coordinates are used to draw the avatar on the map, which moves according to users movement. Subsequently, the application kicks off a background task to send a POST request to the Server to store the user’s position on the database.

In case the user is closer by less than one meter to a Digital Signage, the beacon’s major and minor ID, along with the username are sent to the server. The server then acts accordingly, querying the database in order to retrieve contextual data (media content) for that user. Finally, it updates the Digital Signage with that content so it can be displayed to the user.

**C. Digital Signage**

Consists of having several screens spread around the shopping mall to display targeted advertisements. Upon approach of an user to the screen, it displays potentially attractive promotions based on his user profile.

The Presentation Module of the Digital Signage is responsible for displaying media content, sent by the ShopAssist Server. It consists of a screen which shows individualized promotions for the customer nearby.

There is a REST API that is called to indicate the presence of the customer in the proximity and trigger
actions accordingly. Moreover, the campaigns and media content are retrieved from the database, registering how many times a user has seen them.

Each Digital Signage has a Raspberry (A small-sized computer) with a webpage opened in fullscreen. This page displays a continuous loop of default images (chosen by the Shopkeeper), and upon user approach it silently starts displaying targeted images for the nearby user.

Every digital signage has a beacon associated with it, normally positioned above, as seen on picture 3.

To keep the content of the digital signage updated, we need an alive connection with the server.

With HTTP request-response method, the digital signage module would have to periodically make GET requests to the server to know if there is new content to be displayed. The server could not send data unless the digital signage explicitly requested it.

Hence, a Websocket connection between the digital signage and the server is maintained, allowing the server to immediately send updated data once available.

IV. Evaluation

We performed accuracy tests on different places, with different devices, to observe how the accurateness of the indoor positioning varied. We also run load tests on our server to assess its response time and resources consumption at unusually high loads. Likewise, we measured the resources consumption of our mobile application. Moreover, user tests were carried out to survey the usability of our prototype as a whole and to collect the suggested improvements.

A. Accuracy Tests

Accuracy tests were made in two different locations (an university office and a room of an apartment), with two different devices: an Apple iPad Mini 2 and iPhone 6s.

Figure 4 presents an histogram of the error distribution, measured with both used devices (iPad Mini 2 and iPhone 6s), on an university office. We can observe that the iPad achieved a lower error margin. We were expecting to achieve a better accuracy from the iPhone 6s, as Estimote Indoor Location claims to be better tuned around iPhone’s rather than iPads. But surprisingly, the iPhone reported a lower accuracy comparing to the iPad, under the same test scenario.

From the 32 taken measurements of the accuracy tests conducted in a room of an apartment, we estimated a probability interval for 95 percent confidence using a t-student distribution. By the made calculations, we can be 95% confident that our accuracy error will fall between 0.942 and 1.272 meters.

Overall, the accuracy tests carried out resulted on an average error of 1 meter, which we find acceptable for an emerging technology in the field of indoor localization the Bluetooth Low-Energy. If the average error remains the same in bigger locations, such as large retail spaces, the impact will be smaller. Nevertheless, it does not offer enough accuracy to find specific products within store shelves.

B. Load Tests

We tested our server under an increasing number of client requests and measured the network, memory and CPU usage of the server. We made six different tests, doubling the amount of requests. We queried the server with 1, 10, 20, 40, 80 and 160 requests per second, during one minute. In other words, these numbers mean client requests made each second. For instance, it lets us know how does our server perform when 160 clients connect every second, over a 1 minute period (totalling 9600 requests on one minute).

From the load tests performed, we obtained a response time of less than 6 seconds when querying the server with 160 requests per second, over a minute. As having 160 users starting the ShopAssist Mobile application in the exact same is a scenario that requires the adoption of our system by a large number of users, we can conclude that our server responds in a acceptable time under heavy-load.

We also measured the network, memory and CPU usage of the server. Regarding memory usage, we observed that memory usage of both Java and MySQL processes barely fluctuated, allowing us to confirm that our Java code of the Server does not have any memory leak. The CPU usage of the server was also not significant, with a large margin for expansion: 40% usage of one core out of 8 total cores, under 160 requests/second. Regarding the
network usage, we measured a transfer rate lower than 30 kB/s under 160 requests/second, confirming that using JSON for data exchange was a good choice.

C. User Tests

From the user tests conducted, we observed the main faced difficulties allowing us to understand where the system can be improved, concerning user experience. We encountered significant differences in the time-of-accomplishment of the tasks among users, which explained by the fact that some participants felt the application easier to operate than others.

