

Acknowledgments

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Resumo

O futebol é um dos desportos mais populares no mundo, criando negócios de muitos milhões de euros. Os fãs seguem as suas equipas incondicionalmente, e é nos dias de jogo que a emotividade atinge o seu máximo. A sua relação emocional com os clubes torna-os num alvo apetecível para as marcas associadas ao desporto, promovendo a criação de serviços e soluções neste mercado. A exploração de soluções inovadoras que integrem a Realidade Aumentada e a Internet das Coisas permitirá aos clubes criar novas experiências para os adeptos, sendo também uma oportunidade para que os patrocinadores cheguem ao seu público alvo. Este projecto pretende desenvolver uma prova de conceito que tire partido do contexto emocional dos fãs e das tendências tecnológicas, com o objectivo de promover o consumo de produtos e serviços dos patrocinadores associados ao clube. Foi desenvolvido um protótipo que utiliza a Internet das Coisas em conjunto com a Realidade Aumentada para oferecer uma nova experiência no estádio aos fãs. O protótipo desenvolvido inclui um jogo para smart phone, para que os adeptos se entretendam durante a partida, e um sistema de backend para que os patrocinadores cheguem até ao seu público alvo. No jogo, a Realidade Aumentada é utilizada para criar as personagens, o cenário e o evento social, permitindo que o adepto jogue num ambiente imersivo e que tire uma foto com uma personagem virtual, enquanto que a Internet das Coisas é utilizada para fornecer informação de contexto do estádio, tal como ruído e temperatura, que influenciando o nível de dificuldade do jogo.

Palavras-Chave

Futebol, Interactividade, Internet das coisas, Jogos, Realidade Aumentada, Unity, Usabilidade

Abstract

Soccer is one of the most popular sports in the world, generating multi-million dollar businesses. The teams are followed by passionate fans, with a surge of enthusiasm on game days. The fans' emotional attachment to the sport makes them an obvious prey to sports-related marketing initiatives. The integration of Augmented Reality and Internet of Things enables the sport entities to provide more immersive experiences to their fans and create an opportunity to the team sponsors to reach their targets on their personal smart phones. This project aims to develop a proof of concept to potentiate the fans' engagement by taking advantage of new technological trends, with the goal of promoting the consumption of products and services of the club associated sponsors. A prototype of a service has been developed using the Internet of Things and Augmented Reality technologies, providing fans with an enhanced stadium experience. It encompasses a mobile game to keep adepts entertained during the event's idle times and also the ability to provide advertisers with a service allowing them to promptly reach their audience targets. In the mobile game, Augmented Reality is used to build the characters, the game scenario, and a social feature, enabling fans to play in an immersive environment and take photos with a virtual character; while Internet of Things is used to provide sensor information related with the stadium environment, such as noise and temperature, that will influence the game difficulty level.

Keywords

Augmented Reality, Gaming, Interactivity, Internet of Things, Soccer, Unity, Usability

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Acronyms

ACID Atomicity, Consistency, Isolation, Durability

API Application Programming Interface

AR Augmented Reality

DMZ Demilitarized Zone

GPS Global Position System

HTTP Hypertext Transfer Protocol

IoT Internet of Things

JSON JavaScript Object Notation

MSc Master of Science

MVP minimum viable product

NBA National Basketball Association

OS Operating System

REST Representational State Transfer

SDK Software Development Kit

SLA Service Level Agreement

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Chapter 1

Introduction

Context

The internship is the final course of the Master's Degree in Informatics Engineering from department of informatics engineering of the University of Coimbra.

This internship was done in a business environment framed by an existing collaboration between University of Coimbra and Altice Labs, the research and development company of Altice Group.

As referred in [1], Altice Labs is a company that develops products and services for several markets around the world and invests on research, innovation and development as part of its sustained technological leadership strategy. Altice Labs mission is to support its clients by building technological innovation and creating added value for them.

Altice Labs expects Augmented Reality (AR) and Internet of Things (IoT) technologies to impact its business in the near future. In order to become better prepared for next trends, Altice Labs proposed the Master of Science (MSc) project to better understand the potential of these technologies and the possible impact on its operations.

Motivation

Technological evolution has fostered the transformation of cell phones into pocket computers. Smart phones already have powerful computational capacity, different interfaces to connect over heterogeneous networks and a growing number of sensors and cameras [2]. The motivation of this project was to apply AR and IoT technologies to mobile devices in order to build an innovative application with a high business potential.

Altice Labs wants to diversify their business solutions portfolio gaining other clients besides Telcos. IoT, AR and sports [3] emerge as an opportunity area to be explored. As so, in the beginning of this internship there was interest in combining funs entertainment during the game with the possibility of targeted marketing actions. Choosing soccer was an obvious option: on one hand it is the king of the sports in Portugal and on the other Altice is the official sponsor of the main Portuguese soccer teams.

From an academic perspective, this project made it possible to contact with new technologies, which are not taught in the university, applied in a business environment, following the best practices on system's processes application and services development.

Objectives

This project aims at using IoT and AR in a prototype system targeting sporting events in order to entertain fans during idle periods and to enable customized targeted advertizing. The detailed objectives are:

1. To develop a **game application** prototype (**SoccAR**) to entertain fans during idle periods in soccer matches.
 - Fans of different teams will compete with each other trying to score as many goals as possible in a penalty shootout. The game uses AR models in the character construction and stadium IoT information in the dynamic definition of the ball trajectory.
2. To develop **marketing functionalities** allowing fans to attend and participate in special events promoted by advertisers.
 - This project allows creating special events where fans can take, for example, photos with virtual soccer players at places of interest. The game characters can be “dressed” by sponsors and the game scenario can have banners advertising products and services.
3. To develop a **backend support system** prototype to manage all the system.
 - The backend system collects user, sensor and game information and delivers responsive output according to the service logic.

Thesis Organization

The document is organized in six different chapters:

- Introduction - This own chapter that presents the context, motivation and objectives of the work.
- State of the art - Provides an insight about IoT and AR technologies and related platforms.
- Scenario Design & Requirements – Describes the usage scenario, details the technical requirements and presents the mockup of the application.
- System Architecture & Implementation – Describes the system architecture and implementation.
- System Tests & Evaluation – Specifies the key tests and presents the results obtained.
- Conclusion - Summarizes the main conclusions and next steps to be taken.

Chapter 2

State of the Art

2.1 Internet of Things

There are several definitions for IoT, but one of the most used is based on the concept of having devices connected to the Internet, able to measure and to actuate on almost anything. IoT is a step forward in merging the physical and virtual worlds, leveraging the creation of new services. The materialization of this new reality presupposes the dissemination of sensors and actuators, with communication capabilities, capable of perceiving and acting in the surrounding environment. Innovative logics can take advantage of the amount of available data to create new business offerings.

This new world of possibilities is growing and the number of devices connected to the Internet is already higher than the number of people in the planet [4]. All forecasts point to a strong growth in the number of IoT devices around the world [4]. The integration of these devices into the most diverse systems will allow access to information from different environments, allowing almost real-time monitoring and control based on informed decision-making, enabling costs reduction and processes optimization.

IoT is now the foundation of a new industry that will have a worldwide impact. According to McKinsey [5], “IoT has a total potential economic impact of \$3.9 (3.18243€) trillion to \$11.1 (9.05782€) trillion a year by 2025”, thus representing about 11 percent of the world’s economy. IoT will cross all sectors of activity in the path to a connected society, including health and well-being, home automation, smart city, mobility, industry 4.0, as well as the entire environmental and sustainability component.

2.2 Augmented Reality

AR is the technology that mixes the real with the digital worlds. AR technology enables new levels of experience through the addition of overlapping layers to the captured image [7].

According to [6], a mobile application needs to:

- Combine real and virtual objects in a real environment.
- Be interactive in real time.
- Register and align real and virtual objects with each other.
- Run or display the augmented view on a mobile device.

The evolution of smart phones facilitates innovation also in the creation of augmented reality applications. A research conducted by [8] stated that the mobile augmented reality market is expected to be worth nearly \$80 (68.57€) Billion by 2022. This growth is related with the high influence that smart phones and tablets are having in markets where these gadgets were not common. These gadgets allow a portable and quick access to augmented reality experiences and they can provide new approaches or experiences to the business [9].

In fact, AR is already applied to several areas like entertainment and advertisement, tourism, education and training, geometry modeling, scene construction, assembly and maintenance.

2.3 Gamification

Games always had and have a major influence in our society. They are a transversal phenomenon that affects people of different ages, and it could be a simple cards game with friends or something more complex and competitive like eSports.

Despite video games being commonly seen as a very bad habit mostly for children, there are some studies that shows that playing videos games has some benefits like improving decision making, fast reaction, vision and hand-eye coordination [10].

One example is described in [11], where it is stated that the surgeons that play regularly video games (3 hours/week) make 37% fewer errors and work 27% faster in laparoscopic surgery, which requires deft use of a joystick and a tiny camera, than the ones who do not play [10]. On the other hand, the game addiction is associated with interpersonal relation difficulties as addicts use video as an alternative to real relationships, where they have the feeling to be more included [12]. On video games addicted teenagers, it is also associated poor effort in school, irregular sleep habits, bad eating habits and they have a greater probability to have depressions and anxiety problems [13].

With the advances in technology, a person daily tasks and actions in real-life can be a part of a game [14]. This is called Gamification. As said in [13], gamification is *“the term given to the use of game design elements outside of games themselves.”*

The gamification concept is already implemented and explored in several areas such as medicine, education, automotive industry, airline industry, sustainability and military, among others. All of them already use video games to prepare and/or evaluate people. US Army already has a \$50M (€40,38M) budget for a video-game unit to develop games [10].

As sensors become more affordable and propagate into our life, it is possible to use this information to provide a realistic impact in the game the user is playing with. This new way of live capturing data brings in many scenarios and opportunities where the user real-life actions come into the virtual game as they are playing [14].

A common set of examples of applications that use gamification is, for instance, tracking applications that allow the user to share their personal achievements (km's traveled, number of steps) or applications that let the user evaluate or be evaluated on some social platform (ex.: tripAdvisor, Uber, Samsung Health, Nike+). The use of game principles creates an engagement between the user and the service increasing an overall enjoyment leading to a better user experience and can even motivate users or players towards a certain behavior change [15].

Another gamification example can be the RecycleBank [16] that was created to encourage people to recycle more and reduce trash by awarding points for recycling in order to save environmental resources. The points earned are redeemable for actual goods at some stores [17].

