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Advertising Platform for Mobile Screens

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Masters Thesis

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Resumo

Com a evolução dos dispositivos móveis, levando à sua desvalorização, juntamente ao crescimento da publicidade digital e o facto da Geolink trabalhar com milhares de Taxis, é criada uma oportunidade de unirmos mobilidade com dispositivos móveis e publicidade. Ao usarmos dispositivos móveis para mostrar publicidade dentro de um Taxi conseguimos chegar a um público alvo diferente. O nosso objectivo principal é desenvolver uma plataform que consiga enviar anúncios para um dispositivo móvel dentro de um Táxi, alguns destes anúncios terão em conta a localização do Táxi.
Esta tese aborda ainda o uso do veículo móvel como plataforma de exibição publicitária orientada para o exterior, tirando partido da mobilidade do veículo para aumentar as áreas de exibição dos anúncios, bem como da localização estratégica das praças de táxi que servem como pontos de exibição com grande visibilidade e grande afluência de pessoas. Definimos critérios de performance espacial da exibição de anúncios, usando dados reais de mobilidade de táxis para avaliação de diversas métricas de exibição, em variáveis espaço-temporais.

Abstract

With the evolution of mobile devices, comes the devaluation of mobile devices, combined with the growth of digital advertising a opportunity and the fact that Geolink works with thousands of Taxis, a opportunity rises for uniting mobility with mobile devices and advertising. By using mobile devices to show Ads inside Taxis we have a new way to reach a certain audience. Our aim is to develop a platform that can deliver advertisements to a mobile device inside a Taxi, where some of these Ads can be based on location.

This thesis also addresses the use of vehicles as an exterior-oriented advertising display platform, taking full advantage of the vehicle's mobility to increase the advertising display areas, as well as the strategic location of the Taxi Stands that work as display points with great visibility and great affluence of people. We defined advertising display with spatial performance criteria, by using real data of mobility from Taxis to evaluate several metrics of display, with spatial-temporal variables.

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Chapter 1

Introduction

With the constant evolution of technology, coupled with the fact that mobile devices are getting better and cheaper by the day, along with the progression of advertising, an opportunity has arisen for developing a new platform for mobile advertisement. It would help advertise small and big businesses, as well as help, entertain the passengers of a taxi.

In this thesis, we wanted to develop an Android platform/application which should be able to deliver different kinds of advertisements to a mobile device inside a taxi, with some of the ads based on geolocation. The application should also have some interaction between the user and the device. The position we wanted the mobile device installed is inside a taxi at the head of the front seat facing the back seats. Also, the app should automatically update its data. E.g., its advertisements and the geographic areas where they are triggered. Adding new ads should be an easy task. There should be many types of ads compatible with the app, images, videos, etc. Another objective we had was to gather data with the help of the application to analyze the data and improve the platform/application.

This thesis is divided into six chapters, which are organized in the following order, "Introduction", "State of the Art", "Electronic Expedition System Taxi-Link", "The Advertising Display Application/Platform", "Spatio-Temporal Analysis of Exterior-Oriented Advertising" and "Conclusions and Future Work".
In State of the Art, chapter 2, we try to give a contextualization of taxis and advertising and how they can work together, we also try to analyze a platform similar to what we are trying to develop. In the 3rd chapter, we explain how the Taxi-Link system works, so we can better understand how things work behind the scenes and how important

they are. The fourth chapter, "The Advertising Display Application/Platform", describes all the work done for completing the platform/application, the requirements, how we show the ads, how we decide which order they are in, all the setbacks we encountered and how we overcame them. In the fifth chapter, we have "Spatio-Temporal Analysis of Exterior-Oriented Advertising". this chapter will be used for representing data about exterior-oriented advertising, analyzing it, and get to reach some conclusions. Lastly, in the last chapter, we will write the conclusions about this thesis and will discuss unfinished features that we want to develop in future work to improve the application.

Chapter 2

State of the Art

2.1 Taxi History

Taxis started appearing in the 1600s, with horse-drawn carriages in Paris and London. About two centuries later, a man called Joseph Hansom designed a faster and lightweight cab, the Hansom cab (Please see Figure 2.1). A single horse was enough to pull these cabs due to their lightweight. Their two wheels made it possible to navigate traffic jams easily. As time went by, the rides became quicker and cheaper, which led to a rise in its popularity.

Figure 2.1: Hansom Cab [13]

In the late 1800s, taxis that had an electric battery-powered became available, and around 1897 the world's first gasoline-powered taximeter-cab was invented, by Gottlieb Daimler [14]. Ten years later, it was possible to ride these taxis in New York City. The taxis were equipped with taximeters, charging customers based on mileage. At the same time, a man called John Hertz asked a Chicago university to scientifically identify which colour was the easiest to spot. After the university identified the colour, the classic yellow taxi was born.

In Portugal the idea of exchanging money for a transportation service exists, at least, since the beginning of the seventeenth century, back then, the vehicles were animal-drawn, there was no such thing as taximeters. The travel costs were fixed by the city council, in the nineteenth century, this cost would be agreed between the driver and the passenger, before starting the trip. These vehicles, usually parked in specific places in the city squares, or "Praça", were known as "Carros de Praça".
At the end of the nineteenth century, in 1891, german Wilhelm Bruhn created the taximeter. In the turn of the century, more specifically in 1907, motorized vehicles were introduced in Portugal. The taximeter, as we know today, started to be used approximately ten years later, around 1920, this device would calculate automatically and accurately the value of the trip making the "Carros de Praça" come to be known simply as taxis (Please see Figure 2.2).

Figure 2.2: 1920 Taxi [1].

2.2 Evolution of Advertisement

Advertising has been around for thousands of years, about 6000 years, not exactly as it is today, but the idea behind it was practically the same. The Egyptians used papyrus to advertise goods and services. In ancient Rome, they used mosaics and pictures on signs or walls. But it was in the classical period of ancient Greece, that the invention of commercial advertising, as we know today, took shape.
In Athens, there were certain persons, who were chosen by their voices and clear elocution, which were called town criers. Their job was to walk around town and make public proclamations, at some point, they would interrupt their announcements with paid-for-advertisement, just like nowadays where we have advertisements in-between television shows, the commercial breaks.

Out-of-Home advertising (OOHA) is a traditional way of offline advertising. It focuses on marketing to consumers when they are "on the go", this can be in public places, transit, specific commercial locations or when consumers are waiting, e.g., in a bus stop, town squares, etc. Outdoor advertising works well for promoting products in specific geographic areas. Some kinds of ads can be useful for any kind of businesses. Any successful outdoor campaign should be bright and conspicuous but easy on the eye to attract attention, it should also be easy to understand, so that customers know, with a glance, what is the advertise about [34].

In the end of the fifteenth century (1477), the first printed ad in English was published by a man called William Caxton.
At the start of the seventeenth-century, advertising was so ordinary that the British government introduced a tax. Everyone that printed their ads in a newspaper had to pay that tax. It did almost nothing against advertisement growth. It was only removed in the second half of the nineteenth century, at that time about two million newspaper advertisements were being taxed annually.

In the early 1800s, the three-part structure of the advertising industry was established. It was formed by advertisers, who would buy space to place their advertisements. Media, who would sell space for the ads. And agencies, that would sell space in the name of the media and would create ads for the advertisers, they were the intermediaries. The three-part structure was also known as the advertising tripartite. The advertisers are the retailers, manufacturers, government, etc. The force that pushes the advertising industry, the advertisers are the paymasters, their only concern is about good results. The Media carries and publishes the advertisements in exchange for the advertisers' money. They receive approximately 90% of all the money the advertisers spend. Lastly, we got the advertising agencies. These agencies were hired for producing the advertising campaigns, creating the advertisements and buying the space and time from the media. Advertising agencies were the smallest sector of the advertising tripartite. Until the 1970s they were called "full-service" agencies [33].

At the end of the twentieth century, a new era started for the industry of advertising, the beginning of digital advertising, more specifically Internet advertising. Nowadays, digital advertising is the most dominant force in the advertising universe [5]. In 1994 the first Internet banner ad was published on HotWired.com for a campaign by AT&T (Please see Figure 2.3), this first banner had a clickthrough rate of 44% which would revolutionize the advertising world as was known at the time. Nowadays, that clickthrough rate all over the ad formats from Google is something like 0.05%, for Facebook is 1.11%, Twitter 0.86%, Instagram and LinkedIn is 0.22% [30]. Meanwhile, that first little Internet banner ad made the world realize the true potential of Internet advertising, from there, the advertisements had to evolve quickly. All over the world, the Internet, suddenly, became an enormous advertising medium.
Similar to Out-Of-Home advertising, Digital-Out-of-Home advertising (DOOHA) also focus on reaching the consumers at any time and anywhere in public spaces but takes advantage of digital devices, such as screens, for its benefit [35].

Figure 2.3: First Banner Ad on the Internet [8].

2.3 Evolution of mobile advertising

In 1992, in the United Kingdom, Engineer Neil Papworth sent the first SMS message. It simply said "Merry Christmas", after a few years, advertisers recognized text messages as a way of advertising, it had no creative elements, no possibility of targeting, just simple mass text messaging. In 2002, SMS became the new mass media channel. Jumping to 2007, Apple launched the first iPhone, which revolutionized the smartphone industry and made the growth of mobile advertising accelerate even more. The original mobile ad exchanges showed up, a technology platform that facilitates the buying and selling of media advertising. Not long after, about one year later, the App

Store was introduced, making users able to change between web browsers and mobile apps. Users started migrating from desktop to mobile browsing, which was great for advertisers, but awful for users. The mobile browser ads had a negative effect on user experience. Mainly, because the ads were not optimized for mobile screens, they were made for desktop browsing, the only thing that they would change to the ads was its dimensions [37], as smartphone were evolving, mobile ads were evolving as well. By 2014, users, while on the smartphone, spent most of their time in mobile apps. Therefore, the importance of including mobile advertising with little effort in app development was increasing. In the meantime, the mobile browser was getting used less and less [7].

With the evolution of mobile devices coupled with the Internet, advertisements nowadays go directly to the consumers in real-time wherever and whenever it matters. People, possible consumers, spend an average of three hours and fifteen minutes per day on their phones, checking Facebook, reading emails, or just browsing, mostly on apps, people now hold the buying process in their hands [36]. It is possible to reach an audience on a national scale with small effort. In this thesis, we will try to follow this idea of delivering advertising "on the go". However, we will focus on a specific case, advertising with taxis.