The participants who used the system filled a questionnaire with 7 statements. The questionnaire had a 7-point Likert-scale, where 1 corresponded to Strongly agree, and 7 corresponded to Strongly disagree. The users classified positively our application in terms of simplicity and ease of use, but assigning the worst classification to statement 3 “I am satisfied with system accuracy.”. This classification could be explained by the too high expectations users had, by the fact that users were not holding the iPad in flat position, and because of the small test scenario, where an error of 1.5 m is half the width of the office a significant amount.

D. Mobile App Resource Usage

We measured the resources consumption of our mobile application by monitoring its CPU, RAM, Network and energy usage.

Regarding the CPU usage, an average 6% of CPU usage is obtained after some time running the application. This percentage is explained by the complex algorithms being executed in the background while Estimote Indoor framework is calculating user position. Also, some of this consumption might be explained by our position logger, which reports the user position to the server every second.

Concerning Network usage, the application uses relatively low bandwidth. After receiving the initial JSON message from the server, only a minimal upload bandwidth is used to submit periodically the current user position to the server.

We observed that our app has an high energy demand. This is mainly due to the CPU usage, as our app does complex calculus in order to determine a position, which demands processment and energy. Also, using the network often to report the position to the server consumes energy. Moreover, despite the fact that we are using Bluetooth Low-Energy, it still requires energy to operate.

E. Cost estimation

To estimate the costs of deployment in a larger scale, we assume a small-sized store is between 200 - 800 square meters. Hence, we consider an area of approximately 230 square meters (18.50 * 12.50 m) as an acceptable value for our cost estimation. Regarding the ideal number of beacons, it varies according to the user experience the business owner wants to create. ie., the higher the desired number of digital signage, the greater the number of necessary beacons.

<table>
<thead>
<tr>
<th>Name</th>
<th>Price (€)</th>
<th>Qty</th>
<th>Total (€)</th>
</tr>
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<tbody>
<tr>
<td>Estimote Dev Kit (3 beacons)</td>
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<td>5</td>
<td>500</td>
</tr>
<tr>
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<tr>
<td>Samsung S24C450B Monitor</td>
<td>195</td>
<td>2</td>
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</table>

Total cost: 980€

TABLE 1. COST ESTIMATION FOR AN APPROXIMATELY 230 SQ. METER STORE

As observable in 1, our cost estimation for a small-sized store is of 980€. We find this value accessible to many stores, motivating us to continue the path of this work.

V. Conclusion and Future Work

The goal of this thesis was to develop a system to identify customers and help them locate products in stores, enriching users shopping experience and bringing added value to the business owners. To achieve this, Bluetooth was the chosen underlying indoor location technology. Additionally, we chose the Estimote platform to provide indoor localization services. This company sells beacons which use Bluetooth Low-energy to provide indoor localization, together with a fully documented SDK.

Our system presents an interface for business owners – the Content Management System – that abstracts business owners from the complexity of deploying a beacon infrastructure to provide indoor localization services. Additionally, our prototype was also designed in tandem with the Digital Signage and Mobile platforms. The first provides users a context-aware shopping experience, with targeted content being shown in the Digital Signage. The latter adds an interactive layer over traditional shopping, allowing users to locate themselves within the store and browse for products in the mobile application.

Presently, each different retail space requires a specific application. Our main goal was to deploy a generic system where Business Owners solely need to provide the corresponding map information along with the desired media content to be displayed in Digital Signage. This way we save the customer from the unpleasantness of installing 10 different apps for 10 different stores. The customer only needs to install one mobile application, which works in multiple stores, and thus increasing the chances of adoption of the app.

In other words, we present a layer over Estimote Framework facilitating the deployment of a context-aware system, mixing advertisements with usefulness (indoor positioning, locating products, targeted advertisements). The opportunities are endless, and some that are worth to mention were left for Future Work due to time constraints.

Overall, we accomplished a good accurateness from our prototype, with error distances hovering around 1 meter.

Some features were left for future work due to time restrictions, which we would like to enhance in the future. We would like to extend out test scenario into a more complex space, ideally a retail shop, in which we could test the real application of our platform.

Some possible ideas for further improvement are adding support for video media content, as an animated
and more vivid Digital Signage would attract the attention of more customers. Besides this, another enhancement to our system can be incorporating map-caching. Allowing an offline navigation mode for previously visited stores would dispense the need for requesting the map every time the customer visits the same store. Furthermore, although a unique and generic mobile application is advantageous for customers, in order to increase the chances of adoption by business owners, we would have to provide more personalization and flexibility, i.e., displaying promotions in the mobile phone, in-app purchases, and so on.

References