2.4 Related Applications

Since these technologies can be applied to several areas, next it is presented some successful use cases.

Pepsi Campaign

In 2014, Pepsi [18] created an AR campaign in a bus shelter in London (See Figure: 2.1). This campaign replaced a window in a bus shelter by a TV screen filming the other side of the bus shelter but creating the illusion of simply being an ordinary window. While people were waiting for the bus, the "window" started showing unbelievable scenarios, like a meteorite crashing into the window or a tiger going towards the bus shelter, offering implausible effects. This unique experience generated several reactions, but it was common to watch people get scared and flee the place. This video has almost 8 millions of visualizations on YouTube [19] and it was a very successful campaign [20].



Figure 2.1 - Pepsi Youtube Video Screenshot [21]

IKEA Places application

IKEA [22] increased their clients experience with an app that allows them to visualize IKEA furniture at their own houses and see how it fits. This is possible through AR technology that scans the room and displays the furniture with the real measures with an accuracy of 98% [23]. With this new approach, the clients can have an almost real experience before buying any furniture, seeing if it matches the color and the style of the room (See Figure: 2.2).



Figure 2.2 - IKEA app Screenshot [24]

Pokémon Go

With millions of downloads, Pokémon Go was the first AR game with global success [25]. Pokémon Go was developed by Niantic, which teamed up with Nintendo (owner of

Pokémon's intellectual property), being the recreation of the 90's hit game *Pokémon*, very popular amongst the younger demography. But now, instead of being played on a Gameboy, it is played in the real world using a smart phone and taking advantage of its camera and Global Position System (GPS) location (see Figure 2.3) to provide an AR experience.

To find Pokémons, the player just needs to walk around. When the player is close enough, the Pokémon will show up on the user screen. To catch them all, the player just needs to tap the PokéBall and throw it to the Pokémon. Typically, Pokémons are seen more frequently near public places where the user needs to go to collect game items (PokéStops).

Pokémon Go also has Gyms where the players can join one team (Red, Yellow or Blue) and battle for the gym against the gym owner. These Gyms are located in some places in the world being controlled by a specific team. Members of that team can evolve their Pokémon's there. The other teams need to fight the Pokémon that is guarding to take over the place. The Pokémon standing guard is not from a single player but every one of the team can evolve it when they train their own Pokémon's inside of that gym.

The adaptation of the game to the new technology was the perfect recipe to release a tremendous successful game [26]. However, after the initial boom, Pokémon Go decreased its popularity and the number of active users. The main reason was the disinvestment on updating the game with new battles forms and new features [27].

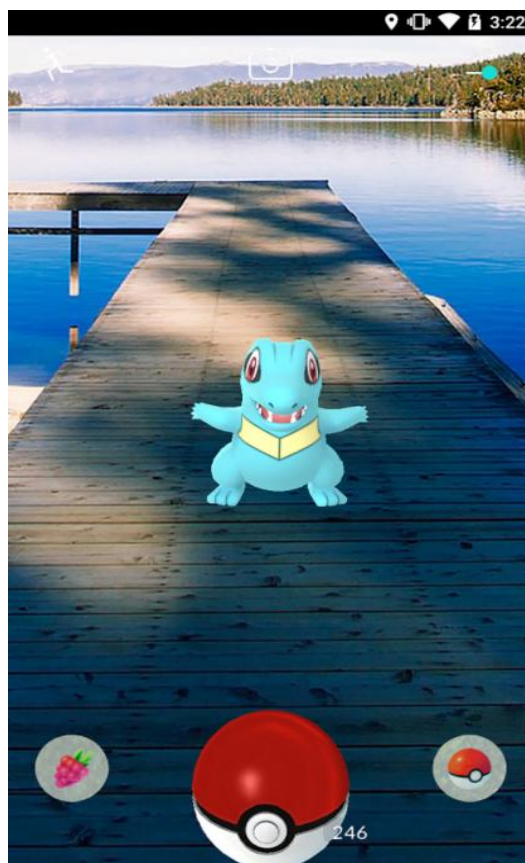


Figure 2.3 – Pokémon Go Screenshot [28]

NBA AR App

As AR gets more enthusiasts, the National Basketball Association (NBA) released in 2017 an application where users can have a basket wherever they are and "practice" their jump shot. In this game, there is an authentic NBA hoop and users should score as many baskets as they can in 30 seconds (see Figure 2.4). The user can choose the spot from where he/she wants to shoot, an easy 2 pointer to start and after the warm up the user can try a 3 point shot. To play the game, the application needs to scan the place where the user is to set up the court in the right position. In this game, the user can shoot the ball simulating the real movement or can use the finger to launch the ball towards the basket [29].

Before the game start, the app allows the user to choose its favorite team to then provide the relevant information about it, including news and next game calendar. After ending the game, the app informs about the location of next game and provides a link enabling the purchase of tickets online [30].



Figure 2.4 - NBA AR app Screenshot [29]

2.5 SoccAR related Applications

Although there are many AR games, the research was focused on applications that are inserted in the same context as SoccAR (soccer, game, entertainment). As AR is an emerging technology, there are not many soccer games using AR. The applications found were beta versions and having very few downloads (almost all of them had less than 1000 downloads). There are, however, several successful soccer applications that do not use AR. For this reason, it was chosen to research a few examples to get interesting requirements.

This subsection focuses on applications from the three major clubs in Portugal.

2.5.1 Official Clubs Applications

The three major clubs in Portugal are Sporting CP, FC Porto and SL Benfica. Each club has its own application although having similar features.

For Sporting CP, the application name is MeuSporting official App [31], and it features:

- News Feed.
- Online tickets (QR-Code with ticket information).
- Next games information and team schedule.
- Team and players statistics.
- Games highlight.
- Online dues payment.

The FC Porto official App [32] features:

- News Feed.
- Last results information.
- Personal area and associate restrict.
- Player bio.
- Last score and game information.
- Live events.
- Geo location alerts.

Benfica Official App [33] features:

- News Feed.
- Schedule.
- Games result.
- Media.
- Team roster, classification and statistics.
- Virtual RED Pass.
- Associate: Virtual Ticket.
- Online store.

To summarize, all these applications are prepared to display the information related with the team and provide associates with a simple system to buy tickets.

FC Porto official app has one special feature that differentiates it from the others, the Geo Location alerts. If allowed by the user and if the user is near some official store, the user is notified about services or products on sale and can benefit from it.

2.5.2 Soccer Applications

Since this project theme is soccer, one AR soccer game and two soccer games were studied to understand common game mechanics. The criteria to select the AR soccer game were

being a shootout and for free. When selecting the two games, it was assumed that they should also have more than 4 stars as a rate and, finally, have at least 10 000 downloads. All the games were tested on Android.

AR Soccer Strike

AR Soccer Strike is an AR soccer game where the player is challenged to score a penalty to gain points, losing when missing 4 shots. As the user scores more goals, the game difficulty increases as well. To mount the game scenario, the user needs to scan a plane surface and then the game is built over that surface (See Figure 2.5). To shoot the ball, the player has a bar to control the power and then just needs to swipe the ball with its finger towards the goal. This game requires AR Core 1.0.



LATEST AR FOOTBALL

Figure 2.5 - AR Soccer Strike [34]

Flick Shoot 2

Flick Shoot is a soccer game where the user can score goals in different levels. It is possible to play as a single player or a multiplayer and it has several game modes (challenge, arcade, time attack, one shot and practice). In addition, the user has missions to complete so it can win coins. In order to score goals, the user needs to touch the ball and swipe it with its finger towards the goal. The ball will follow the finger path. In each level the user shoots from different places and it has defenders to difficult the task of scoring a goal (See Figure: 2.6).



Figure 2.6 - Flick Shoot 2 Screenshot [35]

Soccer Shootout

Soccer Shootout is also a soccer game very similar to Flick Shoot 2. It follows the same procedure where the finger is used to shoot the ball, but there is only the chance to score penalties (See Figure 2.7). Soccer Shootout has also the particularity of enabling users to play as goalkeepers, in which, they have to swipe their fingers in one direction to move the goalkeepers in that direction. Similar to the previous game, this one also has other features, such as collecting coins to buy in-game cosmetics, such as boots and ball skins, or changing the team roster.



Figure 2.7 - Soccer Shootout Screenshot [36]

2.6 Conclusion

It becomes noticeable that IoT and AR are two growing technologies, each one promising huge opportunities in many areas of our society. The study above shows diverse applications applied to different areas, where these technologies are used with success. Using them together is already a reality in several areas, and in the game arena, new possibilities will emerge. With the evolution of smart phones, both technologies can now be explored to create new experiences for the users in an easy way.

After analyzing the soccer apps and games available in the market, it was inferred that AR soccer games are not as popular as regular soccer games, especially when compared to the number of downloads. From the experience gathered, it is possible to assume that this can be due to the difficulty of having a “real” ball movement or the need to be constantly holding the phone to point the camera to the surrounding, which can cause some physical tiredness.

The project adopted some of the features presented above. In particular, it used the feature of swiping the ball into the goal because it is the common feature shared by all the games studied.

From the FC Porto official app it was adopted the geo location feature allowing users to access special events based on their location. This prototype presents a new social feature that permits users to see and take a photo with their favorite players virtually depending on their location. Furthermore, this project differentiates from the other applications because in addition to the use of AR technology it also adds IoT information to create an immersive experience allowing that real life perceptions interfere in “real time” with the course of the game.

From a business perspective this project is innovative because it is not only a game but mainly a platform for advertisers where they can promote their events, services and/or products. With such a platform, advertisers can reach their target audience in an easy way, through their smart phones, and can promote their products, launch campaign or create special events in their stores.

Chapter 3

Scenario Design & Requirements

This section presents a real scenario to contextualize the SoccAR application. The story is divided into three moments: before the game, half time break and after the game. It also presents the main prototype screenshots, which were made with UXPin software [37].

3.1 Usage Scenario

A usage scenario describes a real world example of how the user interacts with a system [38]. The scenarios described next are the base to extract the requirements to be implemented in this project.

Before the Game

John decided to go to the stadium to see the next game of Altice Football Club. In order to avoid traffic jams, he went much earlier to the stadium. When he arrived there, he picked up his phone, opened the SoccAR application and saw a special event being announced: the team superstar would show up virtually around the merchandising store one hour before the game. As John was already around the stadium, he moved to the team store and waited there for the special event. There, he realized the team scarf was with 50% discount and he took the opportunity to buy a new one. One hour before the game, he opened the SoccAR special event: the team superstar was already there waiting to take photos with him!