2.4 Ways to Advertise on Taxis

There are some ways to advertise with taxis, but the ones we are going to cover are Taxi Tops, Stickers and mobile devices installed in taxis. Taxi Tops are located above the car roof, they can either be a digital display panel or an analogue panel (Please see Figures 2.4 and 2.5).

Companies such as Curb Taxi Media have Digital Taxi Tops. These digital panels show advertisements based on location, day time or by target audience. According to Chris Polos, Vice President of Curb Taxi Media, "The digital out of home ecosystem is growing significantly. In fact, global spending on digital out-of-home advertising is expected to grow 10% each year between 2018 and 2021. It's a really exciting time to be in this space for everyone." [16]. This Company has a few ways of advertising with taxis, Digital Tops, TaxiTV and Static Tops.

The Figure 2.5 was a campaign made from United Airlines in combination with Curb Taxi Media, which had the objective of debunking the myth about being faster to get

Figure 2.4: Analog Taxi Top [2]

Figure 2.5: Digital Taxi Top [6]

from New York City to the JFK Airport than to the Newark Airport. It was a simple idea, the taxis had a digital screen on their roofs that would show people the travel time from that location to both airports. These digital screens are called Digital Tops. The campaign was a simple idea, but at the same time, it was an effective one. At the end of this campaign, the Newark Airport Authority reported having an increase of, roughly, 810000 new passengers [31]. If the panel above the taxi has no digital screen, then its called Static Tops.

Moving on to mobile devices, they can be put about anywhere inside the taxi, but, the usual place for advertising is, usually, installed near the top of the front seats with the screen facing the back seats. Curb taxi media names them TaxiTV (Please see Figure 2.6). The displayed ads in the mobile device can be measured by the number of clicks, shown ads, how many buys and actions were made, etc. All this data can be used for tweaking the advertisements, as well as the device.
As for the non-digital types of ad, there is not an accurate way of measuring how many times they were seen. It is possible to make estimates of how many people saw the ad or by analyzing the sales of the product being advertised. However, these ways are not as accurate as, for example, the clickthrough rate.

Finally, the last form of taxi advertising that we are going to cover is Stickers (Please see Figure: 2.7), these are by far the easiest to obtain and also the ones that require the least investment. This type of advertising was made for transit. It has to be attractive, short, colourful yet simple and, probably the most important, eye-catching. Unlike TV or Radio advertisements, Taxi Stickers do not require a specific time slot to grab the audience attention. This kind of ad is also a proper way to reach different areas and people since the taxis travel to all sorts of places. When the taxis are parked in a taxi stand the ads are also seen by a considerable amount of people. These stands

Figure 2.6: TaxiTV from Curb Taxi Media [25]

are strategically picked locations with good visibility.

Figure 2.7: Taxi with a Ad Sticker [23]

2.5 Main digital platforms for mobile advertising

There are currently a few applications designed to display advertisements on mobile devices for taxis. However, none of which are available in Portugal and only a small percentage of them has geolocation-based ads. In Figure 2.8 we can see an example of Curb Taxi Media's TaxiTV, if we further inspect it, we see that the top buttons are, mainly, for television news channels, there is also a "LOCAL OFFERS" button which, as the name indicates probably gives the customers offers or discounts of nearby stores.

There is a button to pair the Tablet with their mobile application. In the bottom, we have the current fare, a button to open a map and, additionally, another to contact the TLC, the Taxi & Limousine Commission. We can also get the taxi info, which gives the customer a variety of information about the driver and the taxi. Furthermore, by pressing the "SURVEY" key, the passenger can take a customers satisfaction survey. In addition to the channels in the top row, it is possible to change to other channels by pressing the "CHANGE CHANNEL" button. Lastly, we can modify the volume settings and turn off the screen of the device. At the centre of the screen is where it is displayed, whatever it was chosen, e.g. channels, map, local offers, etc. In both sides, there is the possibility of showing banner ads. Apart from all these functionalities, from time to time or when going through specific locations, an advertise might show up. Of course, all of this depends on the configuration of the tablet application.

Figure 2.8: Taxi TV from Curb Taxi Media with a paired smartphone [26]

Chapter 3

Electronic Expedition System Taxi-Link

3.1 Vehicle Location and GPS

Budget is always a good thing to consider about in businesses. People knew that GPS devices could improve the taxi service but, as the cost of installing this type of device was not so cheap, people would prefer not to invest in it.
GPS, also known as Global Positioning System, is a navigation system that uses satellites. It is owned by the United States of America (USA) and is free. The only device that is required to get a location is a GPS receiver. Initially, this system consisted of twenty-four satellites orbiting the Earth, but nowadays we have a constellation of thirty-one. Where thirty of those are active, only twenty-four satellites are required for the system to work, but the additional satellites improve the location accuracy. The system requires that, from anywhere on Earth, there are at least four visible satellites [21]. It is possible to get a location with only three, but it will not have the best accuracy.
Towards having an accurate location, the GPS receiver listens to, at least, four satellites, it calculates the distance to each satellite and figures out the device's current location. If we draw a sphere with the radius as the distance to the GPS receiver for each one of the four satellites, the spheres interception will be the current position of the receiver (Please see Figure 3.1). If only three satellites are used, the interception of their three spheres will result in two points, sometimes the system can tell which one is the real point, but when it does not, it will return a location that may be hundreds

of meters off. With the trivialization of GPS devices, it became cheaper to install them in taxis. With these devices installed, it is possible to know the location of the vehicle at any given time, which can benefit the driver in different ways, for example, the dispatch centre can assign a service by calculating the distance to a client. In case the driver is in distress and needs help, his/her location is known and the dispatch centre can send help efficiently. It can also use the data to better distribute the taxis throughout a certain region.

Figure 3.1: Four satellites in usage for accurate location [9]

3.2 Vector Cartography, Toponomy and Route Calculation

Building our dispatch system required a structure that would enable us to go through geological data. That structure implementation would have to allow us to make decisions efficiently and offer accurate information through the dispatch system. In order to accomplish this, we got a cartography system which provided us with everything that was required. The system uses objects to represent data, for example, it has objects that represent segments of road, these have information about where and how the segments are portrayed in the map, which segments it connects to and its direction. These segments represent roads on which the taxis can go through, including BUS lanes. This cartography system also has information about points of interest, for

example, historical places, shoppings, museums, etc.
The system has a reverse geocoding feature that also uses segments to determine the closest point to a given location. It is a convenient function because it works like a translator, modifying a place in a map, latitude and longitude, into an address.
The next feature we are going to describe is geocoding, it is similar to reverse geocoding, as it also works as a translator, but geocoding is the process of receiving an address and returning a location. There is the possibility of more than one street sharing the same name, so, to eliminate this ambiguity, the address should/must contain the full address, presenting more data and making the location as accurate as possible. This system also allows us to calculate the best route between two points. It narrows down the two points in its road segments, afterwards, it proceeds to find the best set of steps that links both locations. This step is essential for the next section.

3.3 Vehicle selection, Taxi Stand and Zoning

Before assigning a service, the service goes through several criteria. First, the system has to check which taxis are compatible with each client's needs. These could be the number of seats, the taxi being adapted for reduced mobility people, air conditioning, sanitary separator, and so on. After this selection, the system determines which taxi to pick in a couple of different ways.
In the first case, the system calculates which taxi stand is closer to the pick-up point. When chosen, it will select a taxi based on its place in the queue, if that taxi ignores the service or decides to decline it, the service will be presented to the next vehicle and so on. In this case, the system tries to make sure that every taxi waits on average the same amount of time for a service. But there are cities where these rules do not apply in the same way. For example, the service can always prompt first to the closest taxi of the pick-up location, if declined, the service will be sent to the second nearest taxi, until one the drivers accept the service. These systems dispatch a service for one taxi at a time and in both of them, the client wait time is not linear.
In contrast, there is another system that, instead of dispatching a service to a single taxi at a time, it sends one service to multiple cars. This system works by sending many taxis the same offer with no limit to how many taxis will receive it. After some time the system chooses, from the ones that accepted the offer, the one that has the lowest distance to the pick-up point. This distance is determined by our server, referred in 3.2, by calculating the shortest route between the taxis and the client.
Unlike the first case where the service can be hopping around between taxis, making

the client wait way more time than he/she should, in this case, dispatching to multiple taxis makes the wait time to be almost the same every time. This wait time is basically the amount of time the server gives taxis to decide whether or not to accept the service, usually taking less than one minute. This short waiting time results from having multiple candidates at once for a service, instead of going through each one of them individually, providing a better quality of service.
Assuming a wait time for accepting a service of 20 seconds, if only the tenth car accepts the service on the first system, the client has to wait 200 seconds, 3 min and 20 seconds. However, in the second system, which sends the service to 10 people, the server waits 20 seconds for all accepted responses and it computes, let us say in 10 seconds, which is the closest taxi of the pick-up location, it only takes 30 seconds to assign the service, the client only had to wait nearly a sixth of the 200 seconds. Not all fleets/cities use this latest system because it was only introduced in a newer version of the platform and some people do not want to use it.

3.4 Drivers Application

The car communicates with the server by the drivers app and each driver has to login with their credentials in order to use the app. With the application, the driver can choose in which state he is in, for example, busy, free, parked or pause. The server receives updates with these changes along with the position of the taxi. This way there is always information in the servers about each taxi using our drivers app. It is important because the dispatch system uses the location of taxis to calculate the distance between customers and taxis to decide which taxi to deliver the service.
The drivers application is always running, even in the background, this way it can exchange information with the server at all times without breaks. When the driver accepts a service, the app shows information about that service, for example, the pick-up address, observations or if it is a special service that is paid by credit instead of cash. The drivers app has a navigate button to open a navigation app, can also be used to create and issue invoices for the customer, it is possible to pair the device with a printer to print the invoice for the clients.

3.5 Car-Server Communication Architecture

Each taxi that works with our system has to carry an Android smartphone with our drivers application installed and fully configured. The communication between car and server is made with the help of the app. We use a communication protocol that transmits data in both ways, bidirectional. This communication protocol is required because, at any given moment, either the car or the server may have to send information to each other. The app might send state changes which are critical for the system to work. If by any chance these state changes fail to be sent or received, the taxi could stop receiving services. Another problem could be if the taxi is parked in a taxi stand it could lose its place in the queue.
The server has to know the location of the taxi every X seconds, to do so, the vehicle uses a GPS system to determine its location and sends it to the server. Tracking the taxis is used not only for service dispatch but also for taxi tracking, allowing users to track their assigned taxi through an application.

