

Development of a smart-recycling platform based in RFID

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Dedication

I want to dedicate this work to those people who for one reason or another, if they had not been, reaching this moment would not have been possible.

First of all, my family, who has supported me at all times, valuing everything I have been getting and without taking into account all the bad moments, M^a Carmen, Alberto, my Yaya and my Yayo, Tata, Juan, thank you.

Who has been my second family in the university, and with whom I have spent many more hours than I would have ever thought, both inside and outside the university. Adri, Dani, Fran, Laia, Alberto, Alex, Pau and Arnau, I hope that nothing changes.

Of course, someone who, no matter how far away and who came to my life by chance, has always been "close" to me, supporting me at all times and making me feel better, for my girl, María.

And lastly, the taekwondo party-shakers, with whom I have shared some of the most intense moments outside of the university, and have always understood my hermit mode to study. Thanks guys.

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I want to express my gratitude to those people who have helped me making this project possible.

Starting with my group of friends from the university, who have helped me with any questions I may have during the development of this project.

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Abstract

Global trust and participation in recycling is an important aspect for the sustainable development of our society. However, motivation for recycling is a task currently pending due to the lack of time and interest of users. Experts tried to find this motivation through awareness-raising campaigns for recycling, but since it is not an obvious and close problem to the people, these campaigns have not been as effective as they should be. This project seeks to increase interest and participation in recycling through the realization of a functional prototype of a recycling system using the Internet of Things to reward users. The user who performs the waste disposal is identified in the smart container using a mobile application, accumulating points depending the products he recycles, these points are redeemable for discounts and prizes, thus directly encouraging participation in the recycling.

Resumen

La confianza y participación global en el reciclaje es un aspecto importante para el desarrollo sostenible de nuestra sociedad. Sin embargo, la motivación por el reciclaje es una tarea pendiente actualmente debido a la falta de tiempo e interés de los usuarios. Se ha intentado buscar esta motivación mediante campañas de sensibilización por el reciclaje, pero al no ser un problema evidente y cercano a la gente, no han sido tan efectivas como deberían. Con este proyecto se ha buscado el aumento del interés y la participación en el reciclaje mediante la realización de un prototipo funcional de un sistema de reciclaje utilizando el Internet de las Cosas para premiar a los usuarios. El usuario que realiza la deposición de residuos se identifica en el contenedor inteligente mediante una aplicación móvil, acumulando puntos por los productos que recicla, puntos luego canjeables por descuentos y premios, incentivando así de manera directa la participación en el reciclaje.

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1. INTRODUCTION

The present project seeks the creation of a complete smart-recycling system, combining the use of Radiofrequency Identification (RFID) and Near Field Communication (NFC) technologies applied on smartphones. This system will be both a tool for the control of recycling and a tool for the promotion of recycling.

With the development of a desktop control panel, the monitoring of the recycling made in the containers adapted for this system is guaranteed, and with the development of a platform for smartphones, it is guaranteed an easy accessibility for users to use the system.

The complete system will consist of:

- A smart refuse container equipped with a RFID antenna and a NFC antenna.
- The management software deployed in desktop computers.
- The mobile application for the users.
- Recyclable products identified with RFID tags.

The combination of these elements allows the creation of a smart-recycling system, giving users the opportunity to recycle using this system to obtain points (Recycling Points - RP) depending on the elements they recycle, being able to spend these points on different elements of the store within the application.

The mobile application will be called Recycling Games, this application will have all the functionalities necessary to enjoy the complete system, using the application, the user will be able to identify himself in the container where he will make the deposition of the products, he will be able to check the amount of points he has, and he will be able to make any purchase in store of the application using the points obtained.

The development framework that will be used in the creation of the mobile application is Apache Cordova (previously called PhoneGap), this technology will be explained in more detail later in this report, but the main reason for using this framework is the ease of deploying the application on different platforms.