Half time break

The referee finished the first half and both teams went to the locker room. John had then free time and picked up his phone to enjoy the break. He opened the SoccAR application to start playing the game. During the half time break, John was competing with other fans to get more points and get a free ticket for the next game and a burger in the stadium restaurant. He was full of hope since the game was going very well. Just before the tip off of the second half, he received an update with the game winner. John beat all other users and had access to the prizes through the application!

After the game

The referee has blown the whistle for the last time and Altice Football Club won 3-0. John was enthusiastic! His team won and he also won the half time contest. While he waited inside the stadium, he played one more game before leaving. Then he moved to the burger shop to celebrate with other fans and to collect his prize! John and his friends celebrated the important win and were already excited for the next game.

3.2 Specific Requirements

To specify the requirements of this project some use cases were created, taking into consideration the usage scenario, where different roles were taken into account to enable inferring all the necessary features.

Actors

- **User** - Has access to the front-end of the application and can play the game
- **Advertiser** - Sponsor events and the prizes to the users
- **Sport Entity** - Associates with the application as one of the teams and connects the users in a specific place

User Stories

The requirements of this project were collected using user stories. This technique allows the requirements to be written in an informal way, defining which features are expected in the application for each different user. These user stories were selected with the participation of the stakeholders of the project. Some requirements are in bold, since they are important for the development of the work.

Each user story uses the following template: "As a <Role>, I want <feature> so I can <benefit>".

All the user stories collected are on the Table 3.1 - User Case Stories, Table 3.2 - Advertiser Case Stories and Table 3.3 - Sport Entity Case Stories

ID	Role	Case Story
1	User	I want to face a goalkeeper so I can have some different level of challenges
2	User	I want be able to shoot the ball so I can score goals
3	User	I want to choose the power of the shot so I can control the ball speed
4	User	I want to be able to add effects to the ball so I can control the trajectory of the ball
5	User	I want to be able to choose the side where the ball goes so I can trick the goalkeeper
6	User	I want to see the score so I can get the game score
7	User	I want to see the time left so I can know much time do I have
8	User	I want to be able to see the highest score so I can try to beat it
9	User	I want to be notified if I win some prize so I can easily receive it
10	User	I want to be able to see overall results in the informative/advertising panel of the sports hall (stadium) so I can see who won the competition

11	User	I want to be able to gain points with goals so I can move up the level
12	User	I want to make the biggest number of goals very quickly so I can have the highest score
13	User	I want to be recognized as the winner of the game, so all mobile phones will get my face
14	User	I want the game characters appear in the real world like Pokemon go so I can feel like I'm facing a real goalkeeper
15	User	I want make part of a team so I can get involved with a community
16	User	I want play against other team so I can beat them
17	User	I want a simple register so I can be permanently logged in
18	User	I want to have a quick respawn so I can be continuously playing
19	User	I want to have different weather scenarios so I can feel more immersed in the game
20	User	I want the opponent to have the rivalry colors so I can feel I'm playing against him
21	User	I want to have different kind of balls so I can be able to choose the one that I like the most
22	User	I want to make more noise so I can increase my opponents game difficulty
23	User	I want the ball physics change according the humidity so the game looks more realistic
24	User	I want to get local information based on context so I can experience new games features
25	User	I want to participate in virtual events that occur in specific places so I can interact with the team stars

Table 3.1 – User Case Stories

ID	Role	Case Story
1	Advert.	I want to benefit from marketing channels available on the app so I can show my brand
2	Advert.	I want to have access user info so I can promote the right product or service to make more revenues
3	Advert.	I want the characters on the game to have my brand associated so I can display my brand
4	Advert.	I want the users to have easy access to our prizes so I can increase my brand awareness
5	Advert.	I want to have special events in my store so I can increase people traffic inside the store

Table 3.2 – Advertisers Case Stories

ID	Role	Case Story
1	Sport Ent.	I want people coming to the stadium so I can get more supporters
2	Sport Ent.	I want to create an engagement with supporters so I can sell merchandising
3	Sport Ent.	I want to create a game offer linking Sports, Augmented Reality and IoT component in a contextualized environment so I can engage the maximum users
4	Sport Ent.	I want to get personal information so I can segment my users
5	Sport Ent.	I want to provide advertisement place for segments so I can make revenues
6	Sport Ent.	I want to promote events so I can differentiate my offer

Table 3.3 – Sport Entity Case Stories

Prototype Perspective

The **SoccAR** application developed in this internship aimed to provide a contextualized game to entertain users in a sport arena and at the same time become a promotional platform for brands through a special event or just as part of the scenario through a banner.

Prototype Functions

SoccAR game application enables the user to play a football game and lets advertisers to expose their brand as a product or service.

The game sets up an augmented reality scenario by using the smart phone camera, enabling the user to play and score as many goals as she/he can in a limited time. Besides this, the game is influenced by the environment around the arena like noise, temperatures and humidity.

In the game scenario the user will find out the brand sponsoring the game and when the user unlocks/wins some prize a message sponsored by that brand, will display her/his name on the arena placard.

When a special event occurs all the users are notified with the time and place where it will happen. Then the user needs to move to that place and at the right time a special augmented reality will show it up to all the users present in that place.

3.3 Non-Functional requirements

The non-functional requirements of this project were settled in agreement with the stakeholders of the project. The system was evaluated regarding functional and non-functional requirements to validate the system architecture and developed application that supports the final product.

Usability

As this project will provide a game application, it should offer a good user experience. User should be able to navigate through all menus with just a few clicks and easily understand how to play the game.

Privacy

All users' personal information should be private and encrypted in the database and during the network transmission. In addition, the user should be informed and consent about who could access that data.

Scalability

This system needs to scale some of its components such as storage and processing to high number of users and requests.

Availability

This solution will be permanently available and should have a Service Level Agreement (SLA) level of 99% uptime.

Performance

It is expected that the application perform all the features the user needs to play the game and it should not take too long to mount the augmented reality experience. In addition, the server should reply all requests from the user and store all data that receives from the user and from ThingWorx with a delay of 1 second at maximum.

3.4 Validation Strategy

In order to guarantee that this system was successfully implemented, a validation strategy is prepared to test the system non-functional and functional requirements.

Usability Evaluation

By the end of the project, some users will be invited to try the application and they run a usability test. The mean of those tests will validate the application's usability.

Scalability Evaluation

This system will be tested by running user requests. Initially it will be tested with some basic and low number of requests to test basic features and then by incrementing the user requests so that will be possible to check the system behavior and if all components (like database) are prepared for a large number of users.

Performance Evaluation

This evaluation will check out overall system performance. First, this evaluation will check some basic features with real users being invited to test the application and then some stressing test using software to test the system behavior.

System overall performance evaluation also ensures that all system communications described in the system architecture work well. In addition, most of all of the functional requirements implemented are working so that the user can play the game and navigate through the application.

3.5 Prototype Flow

The prototype map is shown in Figure 3.1 presenting the navigation in the application. This prototype is based on the requirements previously defined and aims to facilitate the user navigation in the application and its interpretation to provide a good user experience.



Figure 3.1 – Prototype sitemap

Mockups

Some mockups before the development are presented below (See the Figures: 3.2 and 3.3). The full application prototype is available in appendix A.

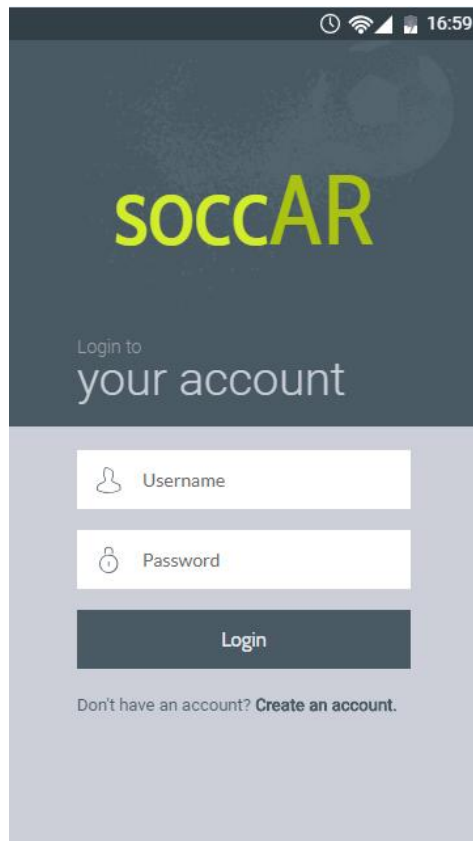


Figure 3.3 - Login Menu prototype

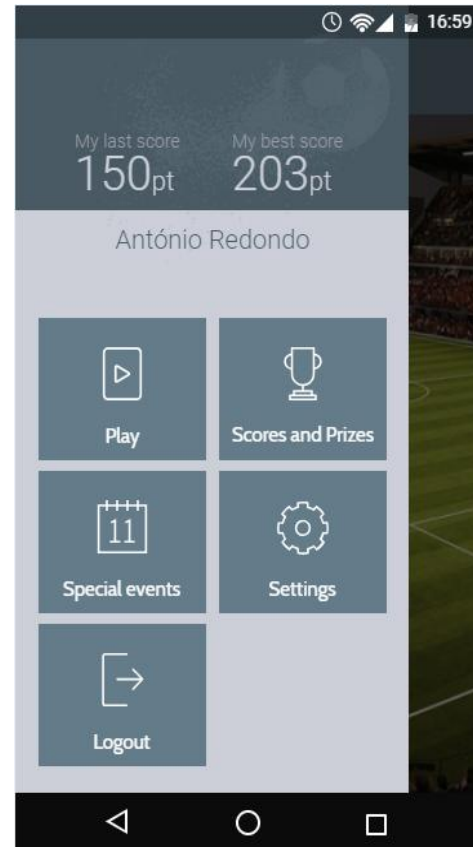


Figure 3.2 - Side Menu prototype

3.6 Conclusion

The scenario described on section 3.1 defines the context in which this application can be used and it gives an overall look of what are the user expectations.

Both the user and the project requirements have been defined based on the scenario description and on the user stories, in order to capture the users' and the system's expectations including the stakeholders' desired functionalities.

The application flow was prepared according to the requirements definition followed by the design of a sketch of the menus application.

The project evaluation should be based on the defined requirements on the tests performed to evaluate the non functional requirements.

Chapter 4

System Architecture & Implementation

This chapter presents the architecture implemented and the technologies used to build the system. The system architecture was derived from the requirements previously defined.