Chapter 4

The Advertising Display Application/Platform

Our main goal was to develop an advertising and interactive application based on geolocation for mobile devices. We opted for Android Tablets because in terms of screen size, performance and price, they were a better choice than any of the other mobile operating systems.
The application was developed in Android for taxis. We analyzed similar apps and got to the conclusion that the functionalities and the visual in all of them were pretty much the same (please see section 2.5), after analyzing the others apps, we had to think on how we could develop our application. So we decided to start thinking about what were the requirements for the application, e.g. server, database, which platform to develop in, types of ads, how to trigger ads in certain areas, how to distribute the ads through taxis. In this chapter, we will describe how we fulfilled these objectives and how we got rid of the problems that arose with them.

4.1 The Developing Framework

4.1.1 What is a Framework

There are a lot of people who tend to mistake the definition of Library and Framework, first and foremost, the big difference between Frameworks and Libraries is the "Inversion of Control", basically when you call a method from a Library, you are in control, you made the call. With a Framework, the control is inverted, the Framework

calls your code [15].
Framework is a platform for developing software applications, usually, with its own rules, which can be customizable. It provides the users with the means to write software for a specific platform, in few words, it is the skeleton of the application.
A Framework may include predefined Libraries, which help the user with some tasks that are well-studied and common among applications, there is no need to reinvent the wheel each time a new application is in development.

Native applications are created and optimized for a specific platform. The official development language used for Android is Java, while for iOS, it is Objective-C. Native apps, performance-wise, run faster than non-native applications (Please see Figures 4.1 and 4.2), as we can see in the Figures, Java and Kotlin are the best, performance-wise, React-native is left far behind. In these examples, React-native takes at least seven times more time doing the same algorithm than Java or Kotlin. Usually, Native apps also run more smoothly.
Native applications can take full advantage of the hardware features of a mobile device such as GPS, camera, microphone, etc. Implementing these features can be done quickly and easily, mainly because of the exclusive APIs offered by Google and iOS. Another point in favour of Native development is that it has an enormous online community, probably, the biggest one of these languages, this comes in handy when there are problems to solve or when some insight is needed to start developing a new utility. Already knowing Java, from previous experiences, was also a point in favour of Native development.
Lack of cross-platform development would be a point against Native development, but in our case, we will only use Android tablets, which means we didn't have to develop for more than one platform.

On the other hand, we got React-Native, the only points in favour of React-Native would be cross-platform development and hot reloading. Hot reloading means that developers can quickly see and test code changes, the ability to do so without manually reloading the app and losing the app state would be a plus for productivity during development [32].
As said before we were going to develop only for Android, so cross-platform was not needed. As for hot reloading, it would be a nice feature, but not a deal-breaker.

After weighing the pros and cons, we decided to go with Native development, mostly because, we would heavily rely on hardware features, cross-platform was not an issue and past knowledge of Java. The immense online community of Java was also a plus.

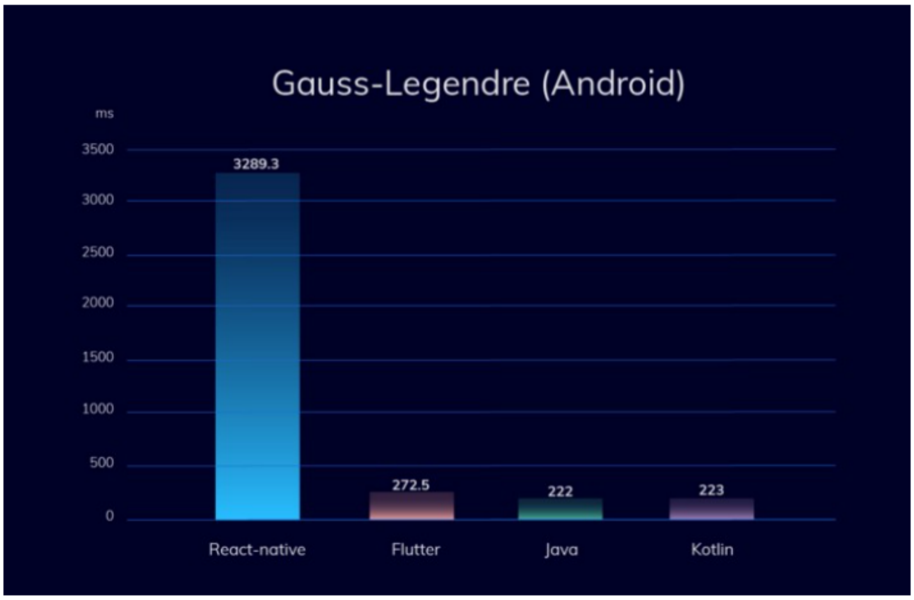

Figure 4.1: Gauss-Legendre Algorithm Performance test [10].

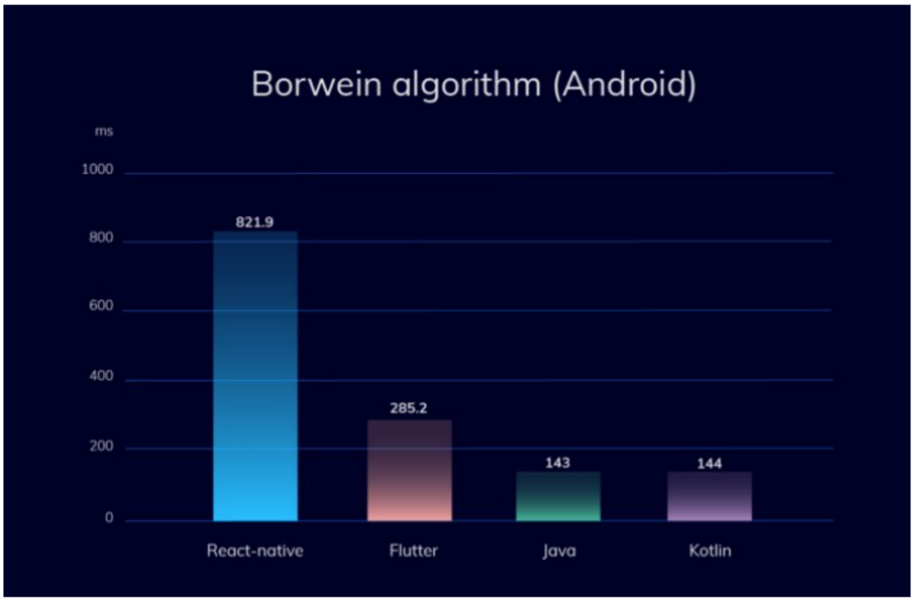

Figure 4.2: Borwein Algorithm Performance test [3].

4.2 Types of Advertisement

The principal purpose of this platform/application was to advertise, so we had to think about the types of advertisements we wanted to showcase,
The main idea was to have multiple types of ads. After some thought, we decided that we would have at least four different types of advertisements.

1. First format, images, this type of ads, are displayed for a short amount of time. Consequently, they must easily capture people's attention, to entice them to read something or to visit the advertised website.

2. Next, we got the video format, nowadays, this form of advertising is, probably, the most popular one and the most successful as well, at least on YouTube [29], this kind of ad does not have to be short, it just has to keep the spectator engaged until the end.

3. The third advertisement format we decided to include in our project was audio. This type of ad can get the attention of passengers even if they are ignoring the screen. Like the other two formats, video and image, it can advertise as well as it can give information about the place the taxi is passing through.

4. Finally, we have questionnaire/quiz, this type of ads vary from multiple choice answers to general culture quizzes. They should be developed with the thought of improving customers experience. Questionnaires can be useful for tweaking the advertisements, e.g. more quizzes, fewer surveys or more videos, fewer audios, etc.

With these four types of advertisements, we think it is enough to reproduce any variety of ad for all sorts of people.

4.3 Requirements

4.3.1 Website

The website is, essentially, used for appending/deleting new advertisements, modifying exhibitions and examine how many times the ads were displayed. As we can see in Figure 4.3, while inserting new ads, we can choose their start and end date, as well as their time window. It is required to write a name, to chose the Fleet this ad will play on and to upload a file, Image, Audio, Video or to introduce the questions and answers for the Questionnaire. In the bottom part, it is possible to introduce a polygon by writing its points or, the easiest way, by clicking on the map symbol and drawing the polygon (Please see Figure: 4.4), this polygon will later be used to trigger the ad. If there were no polygon introduced, the ad should be played in a loop together with all other advertisements that have no polygon and are in the same exhibition.

Lastly, we can choose the duration of the ad, "Cancelar" to not create the ad or "Salvar" to save it.

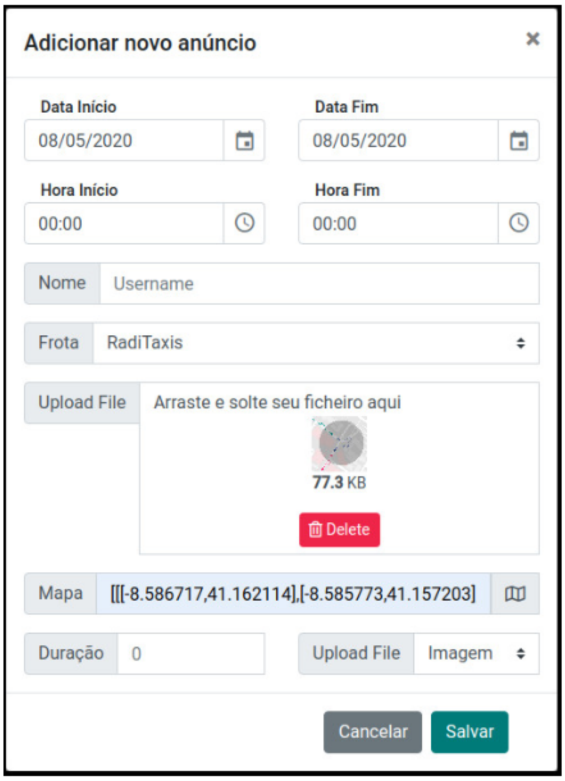

Figure 4.3: Adding new Ads in Website.

Figure 4.4: Choosing area for new Ads.

Next, we got exhibitions these are collections of ads, they can be of multiple types and are used to describe the order in which advertisements are displayed for a specific fleet. As we can see in Figure 4.5, when adding a new exhibition, similar to inserting an ad, it is possible to choose the start and end dates. We can choose a name for it, select a fleet and determine which ads we want to show. The advertisements have to be in the order we want them to appear in the mobile device. Finally, we have to press "Salvar" to save the new exhibition.

When creating ads or exhibitions with the website, all the introduced information is stored in a database. Databases are useful for storing large amounts of records efficiently, as well as providing a fast way to access them.

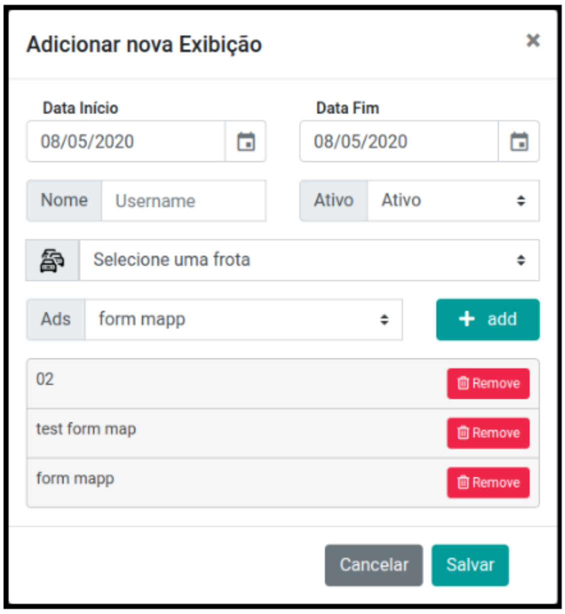

Figure 4.5: Adding new Exhibition in Website.

4.3.2 Communication Server-Database-Client

Another requirement we had was the communication between server, database and application. It was one of the most critical parts without it the app would not work.

The principal purpose of the server is to receive, send requests from and to the clients, as well as to store data on the database, it uses a RESTful API. REST, or REpresentational State Transfer, is an architectural style that makes communication between client and server easier. It uses a low amount of bandwidth and all of its calls are stateless, meaning that every HTTP request happens in complete isolation, each request is completely independent of any other.

We used Retrofit on our application as a REST client, it uses OkHttpClient as an HTTP client, OkHttpClient creates other objects, also known as Factory, it is used for sending/receiving HTTP requests/responses. We have to send/receive these requests/responses in a specific format, in our case that is JSON, it is a lightweight format for storing and transporting data [28].
To serialize/deserialize the data, Retrofit needs some sort of converter. We have decided to go with GSON, it is a Java serialization/deserialization library that converts Java Objects into JSON and JSON into Java Objects. Serialization is a method of converting an object into a stream of bytes to store it or transmit it to memory [20].

We use Retrofit to simplify the way we do HTTP calls, we can divide it into four

parts.
An interface that declares the endpoints, their HTTP type, e.g. GET, POST, PUT, etc, the callback types and the parameters needed.
An adapter, which transforms the interface into an object instance, to work with it a converter is required, in our case GSON.
Finally, a callback mechanism, Retrofit uses two different methods, one for a successful response from the server and another for a failed one. In case of a successful response, Retrofit will also have the server response.
In Figure 4.6 it is possible to see the main API functions used between our server and the client.

4.3.3 Trigger Ad in specific Location (Polygon)

Another requisite of this Thesis was to trigger advertisements in specific locations, e.g. polygons which would translate into geographical boundaries. To achieve so, we used Google Geofencing API.
Geofencing is a location-based service which uses GPS to trigger an action or notification when a mobile device enters, exits or dwells a virtual boundary set up around a geographical area [27] (Please see Figure 4.7).

The two main reasons that led us to opt for the Google API were the usefulness of the tutorials and the vast amount of information online. Every doubt, error, problem that we had with this API, with a quick search, we would have part of a solution, some times a solution, in other cases, the search would set us on the right path to reach a solution.
To create a virtual boundary set up around a geographical area, also known as geofence, it is required at least two things, a point (latitude and longitude) and a radius. These virtual boundaries and its transitions are created with the help of the GeofencingRequest class. To know when there was a transition, as the tutorial advises, we used the BroadcastReceiver class, which is a listener for geofence transitions. When a device moves within a geographic fence the BroadcastReceiver will get an update with the event, e.g., "entering the geofence" [4] and will do the necessary work for, in our case, start the specific advertisement for that geofence. Examples of advertisements can be seen in Figures 4.8.

The first problem we had with this API, was the impossibility of choosing the shape of the geofence, the only available one was a circle. In many cases a circular shape is

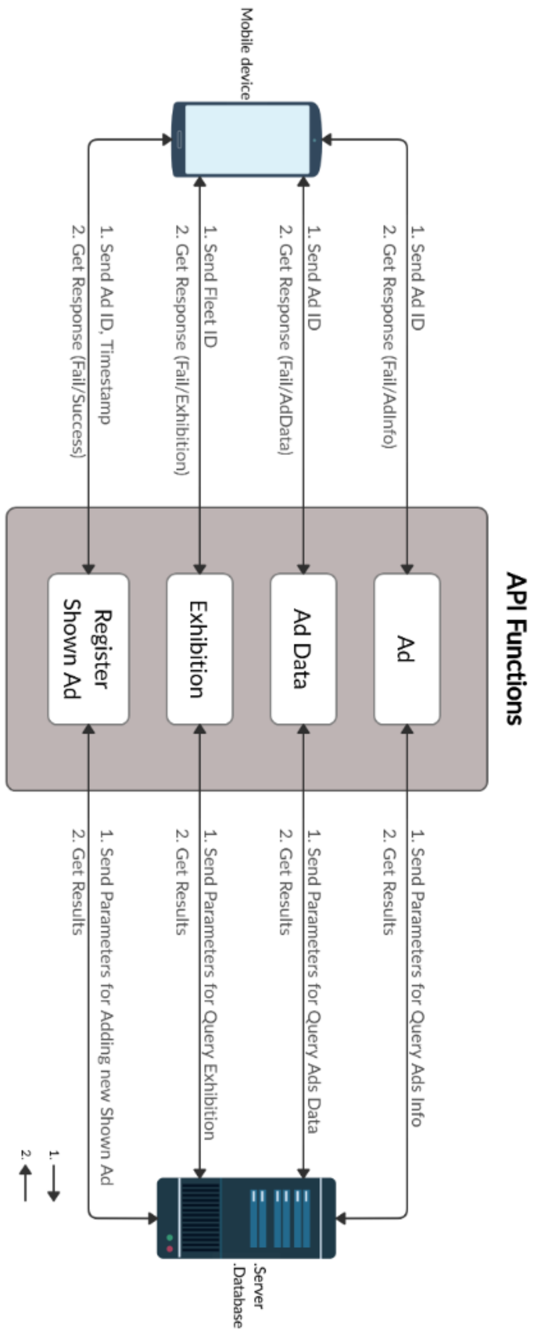

Figure 4.6: Main API functions used for the Application - Server Communication.

not the most optimal shape for an area, e.g., for a street, it would be better to use a rectangular shape. If the created areas were too narrow, the error in the GPS system would also be a problem, GPS would make it hard to know if the device location was in that tight shape.

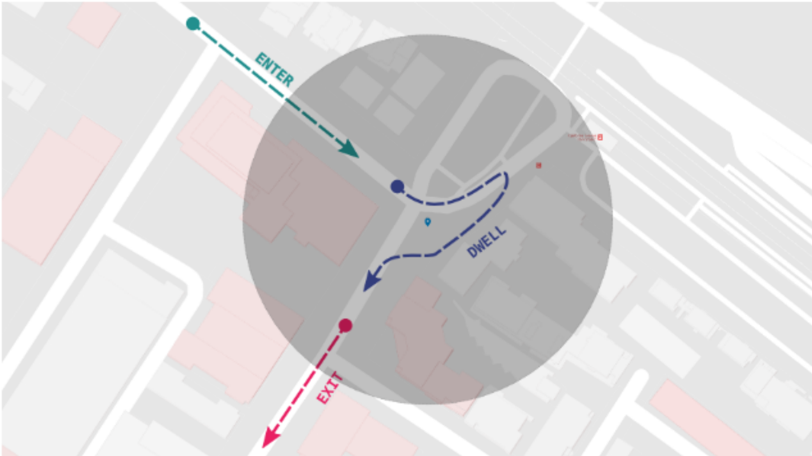

Figure 4.7: Geofencing Area with the three possible transitions, enter, exit and dwell [11].

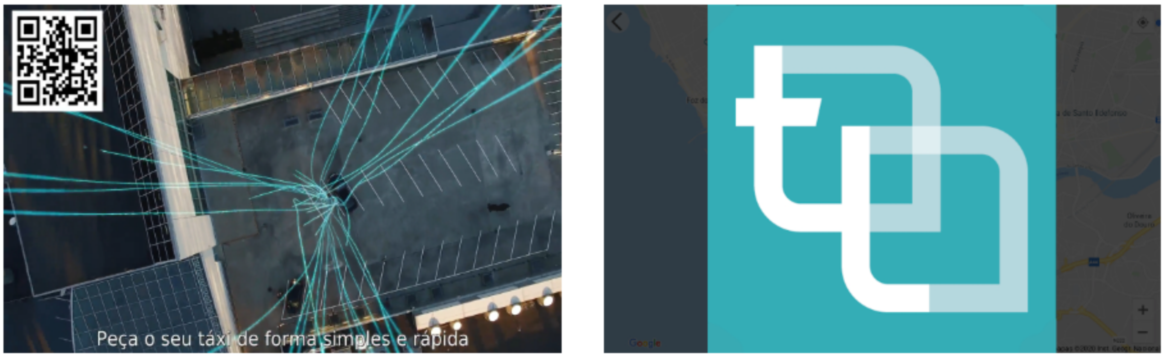

Figure 4.8: Examples of Advertisements on App screen [23]

For these reasons, we had two alternatives, to build our geofence system or develop a way to use Google API with different shapes. We opted for the second option as it was faster to append functions to an API than to create one.

Every idea we got had some things in common, for them to work, we needed a point and a radius for the Google geofence circle. Later on, we had to think about how we would implement the polygon trigger. We already decided that we would need to receive from the server a set of coordinates, which would form a polygon and we had to, in some way, represent the Google geofence circle, around the polygon, inside it or with fill it with many geofences.

Our first hypothesis was to fill the non-circular polygons with little circles creating multiple Geofences instead of one. This solution had some problems. For instance, the application would try to trigger repetitious times the same advertisement. After the first trigger, it should not show the same ad over and over, but there was a bigger problem. The Google geofence API only allows registering one hundred Geofences for each device. Depending on the algorithm we were going to use, we could waste around twenty circles only to fill one little irregular geographical area, which was a fifth of our capacity in a single geofence.

So we decided to try another way, by calculating the centre of our polygon it should be possible to draw the smallest circle around it. By summing all points and divide them by their total number we get the centre. For the radius, we have calculated the distance between our centre and any point of the polygon. However, if the polygon was irregular, the centre had to be calculated with another formula. This solution could be great, but in the meantime, we found something better.