4.1 Functional Architecture

Figure 4.1 shows the diagram of the system functional architecture, where all the elements are represented as well as the relations between them.

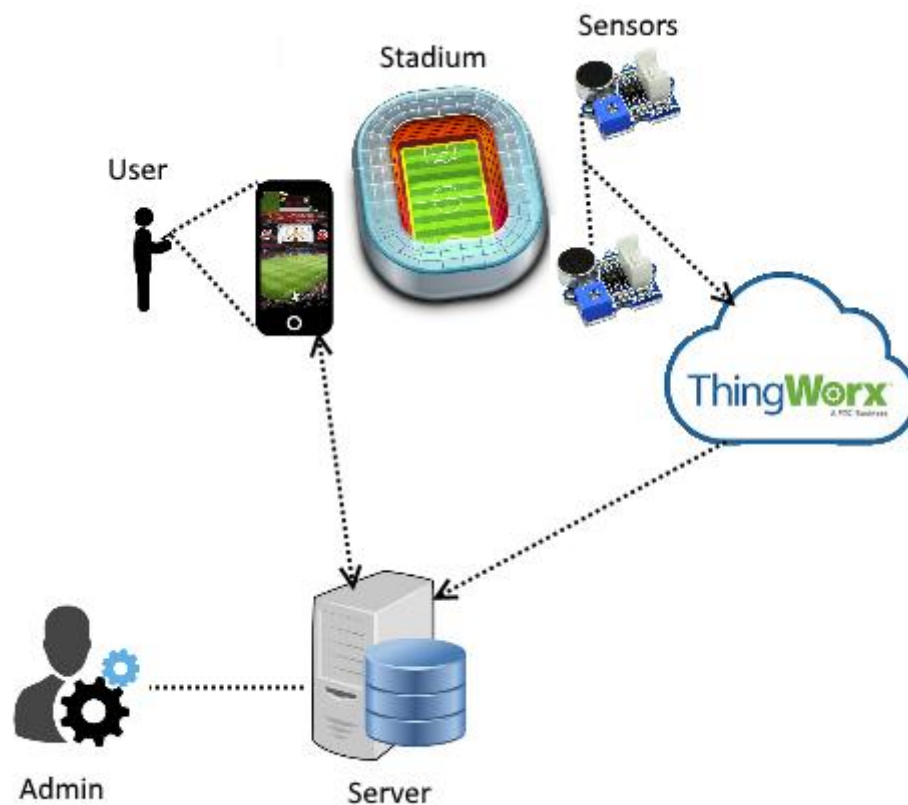


Figure 4.1: Functional Architecture

This system presents the User in the stadium and her/his interaction with the application through a smart phone. The application communicates with the server to update the game score and environment information. The stadium has sensors deployed all around to collect noise, temperature and humidity and then communicate this information to ThingWorx [39]. ThingWorx stores this data and sends it to the server, which forwards it to the user. The administrator of the system will update the server with ads and prizes and support the system if something goes wrong.

4.2 Technical Architecture

Figure 4.2 shows a more detailed architecture of the project where each component is described.

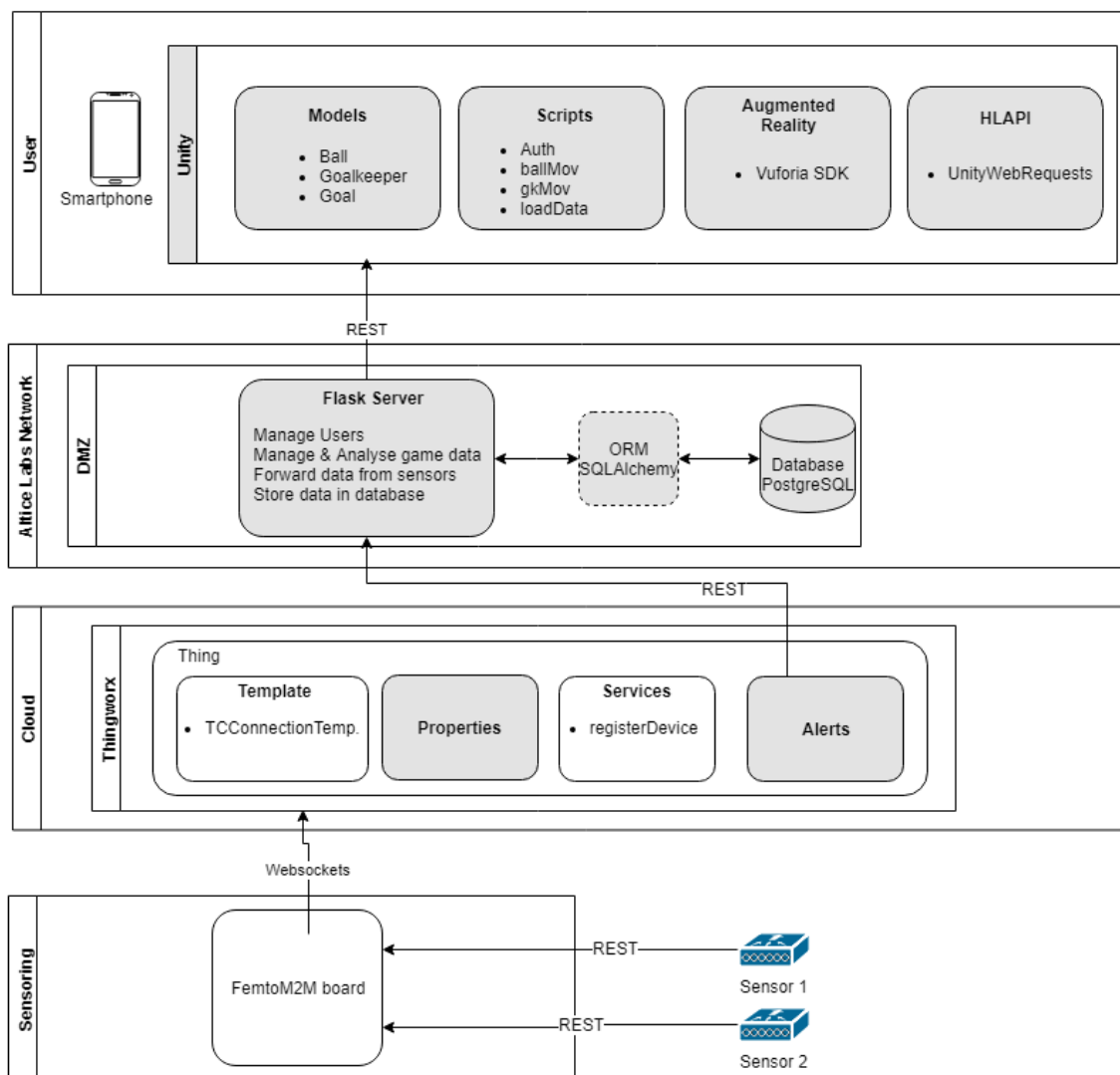


Figure 4.2: Technical Architecture

The game is developed over augmented reality technology using the Vuforia [40] Software Development Kit (SDK) integrated with Unity [41]. Despite Unity being a cross platform engine, the application will only be deployed in Android because it is the only Operating System (OS) available to test.

This application communicates through Hypertext Transfer Protocol (HTTP) requests with a Flask Server hosted on the Demilitarized Zone (DMZ) from Alice Labs data network. The server will store the data in a PostgreSQL database [42], will manage the users, the data from the clients and it will also connect to ThingWorx to receive data from the sensors in the soccer stadium.

ThingWorx will manage the data received from sensors (creating digital representations of the sensors and creating services with that data) and will connect to the FemtoM2M board via websockets to communicate with sensors.

4.3 Components implementation

This section presents a brief introduction to the technologies used in SoccAR system and describes the implementation of the main components of the prototype. This system is divided into three main components: application, web server and ThingWorx.

4.3.1 Application

The application is the component that connects the user to the system and as so it will provide a graphical user interface to allow the user to interact with it. It is an Android application built on the Unity Platform using C#. Since Unity is a cross-platform, in order to deploy other OS, it requires that some functions must be modified. The game also includes the AR technology used in the special events. The development of this component was divided in three steps:

Navigation & Game Logic Menu

The first task implemented in the application was the navigation menu. The navigation menu was based on the sitemap of the application defined in the prototype and allows the user to navigate in the application and access any screen. A prototype of the menus design was built on UXPin and then recreated on Unity.

The game logic was also defined here. In this step the menus were prepared to communicate with the server to send and receive information. Below it is presented the Login Menu (See Figure 4.3).

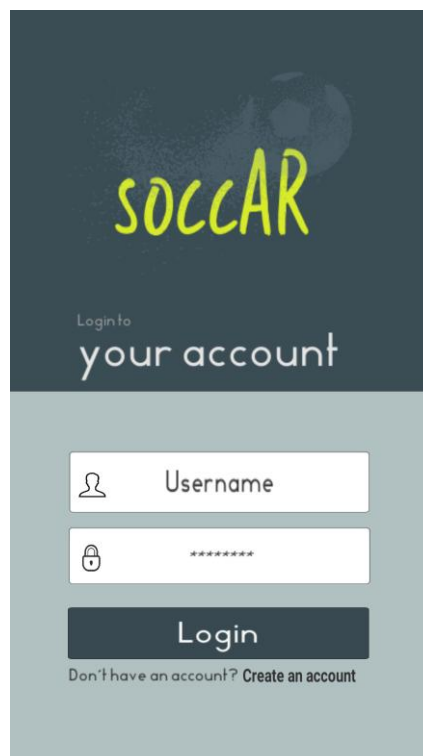


Figure 4.3 - Menu screenshot

Game

One of the main features of the application is the game itself. The game is a penalty shootout where the user plays as the striker and the objective is to score the maximum number of goals in 1 minute. To play the game, the user, first needs to select the team it wants to be in. Then the user has to scan the “*Vuforia stones*” image so the game can be built over it, in AR. When the game is set, the timer starts to count 1 minute and the user needs to swipe the ball, with the finger, into the goal. Each goal increases the user score in 10 points and every 10 seconds the game is updated with the sensor information from the server. When the time is over, the application sends to the server the game data (user id, team id and points).

The game characters are 3D models. The goalkeeper and the ball are free assets from Unity’s store and the goal was developed on OnShape [43].