Finally, we came upon a well-known problem, which is named "Smallest Enclosing Circle Problem". Basically, given a set of coordinates, this algorithm will calculate the smallest circle that envelops every coordinate [38]. The number of points of our polygons should always be small, less than twenty, so the time needed for any of the algorithms to run and return a centroid should also be small, under one second. This algorithm was what we were looking for, what was left was to mould the behaviour of the BroadcastReceiver to fit our problem.
At that point, we had the two things that we needed for creating a geographic fence, the centre of the circle and its radius. With these values, we can produce the smallest circular area which will envelop the polygon (Please see Figure 4.9). In colour blue, we have the circular area required for Google API and, in the colour red, we have the polygon that we use for triggering the advertisements.

When the device enters the blue area, the BroadcastReceiver will try to start the advertisement, at that point, it will have to check whether or not the device location is inside the red polygon. If it is not, the BroadcastReceiver will start an Async Task which will monitor at every X second if the device position is inside the polygon, whenever it is, it stops the Async Task and initializes the ad. If the mobile device leaves the circular geographic boundary, this Async Task should also terminate.

4.3.4 Relevant time period for the exhibition of Ads

One of the only, if not the only, requirement(s) that the taxi drivers made was(were), while there were no passengers inside the car, the mobile device or its screen should not be on. To further support this functionality, we decided to use some log files from

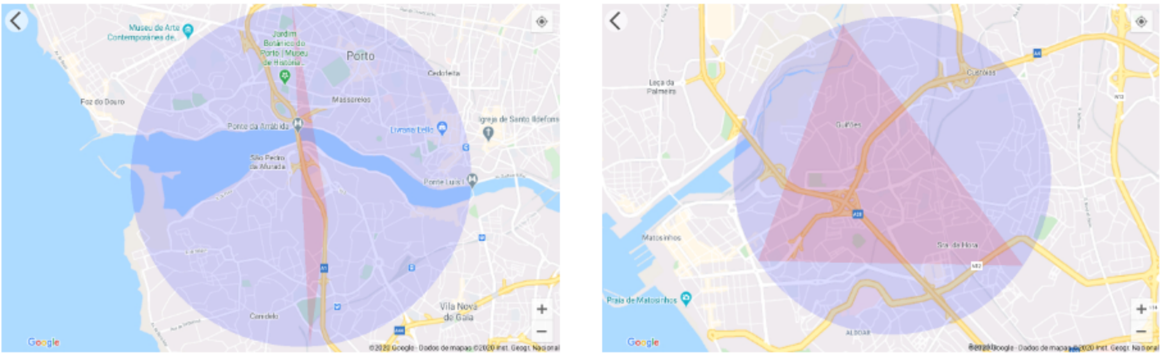

Figure 4.9: Geofence circle created from Smallest Enclosing Circle algorithm (blue) from its polygon (red)

Geolink which go by the name TDBs.

4.3.4.1 TDBs

TDBs are files that have information about every event a taxi goes through each second of the day, taxi id, event type, the time of the event, and in some cases a message that further explains what happened. TDBs files are in Binary which requires conversion to plain text, converting a month worth of data takes roughly a couple of hours, some of these files have some errors and cannot be, easily, converted. That is why we only chose to investigate six months of data, three from 2019 and the other three months from 2020. After converting the binary files to plain text, we still have to parse the new files to get relevant information.

The Charts below (Please see Figure 4.10) show the different values that taxis of a given fleet had in Portugal between the 1st of February and 31st of April before COVID-19 pandemic, 2019, and when this disease reached Portugal, in the same dates but 2020. We decided to divide these values into four states, "FREE", represented by the Blue colour, "BUSY", which is represented by the colour Orange, "TAXI STOP" with the Grey colour and, lastly, "OTHER", represented by the Yellow colour. The description of each one of these state is as follows.
The state "FREE" is whenever the taxi is without a passenger, not doing a Service and not parked in a taxi stand. Most of the time it is, probably, moving back to a taxi stand after a service.
When the taxi is doing a Service with a passenger inside the taxi, the state is defined as "BUSY".
The "TAXI STOP" state is used to describe a taxi parked at a taxi stand.

As for the last state, we have "OTHER" that represents every other possible state that a taxi goes through every day, e.g. picking up a passenger, break time, etc. These are not so important as the other three, only together they have a good percentage of the events, around 15%.

We can deduce from the charts that, overall, the amount of "FREE" and "BUSY" values has declined for every taxi id from "PRE COVID" to "COVID" chart. We sorted them in ascending order by the column "OTHER" because, in that way, we can see that "FREE" and "BUSY" are practically constant in both left-side charts, while the values of "TAXI STOP" and "OTHER" are complementing each other.
We noticed that the sum of the values "FREE" and "BUSY" in the "PRE COVID" chart is almost equal to "TAXI STOP", and in the "COVID" chart the "TAXI STOP" value is greater than that sum.
We could also verify that there was a drop in the "BUSY" value from "PRE COVID" to "COVID" charts, a decline of approximately 9% and an increase in the "TAXI STOP" value, around 12%. There was also a small decrease in "OTHER" and "FREE", of about 1% and 4%, respectively.
Everything discussed above translates into, the amount of time a taxi spends parked at a taxi stand is almost equal to the sum of all other events together. During COVID-19, the amount of time spent parked is actually higher than the sum. We can additionally infer that there was a decrease in taxi services of about 9%, and an increase in the time taxis spent parked in a taxi stand of 12%, because of the COVID-19 pandemic.

There are two ways of changing these states, through the driver app or the taximeter buttons (Please see Figures 4.14 and 4.11). First of all, The taxi driver has to start the engine of the car, when he/she does so the Bluetooth box will turn on (Please see Figure 4.13) and the driver must start the drivers app (Please see Figure 4.12).

The Bluetooth box has to be connected to the taxi (for power), to the taximeter, in order to know if it is busy or free, it does so by checking the current of the taximeter. And it also has to be connected to an emergency button, in case the taxi driver needs help and is unable to talk for any reason. In the past, in Lisbon, this emergency button would alert every other taxi driver that the driver in question required help. The Bluetooth Box, with the assistance of the Call Centers, guarantees that the taxis in the "Busy" state are not able to accept additional services. If the Central has sent a service to a taxi and the driver chooses to accept it, when he/she arrives at the client location, the taxi state will automatically change to "Busy".
Lastly, the Box has to be paired via Bluetooth with the driver app, in order to send (and receive) information about state changes.

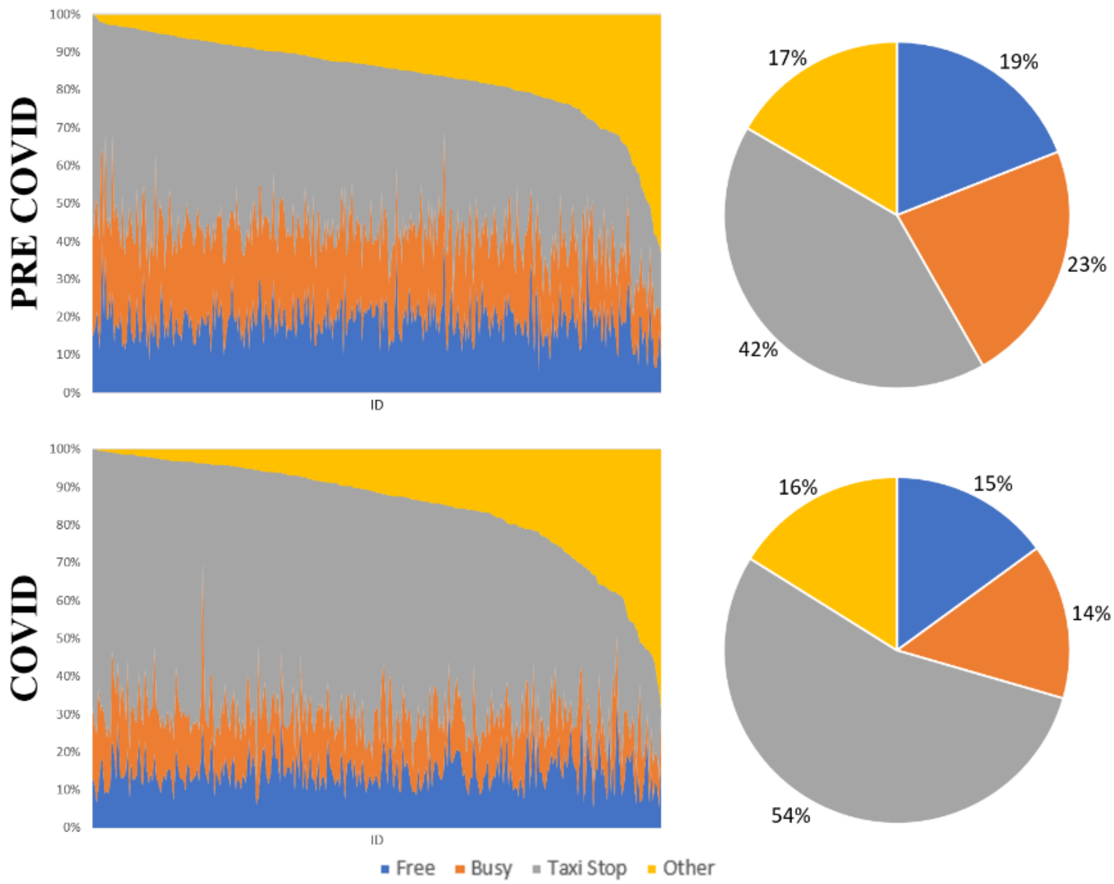

Figure 4.10: PRE COVID and COVID charts sorted by value "OTHER"

When the taxi driver starts the drivers app, it is required to log into his/her account in order to access the Figure 4.11 screen, the state of the taxi starts at "PAUSE", it is used for whenever the driver wants to take a break (Please see Figure 4.15).
The driver can click on button 1, "Livre", and the state alters to "FREE", he/she can press button 2, "Fim de Turno", to end work, to log out of the account or he/she can press button 3, "Extras", to access multiple options of the driver's app. In case the driver presses button 1, he/she can choose afterwards to click on button number 6, "Iniciar Serviço", to start a service and the state will change to "BUSY" (Please see Figure 4.16). While in this state there are two possibilities, The driver can be alone in the car or with a passenger, if a passenger is in the car, the driver should turn on the taximeter, the button 8, "Com Passageiro", should automatically get greyed out, the driver should start the trip. If for some reason he/she does not pick up a passenger, he/she can press the button 10, "X", to cancel the service and go back to the "FREE" screen and state, there is also the possibility of pressing the button 11, "P?".