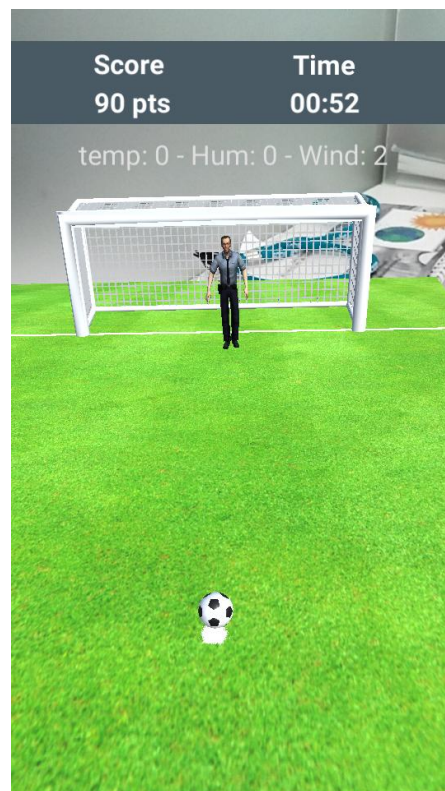


Figure 4.4 - Game Screenshot

Special Event

The other main feature of the application is the special event. The special event is a feature that provides the user with the possibility to take a photo with a virtual character that shows up as AR. This feature is only active if the user is inside a 50m radius from the specified place and its smart phone has a gyroscope. The application checks if the user fulfills the location and smart phone constraints to activate the button that allows the user to enter this feature. If all the conditions are fulfilled the user just needs to point to the ground, where it wants the character to appear, and touch the screen. After that, the character shows up and the user can take a photo with it. The photo is stored on the smart phone’s gallery.

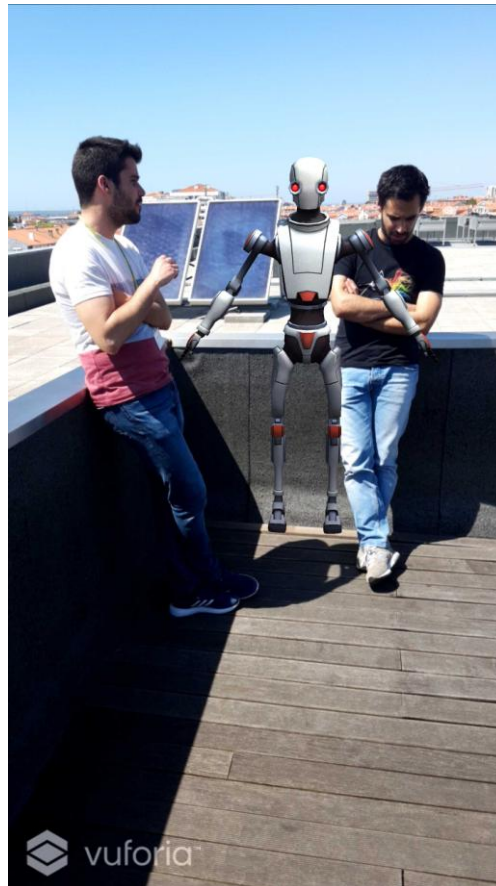


Figure 4.5 - Photo with virtual character

Used Technologies to develop the application

Unity is one of the top game development platforms that includes an editor and a game engine and it can be used to develop games and interactive applications. It allows the user to deploy to more than 25 platforms like Android, iOS and PC and also integrates social media SDK, like Vuforia SDK to develop AR applications. Unity big advantage is their large community that provide a lot of help and support to beginners besides that Unity also has an Asset Store where is possible to download game assets [44].

Vuforia is the leading AR platform and is integrated with unity to develop AR experiences. Vuforia enables the devices to recognize and track image targets and ground planes where the user can build 3D models over it and see them through its device [45].

4.3.2 Web server

The system web server connects all components defined in the architecture. The web server is implemented on the Altice Labs DMZ (See Figure 4.5) on a CentOS7 virtual machine. The web server receives HTTP requests from the application and ThingWorx platform and processes them. It is also the web server that communicates with the PostgreSQL Database to store the data that comes from the clients and from the sensors.

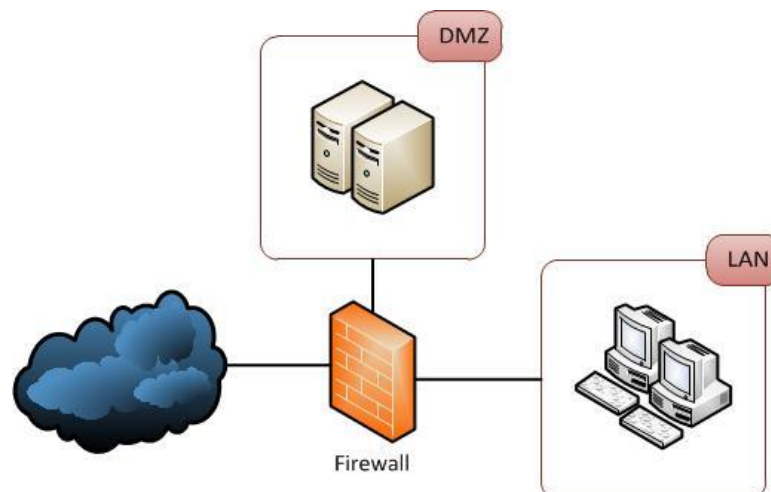


Figure 4.6 – DMZ architecture example [46]

The communication with PostgreSQL is through Flask-SQLAlchemy and Flask-Migrate that are integrated with Flask. To create the database and tables, it just needs to import the database from the python file and use the SQLAlchemy command to create it.

The web server is also in charge of the application security, namely the user authentication. Moreover it deals with the data that is received after a game and calculates the final results. Finally it also receives and forwards sensor data.

Web server used technologies

Flask is a web framework, developed in Python and it is on the micro-framework categories since it has little or no dependencies on external libraries [47].

PostgreSQL is the database that will be used in this system. It is an open source database, is Atomicity, Consistency, Isolation, Durability (ACID) compliant and is ready for Python [48]. PostgreSQL can be integrated with flask with SQLAlchemy. "SQLAlchemy is a library that facilitates the communication between Python programs and databases".

4.3.3 ThingWorx

Since this is a project to build a prototype and only a temperature and humidity sensor are available, this project uses both together with a virtual sensor to simulate a wind sensor.

ThingWorx is the component that handles the sensor information. This platform is connected with the board with the real sensors and communicates it through webSockets. The virtual representations of the real sensors on ThingWorx have alerts attached to them so when a sensor exceeds a predefined limit, the values are communicated to the server through a service that sends the sensor data in a JavaScript Object Notation (JSON) file.

The limits to fire those alerts are:

- Temperature – above: 28°C or below: 10°C
- Humidity – above: 60% or below: 30%
- Wind – 0: North or 1: South or 2: East and 3: West

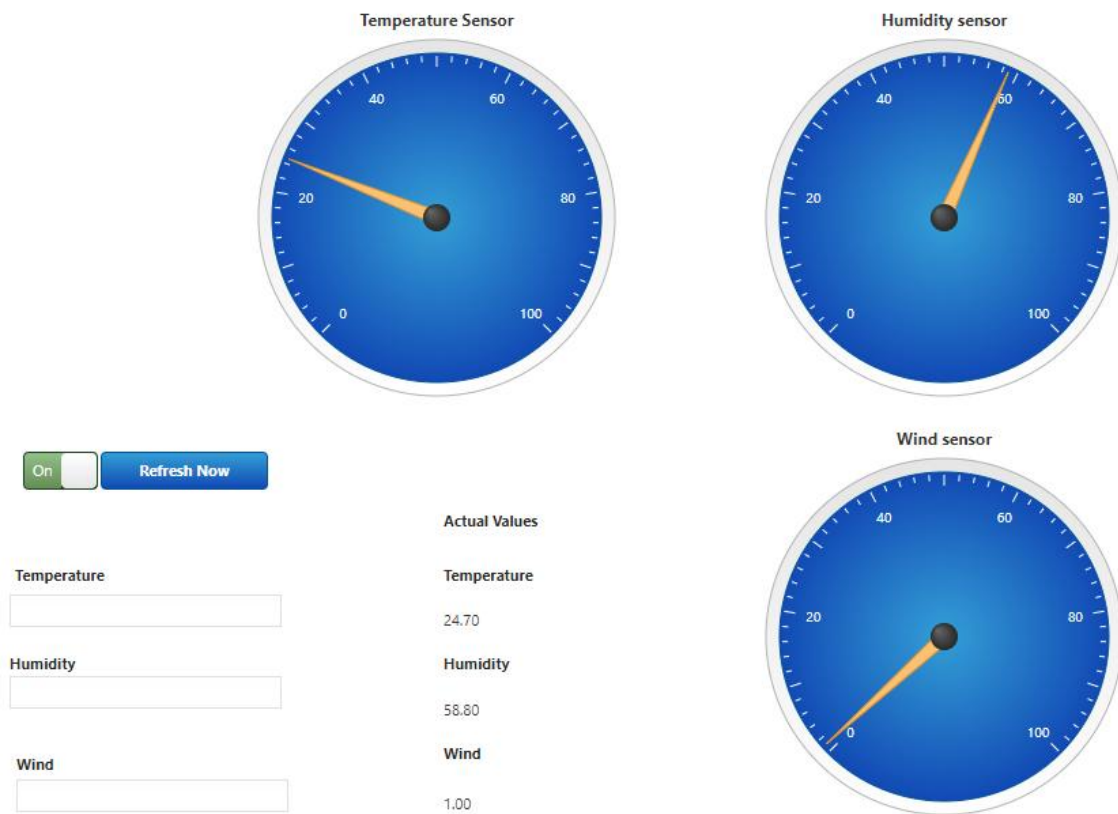


Figure 4.7 - ThingWorx mashup

To facilitate the visualization of the sensor data, a mashup was created where the developer can see the actual values and also can change the values of the sensors.

Technologies Used

ThingWorx is an end-to-end application that enables the developer to model her/his solution and connect everything around an IoT application in a very easy way. This application employs modeling instead of coding, so the user does not need to debug, but only focus on the agility and composition of her/his solution.

4.4 Conclusions

After the definition of requirements, the next step was the design of the system architecture. The system architecture needed to serve and support all the requirements defined before. From the defined requirements the system needed to have an application – the frontend of the system and the interface through which the user interacts with the system; a server and a database – to manage and store the data and connect all the components; and finally the ThingWorx platform – to create virtual things that will map with the sensors and connect them to the server.

For this system to work properly, it needed to have a server to receive HTTP connections from the clients and manage the data received. The data received needed to be stored, so a PostgreSQL database was created. Finally the communication between the ThingWorx platform and the server it was also made through HTTP because ThingWorx has a Representational State Transfer (REST) Application Programming Interface (API).

The development of the system started with the application. The first implemented tasks were the menus and the navigation between them. After concluding it, the next step was to implement the game. This was the hardest task due to its complexity and there was no help or support for the AR application component, as this is a new and still evolving technology. The next task was to develop the server. The server manages the application security (user authentication) and the requests from clients. Together with the development of the server, the database was also created. The final feature to be developed was the special event: to take a photo with a virtual character. To implement the special event, it was required to update the Vuforia SDK to use new functionalities such as the Ground Plane detection. This one, in particular, enables the smart phone to detect a plane and build an AR model over it without an image target.

Finally, the ThingWorx platform was connected to the real sensors. To manage the data received from the sensors, some alerts were created, so when the values from the sensors reached pre-defined thresholds, a service was triggered to communicate it with the server through the REST API.

Chapter 5

System Tests & Evaluation

5.1 Functional requirements

Since this is a proof of concept and the business details are not in the scope of this project, the application developed only focused on the User and its experience, so only the User case stories will be evaluated despite the Advertisers and Sport Entity case stories were also taken into account during the application development. The following requirements were classified as success as they were all implemented and tested by the developer.

ID	Role	Case Story	Success
1	User	I want to face a goalkeeper so I can have some different level of challenges	X
2	User	I want be able to shoot the ball so I can score goals	X
3	User	I want to choose the power of the shot so I can control the ball speed	X
4	User	I want to be able to add effects to the ball so I can control the trajectory of the ball	X
5	User	I want to be able to choose the side where the ball goes so I can trick the goalkeeper	X
6	User	I want to see the score so I can get the game score	X
7	User	I want to see the time left so I can know much time do I have	X
8	User	I want to be able to see the highest score so I can try to beat it	X
9	User	I want to be notified if I win some prize so I can easily receive it.	(*)
10	User	I want to be able to see overall results in the informative/advertising panel of the sports hall (stadium) so I can see who won the competition.	(*)
11	User	I want to be able to gain points with goals so I can move up the level	X
12	User	I want to make the biggest number of goals very quickly so I can have the highest score	X
13	User	I want to be recognized as the winner of the game, so all mobile phones will get	X

		my face	
14	User	I want the game characters appear in the real world like pokemon go so I can feel like I'm facing a real goalkeeper	X
15	User	I want make part of a team so I can get involved with a community	X
16	User	I want play against other team so I can beat them	X
17	User	I want a simple register so I can be permanently logged in	X
18	User	I want to have a quick respawn so I can be continuously playing	X
23	User	I want the ball physics change according the humidity so the game looks more realistic	X
24	User	I want to get local information based on context so I can experience new games features	X
25	User	I want to participate in virtual events that occur in specific places so I can interact with the team stars	X

(*) These requirements were implemented but not tested in a real scenario that is in a stadium environment.

From the user stories defined in the beginning of the project, some of them were not implemented for several reasons that are detailed below:

User Stories not implemented

19 – *"I want to have different weather scenarios so I can feel more immersed in the game."*

Despite the data from the sensors is received in the application, it was not possible to change the game scenario due to instabilities caused in 3D characters probably due to resources limitation.

20- *"I want the opponent to have the rivalry colors so I can feel I am playing against him."*

21- *"I want to have different kind of balls so I can be able to choose the one that I like the most."*

It was decided that this requirement did not need to be implemented because it was not critical and it requires more time to implement it.

5.2 Usability Test

Summary

To test if the application developed was easy to use, a usability test (see appendix D) was designed, where the testers needed to perform autonomously 4 different tasks and evaluate them. The test was performed by 12 users that worked at Altice Labs on June 13. To perform the test, it was used a smart phone to test the application and a computer to answer the questionnaire on Google forms (See appendix B). The questionnaire was in Portuguese because all of the testers are Portuguese and they all signed a consent form for legal issues (See appendix C).

Participants

The selected participants represented the prototype audience target and are aged between 18 and 30 years old and are of both genders. The participants are all familiar with smart phones and are familiarized with mobile applications but not all are familiar with IoT and AR. This was important to get a perception about those technologies that are new to the testers to understand if they were user friendly and captivate the user's attention.

Methodology

To perform this test the testers were required to accomplish 4 tasks:

1. Register & Login – test the application authentication and check the expected behavior.
2. Play the game – test the mechanics like the ball and the goalkeeper movements and the detection of the AR functionalities.
3. Take a photo with a virtual character – test the ground detection and the AR over it.
4. Turn off sound and see the score – test the navigation between the menus.

After finishing each task the tester had to evaluate it from 1 (totally disagree) to 4 (totally agree). Each task was considered to have success if the tester was able to finish it and evaluates the task positively. Finally the users were asked about the general performance of the application and to suggest modifications or upgrades to improve the application.

Test Results and Recommendations

All the testers were able to complete all the tasks but despite this fact, when they needed to evaluate it, some of the features were not as they had expected. Next it is presented the detected problems, some suggestions from the testers and what they liked the most.

From this test, it was possible to identify some problems. The problems identified by the users were classified as minor, serious and critical. **Minor** meant that the problem did not stop the user of finish the task; **serious** meant that the user really took some time to finish the task; **critical** meant that the user was not able to finish the task.

Problems detected:

Problem	Classification	Solved
Feedback after registration	Minor	
Back button on settings menu don't work	Serious	X
Typo on special event tutorial	Minor	X
After the special event if the user tries to play again the game the characters are not in the right place	Critical	
Ball movement not real	Critical	X

Table 5.1 - Problems detected

After the problems have been identified, they were analyzed and solved. Since the time to adjust all the problems was not enough, some choices needed to be made in order to have the project ready on schedule. The problems classified as critical had higher priority to solve, next the serious ones and finally the minors.

In Figure 5.1 it is represented the overall results of the test performed.

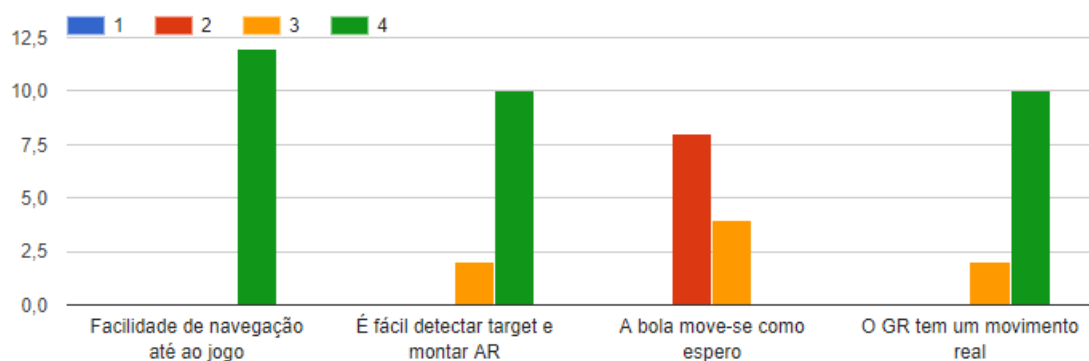


Figure 5.1- Usability test - task: play

As shown in the Figure 5.1, the feature with the worst evaluation was the ball movement that was not real and the tester didn't feel motivated to keep playing. This feature was very important to solve since the game is one of the features that will keep the user attached to the application.

Other major problem detected was that after using the special event feature when returning to the game, the ball and the goalkeeper did not show up in the right place. This problem was not solved due to the need of changing the Vuforia API and that fact interferes with other features. The problem occurs because when the special event feature is activated the Vuforia SDK activates two properties to detect the ground plane that are on a more recent version than the one that is used on the game, and when the user returns to the game, the game uses the most recent version of the Vuforia SDK that disturbs the target recognition.

Other testers' **suggestions** were taken into account and some were used to improve the application:

Suggestion	Applied
Improve tutorials design	X
Add sound when a goal is scored	X
Show the photo taken on the special event	
Facebook login	
Possibility to take a selfie	
When seeing the scores, possibility to select one team and see individual scores	
Game score shows up as a pop up	
Username & Password text should disappear on edit	X
Sensor information change game scenario	
Improve Goalkeeper movement	X
Change virtual character, instead of a robot someone famous	

Table 5.2 - Suggestions from testers

Again due to time constraints, some suggestions were not implemented in the prototype but they can be easily implemented in newer versions.

Finally the **main positive features** to the testers were:

- The AR approach applied to the application.
- The feature that allowed them to take a photo with a virtual character.
- The easiness to build the AR features.

Since this application uses two technologies that are still emerging and some of the testers never heard of, their first impression was good and they were surprised and described it as innovative. Overall 66.7% of the testers classified their experience as very good and 33.7% as good as we can see in Figure 5.2.

12 respostas

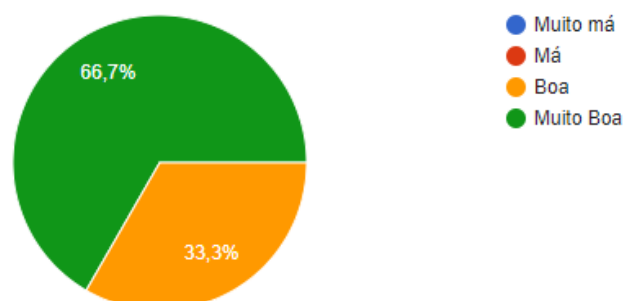


Figure 5.2 - Overall satisfaction evaluation

Retest

After all the adjustments made, three of the testers were invited again to retest the application and evaluate the new version. They all agreed that the ball movement was much better and that they were motivated to play the game. They also commented that with the tutorials the application was much easier to understand and the goalkeeper movement was better despite not being yet perfect.

5.3 Load Tests

Since this project is a proof of concept, the main goal of load tests was to understand how the system behaved in a real environment and what adjustments should be applied to the system in order to have a minimum viable product (MVP). The tests were performed to the web server and the database.