In case the driver pressed the button 11 he/she will have access to all taxi stands and

Figure 4.11: Driver App Login Screen

Figure 4.12: Driver App Pause Screen

some information about them (Please see Figure 4.18), in that same page is possible to sort the taxi stands by name, button number 15, or by distance, button 16. In this screen we have the name of every taxi stand and two values for each stand, the first value translates to the number of taxis parked in that taxi stand, the other is the number of taxis that left the taxi stand with a passenger or with a service in the past fifteen minutes.

To park in a taxi stand the driver need to be in the "FREE" state and enter a taxi stand through a specific street or place, the driver application will automatically change screen and state to "TAXI STOP" (Please see Figure 4.17). In this screen the driver can start a service by pressing button 12 which will do the same as button 6, the difference is in the change of states, in this case, it will change from "TAXI STOP" to "BUSY". On the other hand, he/she can click on button 13, "Abandonar", which will make him/her lose his/her place on the taxi stand queue, changing state to "FREE", the driver can rejoin the taxi stand, going to the last position in the queue. Lastly, the driver can press button 14, "Ceder Vez", to swap his/her spot in the queue with the driver behind him/her, remaining in "TAXI STOP" state.

All these state changes are sent by the driver app to the server in multiple events,

Figure 4.13: Bluetooth Box.

Figure 4.14: Portugal Taximeter [18].

each describing the new state a taxi has. Below is a state diagram showing how these states change (Please see Figure 4.19).

4.3.4.2 The Verdict

After having the data that supports the idea of turning off the screen when there is no passenger inside the taxi, we had to implement a way of doing so. So as to achieve it, first of all, we had to develop a web socket server. This server would help us by sending relevant information to the device about the taxi. When a passenger gets inside the car, the driver and the passenger discuss the destination, after reaching an agreement, the taxi driver starts the taximeter. The driver app sends that information to the server, the server sends it to the web socket server, in its turn sends an event to the Android device with the value "CLIENT_PICKUP". This event will trigger a method that uses the class "PowerManager" and, in its turn, use "WakeLock" to force the screen to turn on. On the other hand, when the trip comes to an end, the driver turns off the taximeter, the information goes through the same process as it did before, but with a different value, in this case, the mobile device receives an event with the value "TAXIMETER_OFF". Upon receiving this event, the application will trigger a function that will use the "DevicePolicyManager", which requires application administration permissions, in order to lock the device.

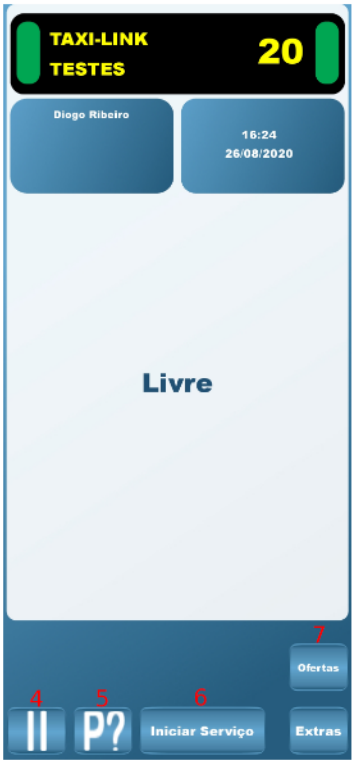

Figure 4.15: Driver App Free Screen

Figure 4.16: Driver App Busy Screen

4.3.5 Service

For our final requirement, we have Android Service. A Service is a component that is used for performing operations in the background, in our case, handle network transactions and the geofence functions.
Services are divided, basically, into two types, Background and Foreground. Background Services perform operations that are not directly noticed by the user. As for Foreground Services, they are used to perform actions that are noticeable to the user, for example, when the mobile device enters a specific geographic area, the Service will help to display the advertisement.
when using a Foreground Service a notification must be displayed at all times, so users know the application is running. Unlike Background Services, if the device is running low on memory Foreground Services will not be killed.

We decided to go with the Foreground Service, mainly because our app had to be running all day, had to send and receive data asynchronously and had to do this regardless of the state of the phone, with the phone locked or unlocked. For example, the only way to guarantee that the mobile device will receive from the WebSocket

Figure 4.17: Driver App Parked in Taxi Stand Screen

Figure 4.18: Driver App Taxi Stand Info Screen

server the event "CLIENT_PICKUP" while locked, to unlock the device. Is by having a Service that does not get killed because of a memory shortage.

4.4 Advertisement delivery/exhibition criteria

In this section, we will explain how we decided to allocate the advertisements. We decided that a taxi that belongs to a given fleet should not have a different set of ads than any other within that fleet. It would be better for the same fleet to have their specific advertisements, since the taxis from one fleet are all from the same geographic area and will, most likely, travel to the same places. Each taxi having personalised ads would not be a good idea, because the management of said ads would not be done by the taxi drivers, but by the owners of the fleets. It is easier to manage their ads globally instead of going through each taxi. It would be better if the personalised ads are triggered by location, making every taxi in a fleet capable of activating them by travelling to those specific locations and thus discarding the need of managing ads for every car.

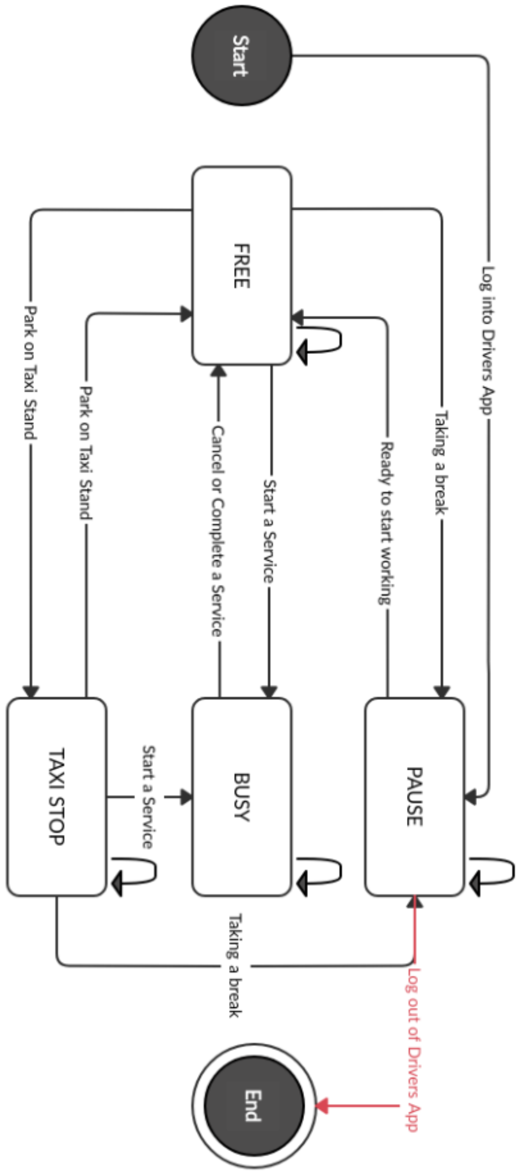

Figure 4.19: Taxi State Diagram.

First of all, for a fleet to have their ads, it is necessary to add the advertisements on the website, create an exhibition and chose the order to display the ads.
When adding advertisements to a fleet, it is possible to introduce a geographic area. If that field is filled, the display of that ad will only occur in that specific area(s). In the other case, the ads will be displayed in a loop, depending on the order chosen when creating the exhibition. There can be multiple exhibitions per fleet, for example, one can have ads that play at night, the other displays their advertisements during the day.

4.4.1 Taxi Geographical Context

One of our main objectives was to display advertisements based on the taxi or mobile device location. Like explained in section 4.3.3, we used Google Geofencing API to create these geographical boundaries that can be triggered by the taxi location when it goes through those boundaries. In this section, we will discuss why we use the taxi geographical context to display ads.
By using the current location of a taxi, we can display certain advertisements that are targeted to that specific location. For example, a shoe store that wants to advertise their wares or give exclusive promotions to people who travel by taxi, we can show those ads every time the device installed in the taxis intercepts the geographic boundary created for that store or any of their stores. Like it was discussed in the section above, the taxis from a given fleet share the same advertisements, this way multiple taxis will deliver the same ad when going through the same Geofences, delivering the same impression to several different people.

4.5 Advertisement with user interaction

In the beginning, we wanted to have at least one ad that would require user interaction, but in the end, we did not manage to have something like it, the only ads that are interactive are the Questionnaires/Quiz. We thought of ways to implement interactive ads but did not manage to finish developing them. This section will continue in the last Chapter, section Future Work 6.2.

Chapter 5

Spatio-Temporal Analysis of Exterior-Oriented Advertising

In this chapter, we describe the Spatio-temporal analysis that was developed in the context of the exterior-oriented advertising installed in taxis. Due to the pandemic, the installation of in-car displays faced some difficulties, namely because of the sanitary separator that was installed on the majority of the fleet. We thus decided to centre our evaluation on the Spatio-temporal impact of the ads placed on banners installed on the taxis.

5.1 Vinyl panels on taxi doors

As explained previously, taxis are often used to display banners that promote several products and services. Several companies have specialized in producing and applying such banners to taxis, covering different parts of the vehicle. In Portugal, the rooftop supports have not become popular and the most common type of banners are applied based on vinyl panels. Figures 5.1, 5.2 and 5.3 illustrates different types of vinyl panels covering different percentages of the car exterior, as listed on the website of the taxi advertising company.

Figure 5.1: Side doors vinyl panel [22].

Figure 5.2: Full body vynil panel [22].

Figure 5.3: Window vynil ad [22].

5.1.1 The Taxi-Link "Vamos juntos" banner

The Taxi-Link passenger APP was launched at the beginning of 2020 and several marketing campaigns are being launched to promote its download. One of these campaigns is based on the Taxi-Link banner with its slogan "Vamos juntos" ("we go together"), illustrated in Fig. 5.5.

We decided to use this campaign to define a Spatio-temporal framework to evaluate the impact and extension of this campaign. We also use historical data from taxis to support an effective distribution of the banners in order to maximize the potential of the campaign in terms of audience.

Table 5.1 lists the number of banners that were installed by municipality, as of September 29th.

Municipality	Count
Porto	53
Gaia	30
Lisboa	190
Amadora	16
Sintra	6
Oeiras	31

Table 5.1: Number of banners installed by Municipality.

5.2 Spatio-temporal Analysis of the Taxi-Link Banner

As said before in this thesis, there are some ways to advertise with taxis, in this chapter we are going to focus on exterior-oriented ads, for example, Taxi Tops and Stickers (Please see Figures 5.4 and 5.5).
The main goal in this chapter is to try to prove that taxis are a suitable medium for exterior-oriented advertisements. To do so, we are going to calculate the geographical area they cover, giving a good way of measuring the number of people that can see the ads. By doing so, advertisers can better understand if they should invest in exterior-oriented advertisements for taxis.

Figure 5.4: Snickers Taxi top Advertisement [24]

Figure 5.5: Taxi-Link "Vamos juntos" side banner Advertisement

5.2.1 Generating data for potential viewers

People on the streets are the potential viewers of taxi-door-based banners. We need an approximation of the number of people on the streets and their location. Since we have data about where people get a taxi, both in terms of the temporal and spatial dimensions, we decided to use this data to create synthetic datasets about potential viewers of our ads.

For each municipality where the Taxi-Link banners were deployed, we aggregated several days from our datasets to generate a single day with the synthetic location and timestamp for each viewer. We used the populations of each municipality to derive the number of days that were necessary to be aggregated in terms of taxi requests. Table 5.2 lists for each municipality the population and the number of days that were aggregated to generate a similar population in terms of magnitude. Figures 5.6 and 5.7 show the spatial distribution of these people at 12 p.m.

Municipality	Services	Time (in days)
Porto	243572	274
Lisbon	401140	444

Table 5.2: Amount of services used to represent the population of the municipality and the number of days it was required to agglomerate the services.

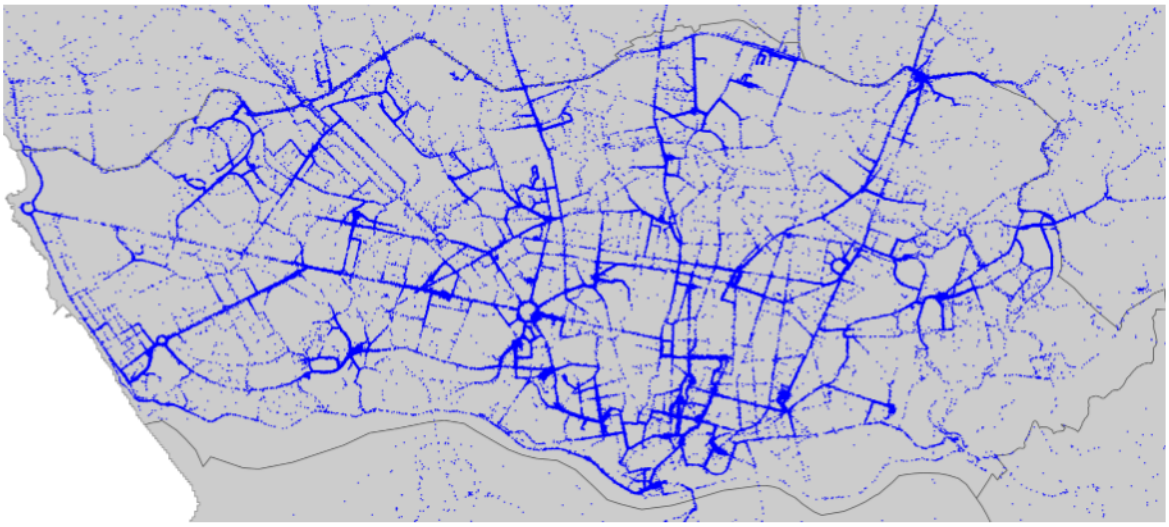

Figure 5.6: Spatial distribution of 243572 services (in blue) throughout Porto city during ten months, in order to get around the same population as the municipality.

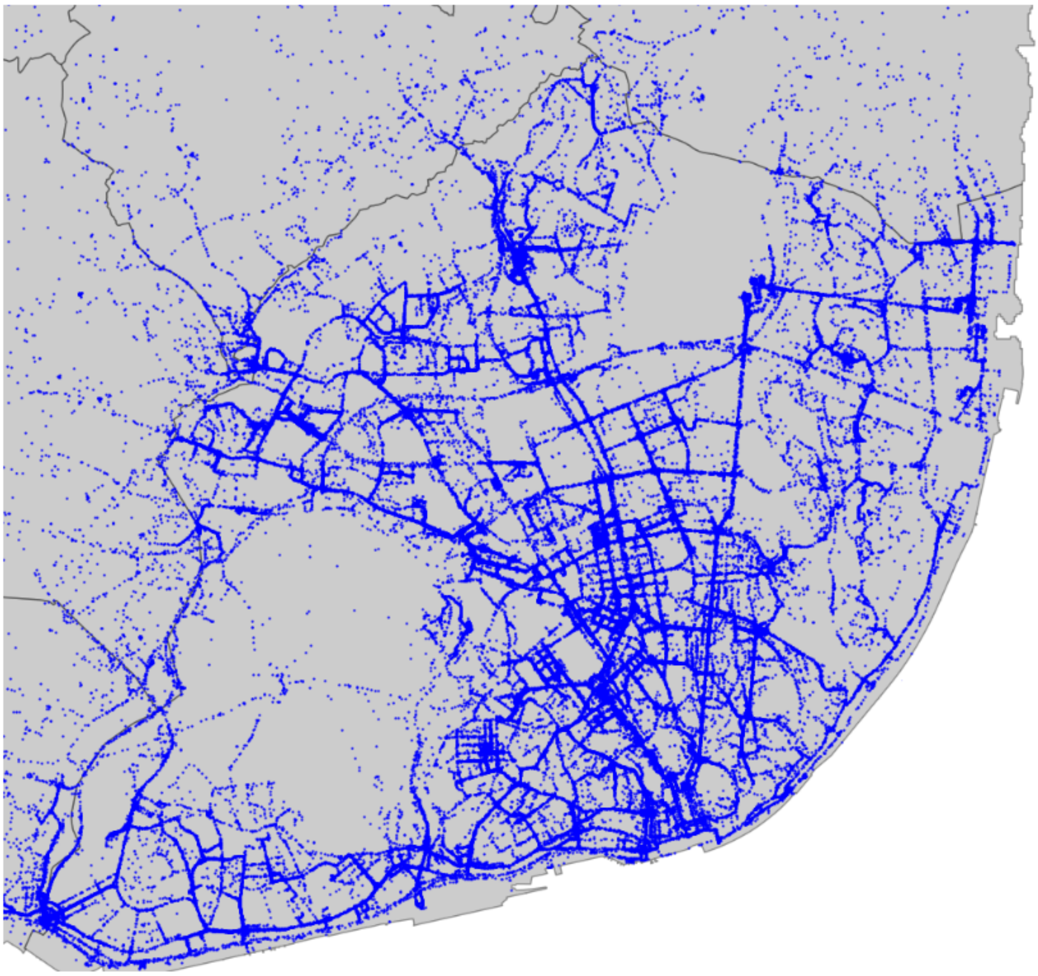

Figure 5.7: Spatial distribution of 401140 services (in blue) throughout Lisbon city with a year and two months span, in order to get around the same population as the municipality.

5.3 Main metrics used in Exterior-Oriented Advertising

One of the metrics we wanted to use for studying exterior-oriented advertisement, was the area that taxis can get covered in a certain period of time. Another metric that we used was combining the data we got from the coverage areas with the services from Table 5.2.

To get all the required information, we had to write some Python code. We knew that eventually, it would be required to use Geospatial data and also to represent it. To do so, we got a shapefile with Portugal Geospatial information [17] and used

GeoPandas to draw it, GeoPandas enables users to easily do Geospatial operations in python without requiring a spatial database [12].

All our geographic data, even the data referred in section 5.2.1, with the exception of the actual map, was calculated with the aid of the TDBs files, using the same methods as in Section 4.3.4.1 with minor changes. For example, in this chapter, we do not need to check the state changes, the only lines that we want from the TDBs are the ones with the value "STATUS" in it. These lines have five values that we require, taxi id, timestamp, latitude, longitude and service id, these five values make it possible to create the essential information that we needed.

To represent the position of taxis, also known as nodes, or their connections, edges, we used Matplotlib. To not represent more map than needed, it was necessary to zoom in to the city we wanted to study.
After these requirements, we only needed a way to differentiate the nodes and their edges from the map. We have done so with the help of a library named Pillow, which has a module named Image that can count the number of pixels for each colour in every picture, one picture at a time (Please see Table 5.3).

For the second metric, we had to use a database that had spacial and geographic features, in order to easily and quickly do queries that could count how many potential customers a taxi passes by on a day of work. We chose PostgreSQL with PostGIS as it was a relational database that we had already used in the past. PostGIS has spatial and geographic objects to cover all our needs. After creating two tables, one for the services and another for taxi locations, we had to insert all the data to them. For the services table, we have an identifier and the points (latitude and longitude) of each service, in the other table we saved the taxi ids and the locations each taxi went through, these locations are the same as the nodes we mentioned above.
To obtain the data we have done a query that uses both tables and counts how many services are within a 100-meter radius of each taxi location, we grouped the result by taxi id. For every taxi id, we have removed all nodes that were too close to each other, within a 100-meter radius. So when the query is calculating how many people are within the taxi radius, it does not count the same people more than once.

5.4 Results

In table 5.3 the first two values represent nodes, created from analysing the TDBs files, we represented each node with a 100-meter radius to simulate the distance at which people can see the taxi and the ad. The next value is the representation of the area created by the connections between nodes, edges. The fourth value represents the area that was not covered by the taxis, also known as "free area". We can translate the last number to the region that the taxi stands cover, where taxis are parked. These stands are strategically located areas with great affluence of people and good visibility for these reasons we decided to give a bigger radius of visibility than other nodes, 200 meters.

Colour	Pixel Count	Proportion
[0 0 254]	2163	3.91%
[0 0 255]	15004	27.14%
[117 161 191]	15144	27.39%
[204 204 204]	16290	29.46%
[255 0 0]	6685	12.09%

Table 5.3: One day coverage area data from ten taxis with Taxi-Link stickers.

With only ten taxis with Taxi-Link Sticker in Porto, we have a coverage area of about 75.33%. This value is the result of summing the first three values with the last value, where 22.65% are taxi stands. With the coverage area, we can calculate, how many people may have seen the advertisement, for example, in Porto, according to 2011 Census [19], there are, roughly, 237000 people living there. Assuming that anyone in a radius of 100 meters of the taxi can see the ad, then we have about 177750 people, who potentially saw the ad, in a single day, with only ten taxis with the Taxi-Link side banner.