Summary

These tests were made using Apache Bench [49], a tool that measures the performance of an HTTP server. To use this tool, the following command line was called: **`ab -n <number of requests> -c <concurrency> -H <custom header>`** **Error! Hyperlink reference not valid.** . The flags used allowed to change the number of requests, the concurrency and simulate a Login request with a header. The results are presented in the Figure 5.3.

```

Benchmarking 194.65.138.64 (be patient)
Completed 100 requests
Completed 200 requests
Completed 300 requests
Completed 400 requests
Completed 500 requests
Completed 600 requests
Completed 700 requests
Completed 800 requests
Completed 900 requests
Completed 1000 requests
Finished 1000 requests

Server Software: Werkzeug/0.14.1
Server Hostname: 194.65.138.64
Server Port: 5000

Document Path: /
Document Length: 233 bytes

Concurrency Level: 200
Time taken for tests: 139.072 seconds
Complete requests: 1000
Failed requests: 9
  (Connect: 9, Receive: 0, Length: 0, Exceptions: 0)
Non-2xx responses: 1000
Total transferred: 38000 bytes
HTML transferred: 23300 bytes
Requests per second: 7.19 [#/sec] (mean)
Time per request: 27814.421 [ms] (mean)
Time per request: 139.072 [ms] (mean, across all concurrent requests)
Transfer rate: 2.67 [Kbytes/sec] received

Connection Times (ms)
  min  mean[+/-sd] median  max
Connect: 16  35 248.7   20  6555
Processing: 26 27246 34919.0  4366 121534
Waiting: 25 15113 29685.0  2736 121437
Total: 45 27281 34930.2  4388 121576

Percentage of the requests served within a certain time (ms)
 50%  4388
 66% 33760
 75% 60872
 80% 60912
 90% 79985
 95% 120700
 98% 121393
 99% 121500
100% 121576 (longest request)

```

Figure 5.3 - Apache Bench results

The main goal of this test was to evaluate the server response time. The request was a Login request in order to pass through all the system components (client, server and database) and the test breaks when 10 requests fail.

This test was performed under several scenarios where the number of requests and concurrent requests were changed as well as the client location. To obtain the best response time from the server, the client location was inside the machine. Afterwards, the location of the client was changed to the internal network of Altice Labs to test the requests in the same network because it could be expected less latency and the route to the server was shorter avoiding other switches and routers. Finally, the location of the client was changed to the outside, Internet, to test how the server would behave in a real environment.

Taking into account the average audience in the 3 largest stadiums in Portugal (around 46 000), the number of requests made was 1000, 10 000, 20 000 and 50 000 [50].

Server machine specifications: CentOS 7, 4GB RAM, 2 CPU (cpu GHz: 2.7, 64bits,)

Results

The results obtained from the tests are shown on tables below (See Tables 5.3 and 5.4). Table 5.3 presents the latency time from the client perspective for each scenario where each row represents the location and the number of requests and each column represents the number of concurrent requests. The “-“ character in the table means that the software did not finish the task and returned an error.

Conc. Requests Requests	1	50	100	200	1K	10K
Out. 1K	133.96	6667.03	14729.62	27814.42	-	-
Int. 1K	11.66	283.67	3137.12	2568.49	-	-
Int. 10K	43.49	1432.08	3392.33	-	-	-
Int. 20K	43.66	2135.82	4437.42	7805.963	-	-
Int. 50K	46.7	2136.21	3831.79	8638.664	41953.94	-
Int. 100K						127633.97
Ins. 1K	5.87	285.41	555.09	1290.54	-	-
Ins. 10K	6.07	282.03	558.46	-	-	-
Ins. 20K	6.06	280.2	571.03	-	-	-
Ins. 50K	6.12	300.97	551.55	-	-	-

Table 5.3 - Latency time (ms)

Abbreviations:

Out. = Internet

Ins. = Inside machine

Int. = Internal Network

K = one thousand

From Table 5.3 analysis, in a real environment (Out – Internet), the system responds to 1000 requests without concurrent requests in 0.1 seconds. According to [51] 0.1 second is acceptable because it is the limit for having the user feel that the system is instantaneous. However, when some concurrency occurs, the values are too high and the user will lose the focus or disposal to keep with the application. This is due to the fact that virtual machine specifications were not good enough to support high loads and the server was not working concurrently. The tests made from the internal network show that the server supports 50 000 requests with 1000 concurrent requests but the latency time is very high.

Table 5.4 presents the number of requests served per second for each test scenario where each row and column represents the same as in Table 5.3.

#/sec	1	50	100	200	1K	10K
Out. 1K	7.46	7.5	6.79	7.19	-	-
Int. 1K	85.74	176.26	31.88	77.87	-	-
Int. 10K	22.99	34.91	29.48	-	-	-
Int. 20K	22.91	23.41	22.54	25.62	-	-
Int. 50K	21.41	23.41	26.10	23.15	23.84	-
Int. 100K						78.35
Ins. 1K	170.27	175.18	180.15	154.97	-	-
Ins. 10K	164.79	177.29	179.06	-	-	-
Ins. 20K	165.07	178.44	175.12	-	-	-
Ins. 50K	163.49	166.13	181.31	-	-	-

Table 5.4 - Mean number of requests served per second

Abbreviations:

Out. = Internet

Ins. = Inside machine

Int. = Internal Network

K = one thousand

From Table 5.4, it is possible to infer that the values obtained from the Internet were not satisfactory because if a stadium has around 10 000 fans and a tenth of the fans (1000) enter the application and estimating that the system will receive 200 concurrent requests, the system only replies to 7.19 requests per second. However, it can be observed that the server is quite stable on the mean of numbers requests served per second. According to [51] it means that the user will not have a freely navigation experience. When testing inside the machine, reducing the network constraints, for 100 concurrent requests, it can be verified that the server was ready to respond to 180 requests per second which allows a better user experience.

Client Location: Inside the machine

The results obtained inside the machine are the reference to the other tests because they do not have interference from external sources. The machine inside the DMZ broke for scenarios with more than 200 open sockets at the same time, so it was only possible to test for 1, 50, 100 and 200 concurrent requests. When testing with concurrent values above 200 concurrent requests the following error message showed up: *“apr_socket_recv: Connection reset by peer (104)”*. Some efforts were done trying to solve this issue such as to install a new version of Apache Bench or run with `-r` command (do not exit on socket receive errors) but they were not succeeded.

Client Location: Internal network at Altice Labs

From Altice Labs internal network it was possible to test for 1000 concurrent requests possibly because it was not the same machine to make the request and reply to, which means that the server resources will not be depleted. The server did not go down for 100 000 requests and 10 000 concurrent requests but failed when testing with 20 000 concurrent requests.

Client Location: Internet

When testing the server from the outside network, the test broke for more than 1000 requests because at least 10 requests fail. This could be explained due to:

- Network bandwidth constraints
- The existence of a firewall installed on the machine inside the DMZ. In this case it could be rejecting the requests from the outside above a certain number to not compromise security (Denial-of-Service attack).

5.4 Conclusion

To evaluate the project, it was ensured that the functional requirements previously defined were implemented. This evaluation validates the application and ensures that the application meets the user expectations.

The functional requirements that were not implemented were in agreement with the project stakeholders as they were not critical at this stage of the project and they can be implemented in a future version.

It was possible to conclude that, with the tests performed to the system, the use of AR in the application was very successful as all the testers were surprised with it and were very pleased with the experience. The game feature did not have as much impact as the photo with a virtual character and this can be explained by several reasons, perhaps being the most important the fact that to play the game the user needs to scan an image target and in the special event the user just needs to scan the ground. Other reason may be that that the ball movement in the game was not really “realistic” before the tests, and the testers felt that the ball did not move as it should. However, after the adjustments and the retest, the testers were much more satisfied with the experience and keen to repeat it again.

Being this project a proof of concept, the server is not ready to support a more commercial product, still some tests were made and it was possible to have an idea of how the system behaves. The results show that in a real environment, the server is not ready to support the required amount of requests per second, as it was already expected since Flask is not suitable

for being used in a production environment. To use Flask in a production environment it should be handled by a Web Server Gateway Interface (WSGI) application server.

Chapter 6

Conclusion

This final chapter concludes this dissertation with a summary of the work done some suggestions to improve this project and some personal thoughts about gained experience during this internship.

Summary

This work aimed to develop a proof of concept, where AR and IoT technologies could both be applied, with focus on sportive events. In order to fulfill the goals, a game targeting to soccer fans was developed, enabling the creation of an immersive experience during the soccer game day. The produced game includes an Android application - where the user can interact with the system, a ThingWorx mashup - to receive and forward data from the sensors, a web server - to support the system connecting all the components and the database – to data storage.

By analyzing the whole process, it is possible to infer that:

- Understanding the user needs and expectations is central to develop a successful application with commercial acceptance by the market.
- The definition of requirements is critical, as they are the foundation of the functional architecture of the system.
- The system architecture design must respond to the system demands and be able to scale for future evolutions.
- Despite IoT provides real time information about the environment, the user was more fascinated with the AR. The wind or temperature influence on the ball did not have the same impact as the AR models.
- As the majority of testers did not know any AR application besides Pokemon Go, the SoccAR application surprised them as they found it quite “innovative”
- The feature of taking a photo with a virtual character is very promising considering all testers feedback

The key value of the project for Altice Labs was the event management capability, since it innovates the way targeted campaigns can be done in the future.

Future Work

The future work should be aligned with the suggestions received from the users. Those should be implemented as they will improve the user experience. Actually some of them have already been designed to be part of a future version.

The game feature should be improved to use the ground plane scan instead of an image target, so the user can build the game anywhere and anytime without requiring a particular image target. This feature was not implemented in this version because when the application development started this feature was not ready to be used in Vuforia.

Also, the sensors types and data usage must be rethought. Other type of sensors could make more sense or the data from the deployed sensors should produce a much higher visual impact on the game so that the user feels the differences when it is playing.

From a business perspective, a web page should be created in order to have a back office tool enabling to control and manage the backend system allowing the administrator to easy define, for example, which advertisers will sponsor which game and what services and prizes will be available to the users.

Personal Thoughts

I chose this internship as my first option because I was interested in experiment new technologies and I wanted to have an experience in a business environment. This option allowed me to embrace both challenges and improve my computer engineering skills.

The experience at Altice Labs was very challenging but at the same time very enriching as I need to overcome several obstacles to have a functional prototype. The opportunity to work in a business environment was very good as I met many professional and friendly colleagues, I learnt new technologies that provided me new skills, for instance I worked with new software frameworks I did not know that exist, and I evolved as a professional and as a person while contributing to Altice Labs.

For Altice Labs, this project is interesting as it can provide a new business domain opportunity, enriching the Altice Labs product portfolio in the mobile entertainment area, by using IoT together with AR.

During this internship I had the chance to be part of a project and participate through the whole process. The skills that I acquired and those I improved were very important and I was invited to keep working at Altice Labs in a new challenging project.