In a different perspective, we got the coverage area of all taxis with Taxi-Link side banner per hour in a day (Please see Figure 5.8). We can infer from the graph analysis that the best hours in terms of coverage area are between 6 a.m. and 8 a.m., between 10 a.m. and 11 a.m., between 1 p.m. and 2 p.m. and at 2 a.m. In these cases, the coverage area is always above 50%, its peak, the maximum value, is at 1 p.m and is equal to 64.2%.
The worst hours are at 6 p.m., between 9 p.m. and 11 p.m. The lowest value is 11.5% and it is registered at 10 p.m.

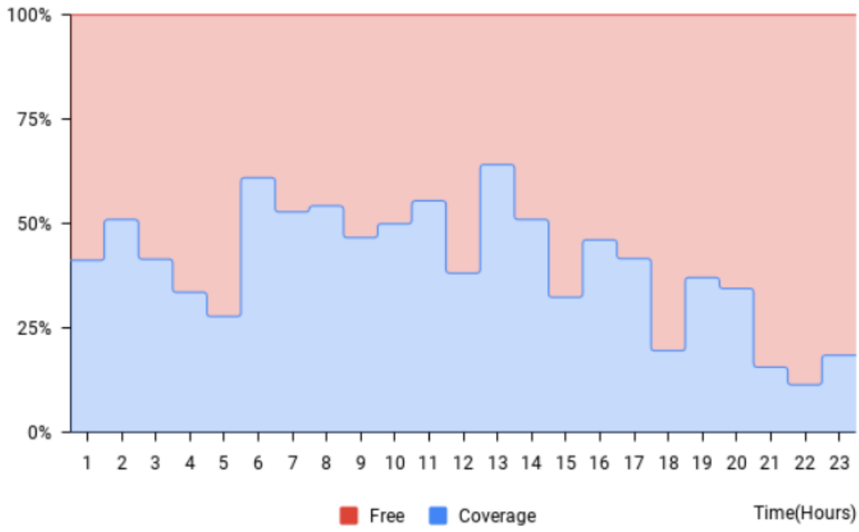

Figure 5.8: Comparison between coverage area and free area for each hour in a day in Porto.

Another idea we had, was to study which taxis would be better for exterior-oriented advertising, that is, for each vehicle, we had to investigate their coverage area, the bigger the region, the more people should see the ad. So as to achieve this idea, we had to create a single image for each taxi id from Porto and Lisbon fleets, using the methods already described earlier in this Chapter. Next, we calculate the coverage and free area, put them on a list alongside the taxi id and sort it by coverage area. This way we know, for example, one hundred taxis that have the most significant coverage area in Porto and Lisbon (Please see Tables 5.4 and 5.5). In case of Porto the taxi with the highest coverage area is the taxi 20000304 with 22.55% of coverage area, as for Lisbon we have the car with id 20090469 and its coverage area is 18.22%.

In Figures 5.9 and 5.10 at the left we got the taxis with the lowest coverage area, on the right, we got the taxis with the highest coverage area, in Porto and Lisbon, respectively. To compare the coverage area values we can check them in Tables 5.4 and 5.5. We could ascertain from these Figures and Tables that the safest bet for exterior-oriented advertising is the highest coverage area, in any of the two fleets, but it is required further investigation. By saying its the safest bet, we mean that in the same period of time taxis with a larger coverage area should reach a larger amount of people. But this data can be misleading, one taxi can have a big coverage area, but that area can be in regions with few people. It is something we will discuss in the following paragraphs.

Taxi ID	Coverage Area	Free Area
20000304	22.55%	77.45%
20000657	20.80%	79.20%
20000015	20.68%	79.32%
20000239	20.46%	79.54%
20000167	18.94%	81.06%
...	...	...
20000902	1.16%	98.84%
20000463	0.95%	99.05%
20000392	0.64%	99.36%
20000909	0.46%	99.54%
20000453	0.30%	99.70%

Table 5.4: Coverage area and Free area of Porto.

Taxi ID	Coverage Area	Free Area
20090469	18.22%	81.78%
20091958	17.82%	82.18%
20091637	16.52%	83.48%
20090665	16.27%	83.73%
20093125	16.19%	83.81%
...	...	...
20090521	0.49%	99.51%
20091691	0.47%	99.53%
20091468	0.43%	99.57%
20091145	0.41%	99.59%
20093005	0.29%	99.71%

Table 5.5: Coverage area and Free area of Lisbon.

In Tables 5.6 and 5.7 we got a table for Porto city and another for Lisbon city, respectively. Both tables have three values, Taxi ID, People and Coverage Area. The first value is the identifier of each taxi, the second one is the amount of services/people the taxi passed nearby, the third is the coverage area of that taxi. The tables are ordered descendingly by the second column, these values are taken from section 5.2. By analyzing them, we can tell that these results do not go accordingly to what we first thought.

Figure 5.9: Smallest and largest coverage area of Porto.

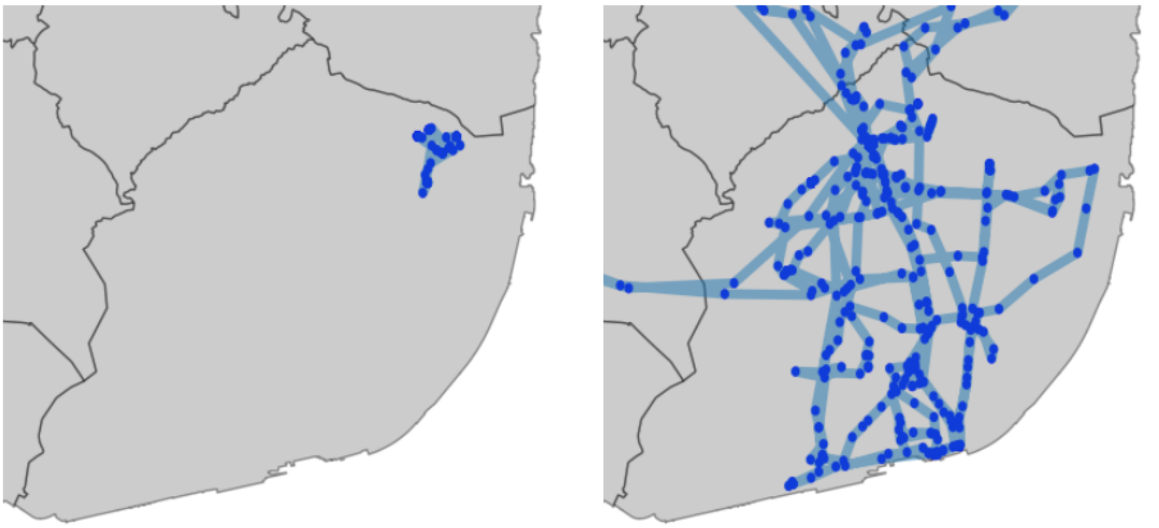

Figure 5.10: Smallest and largest coverage area of Lisbon.

Having a big coverage area is not always the most beneficial, a big coverage area does not mean that the region where the taxi goes through has a large number of people living in, the greater the number of people who sees the ad, the better. The second thought seems to be closer to the truth. By observing Figures 5.7 and 5.6, we can see that there are areas with nearly zero people. If the coverage area matches these regions, the value of the coverage area might be high, but the number of people who probably saw the taxi or the ad may not be that high.

Taxi ID	Number of People	Coverage Area
20000356	118030	17.31%
20000226	114265	18.56%
20000455	112103	18.60%
20000166	111059	11.87%
20000337	107380	16.48%
...	...	...
20000902	3728	1.16%
20000046	2237	1.76%
20000140	1653	1.80%
20000392	777	0.64%
20000453	76	0.30%

Table 5.6: Comparison between the number of people that taxis pass by with their coverage area in the Porto fleet.

Taxi ID	Number of People	Coverage Area
20093182	174192	13.83%
20092180	165564	15.60%
20090574	161840	8.96%
20090665	158314	16.27%
20091635	156650	10.21%
...	...	...
20092674	1220	0.93%
20092618	1207	2.77%
20091298	1026	1.23%
20091741	784	1.38%
20093005	715	0.29%

Table 5.7: Comparison between the number of people that taxis pass by with their coverage area in the Lisbon fleet.

Chapter 6

Conclusions and Future work

6.1 Conclusions

The development of an advertising platform for mobile devices was our principal goal. It was successful to some extent, we could not finish everything we wanted, for example, we did not manage to include interactive ads into our pool of ads type, also we did not gather real data with our app. All these unfinished tasks are set to be done in future work.

We have a functional advertising platform which can deliver different kinds of ads to a mobile device application, these advertisements can be triggered by geographic boundaries. Plus, we have a quick and easy way to add new ads and, lastly, the app can automatically update its data.

We can say that taxis are a perfectly splendid medium for exterior-oriented advertising, since they travel to numerous different places during every day, making the advertisements reach a lot of different people. Even if the taxis are parked in a taxi stand, they can be seen by many possible customers, because the taxi stands are in areas with great visibility and affluence of people. We can also affirm that taxis with a big coverage area are not always the ones that travel near areas with the highest number of people. The "quality" of the coverage area is not only related to its value, but it is also associated with the actual geographic area where the coverage area is located. E.g. the central area of a city versus the non-central region, even if the area value of both is the same, the number of people living in each region would not be the same.

When choosing which taxis to pick for exterior-oriented advertising, it is better to rely on multiple data rather than only the coverage area.

6.2 Future work

As said before, in section 5.2, COVID-19 took a toll on our project, it was not possible to install a mobile device in a taxi. Mainly due to the sanitary separator that was installed on the majority of the fleet. We also could not gather pertinent data with our application, so that is the first objective we want to tackle in the future. Install a mobile device in a taxi to see how the application holds with people using it for a continuous-time and to check for any hidden bugs. Afterwards, use that data for further improvement of the system.

We also wanted to have interactive advertising, we knew it would be a plus to our application, but in the end, we did not manage to make it. For sure it will be a feature to add in the future, something like a puzzle, cutting an image and scattering it randomly in the screen, which would give a reward to the customer if the puzzle was completed, for example, a coupon code.
We gave little thought about the application design, but for a finished product, it is a critical step, for the app to be appealing and intuitive so that people feel compelled to try it and not ignore it. The design will certainly be something to think about in the future.
One feature we also want to add in the future is to pair the mobile device installed on the taxi with the client application Taxi-Link. This feature could help with payment, could be used for seeing a map with the current location and the destination pin on the tablet, current ETA, estimated time of arrival, etc.
Overall, we want to add new features, give the app a good design and install mobile devices with the app inside some taxis to gather data for further improvement.

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