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Appendix A

This appendix presents all application prototype mockups. The Figure A.1 represents when a user is in the stadium playing the game. The Figure A.2 presents when the game is over. The menus like Register, Settings and Choose team are presented in the Figures A.3, A.4 and A.5 respectively.

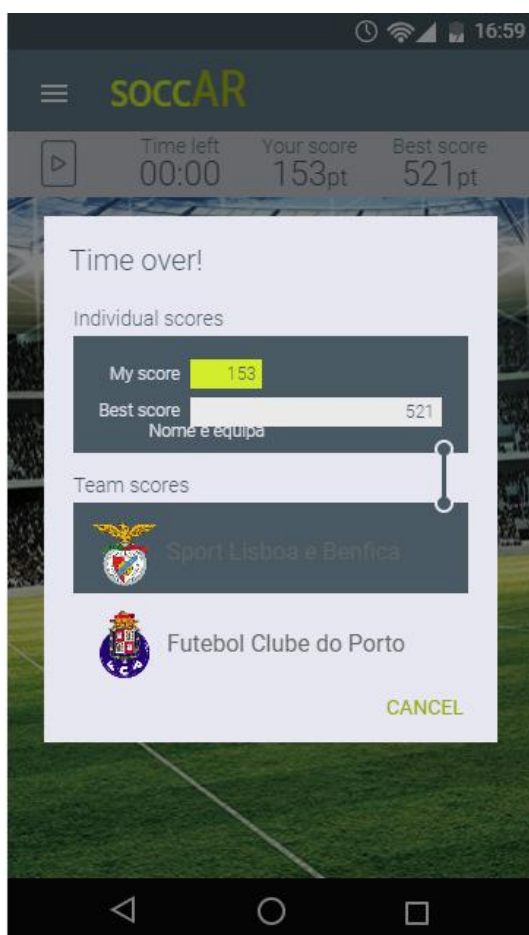


Figure A.2 – Show results prototype



Figure A.1 – Game play prototype

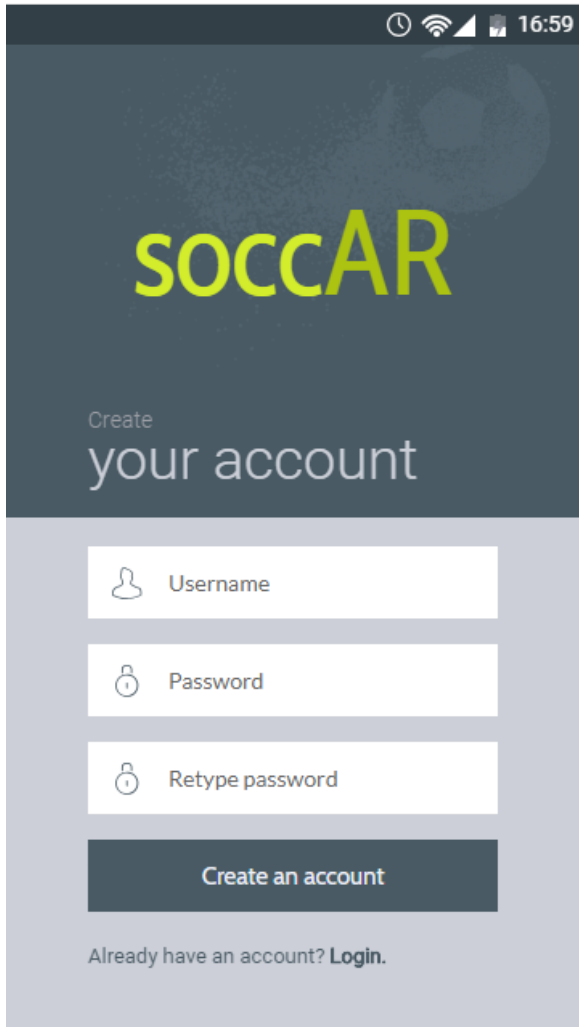


Figure A.4 – Register prototype

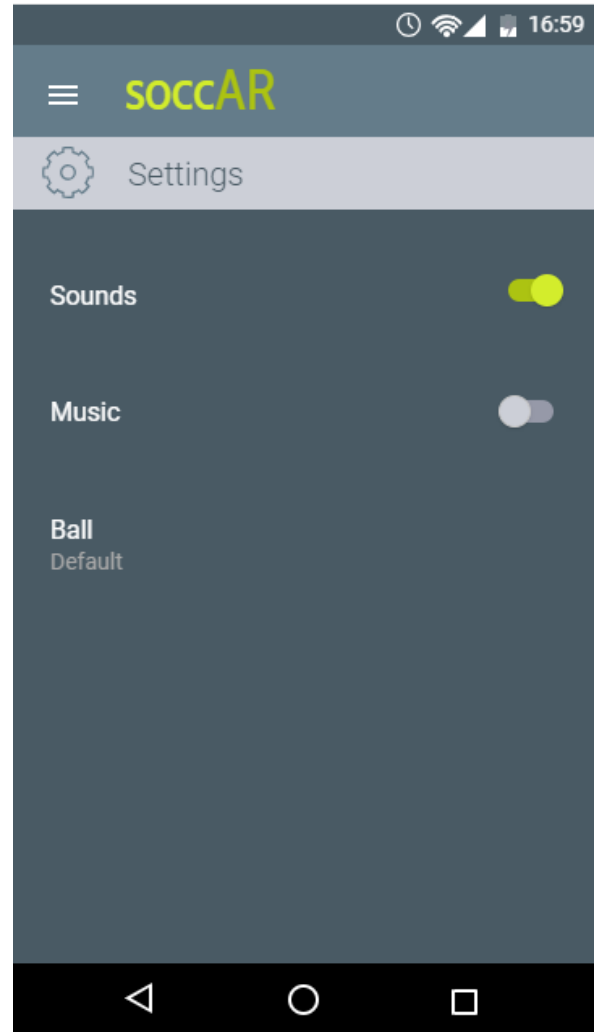


Figure A.3 - Settings prototype

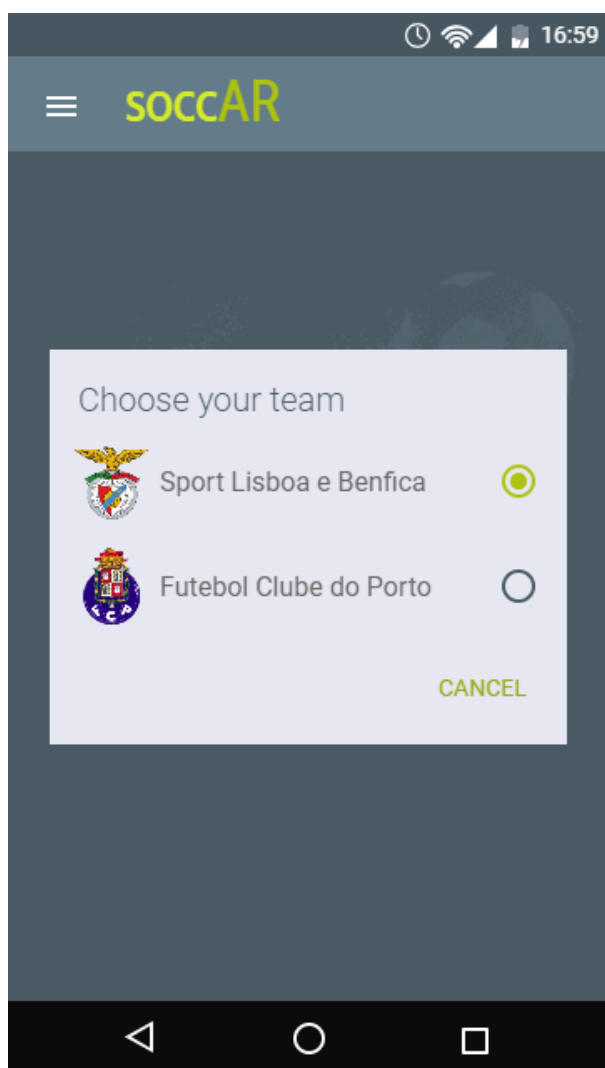


Figure A.5 - Choose team prototype

Appendix B

Usability test questionnaire

SoccAR test

Teste de Usabilidade para a Aplicação SoccAR.

No seguimento do desenvolvimento do projecto SoccAR foi decidido que seria necessário testar a usabilidade da componente aplicação do mesmo projecto. Esse teste tem como objectivos estudar:

- A experiência de navegação da aplicação
- O jogo AR
- Special Event AR

Neste teste o utilizador precisa de realizar simples tarefas e no fim de cada uma fazer uma avaliação.

As tarefas são avaliadas de 1 a 4, onde:

- 1 - discordo totalmente
- 2 - discordo
- 3 - concordo
- 4 - concordo totalmente.

O special event é um evento onde o utilizador usa o smart phone para poder tirar uma fotografia com uma personagem virtualizada.

*Obrigatório

Registar na aplicação e fazer login *

	1	2	3	4
Facilidade de navegação até ao menu	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Comportamento expectavel	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure B.1 - Usability test I

Jogar *

	1	2	3	4
Facilidade de navegação até ao jogo	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
É fácil detectar target e montar AR	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
A bola move-se como espero	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
O GR tem um movimento real	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Tirar uma foto com uma personagem virtual (Special Event) *

	1	2	3	4
Facilidade de navegação até ao special event	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
É fácil detectar base e construir personagem	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
É fácil ter a personagem com uma dimensão semelhante a uma pessoa	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
É fácil tirar uma fotografia com a personagem	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure B.2 - Usability test II

Ver resultado da equipa e desligar som *

	1	2	3	4
Facilidade de navegação até aos menus	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
É fácil perceber o resultado da equipa	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
É fácil desligar/ligar o som	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Comportamento expectavel	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Como classifica a sua experiência com a aplicação? *

- Muito má
- Má
- Boa
- Muito Boa

O que é que gostaste mais e menos?

A sua resposta

Sugestões?

A sua resposta

SUBMETER

Nunca envie palavras-passe através dos Formulários do Google.

Figure B.3 - Usability test III

Appendix C

Consent form

Consent Form (Adult)

I agree to participate in the study conducted by Gonçalo Machado.

I understand that participation in this usability study is voluntary and I agree to immediately raise any concerns or areas of discomfort during the session with the study administrator.

Please sign below to indicate that you have read and you understand the information on this form and that any questions you might have about the session have been answered.

Date: 13/06/2018

Name: Gonçalo Carteado Pinho Machado

Please sign your name: _____

Thank you!

We appreciate your participation.