Any user who wishes to take advantage of the benefits of the system, can do it right after downloading the mobile application and creating an account, because to enjoy all the advantages that this system offers nothing but the mobile application is needed.

2. IDEA AND OBJECTIVES

2.1 What is Recycling Games?

This project is born from an idea that appeared from the union of the terms “Internet of Things” and “Gamification”. In addition, to this project also join two topics that are currently very relevant to society, recycling and sustainability. It is well-known that the commitment to recycling globally would be the ideal position for the sustainable development of the planet, however, there are individuals and companies that need to become more environmentally aware. This is the main premise of Recycling Games, encourage recycling in a direct way.

First of all, since the institutions have realized the importance of recycling, it has been tried to be promoted through awareness campaigns. Following the results, it can be determined that this methodology is not enough to achieve a global awareness about recycling. This is when one of the terms previously mentioned come into play, “Gamification”.

2.1.1 Gamification

The term “Gamification” refers to the application of game-design elements and game principles in non-game contexts (Huotari & Hamari, 2012). In this particular project, the use of the term “Gamification” is given by the inclusion of a factor of competitiveness, collaboration and a reward system to the recycling. The reason of this addition is giving an extra motivation to people to recycle, as it was mentioned above, conventional awareness campaigns are not giving the expected results in terms of environmental awareness, so giving an extra motivation to people to recycle adding this competitive, collaboration and economic incentives, can be the way to encourage people to recycle more, since multiple studies have shown that many people do not recycle because it does not directly contributes anything to them.

2.1.2 Internet of Things

The term “Internet of Things” is defined as the inter-networking of physical devices, vehicles (also referred to as "connected devices" and "smart devices"), buildings, and other items embedded with electronics, software, sensors, actuators, and network connectivity which enable these objects to collect and exchange data. (Internet of things, s.f.) This particular term will be discussed in more detail later in this report, but the reason why this term is necessary for the proper development of the project is because this project is based on the connection between devices capable of identifying a user and give him the amount of points he has obtained by recycling products, products which have been detected automatically by the container where they have been deposited.

2.2 Objectives

As discussed above, the main objective of the platform is to generate a motivation to recycle. It is a very general objective, but the platform has a very specific way of generating that motivation. The main way to achieve the platform's objective is offering people an economic compensation based on what they recycle. This is due to the large number of people who choose as an excuse not to recycle: that they do not receive an economic compensation. (Citron-Fink, s.f.) But do not neglect the other way that the application has to generate a motivation for recycling, competitiveness and collaboration. The fact of existing a competitiveness with other users and with oneself, generates an interest to generate more points and thus obtain another route of satisfaction. In addition, the feeling of collaboration among family members to recycle as efficiently as possible provides another reason to actively participate in the platform.

Another objective is to incorporate de RFID technology, and in general, the IoT, to a field which is currently non-existent, thus generating an interest for the new generations and adapting an important field such as recycling to the coming technologies, in other words, create the Smart-Recycling or Recycling 2.0.

Thus obtaining a tool, which not only offers value to users, as explained so far. But this platform can offer a management, control and analysis tool for recycled products in the area where this platform is deployed. Providing information to the administration and offering possibilities of improvement in the management of recycled waste.

As explained below, in the state of the art, projects related to resource management platforms recycled through RFID are already being implemented. Therefore, why not use such technology to also offer value to users, thus achieving two types of customers, private users, who can enjoy all the advantages of the mobile application, and public and private administration, which can be offered statistics and control over recycling.

2.3 Motivation

The main motivation of this project is obviously the creation of an IoT-based platform that encourages recycling in a way never seen before. Recycling is now in a good time, people are becoming more aware of this issue, however, statistics say that active participation in recycling is declining. From 2013 to 2015, active participation in recycling fell by 6%. (Reciclaje de los españoles, 2015) Although it seems illogical, youth is not as aware of recycling as older people, although it should not be. (Waste & Recycling News, 2012)

In addition, 56% of citizens who do not recycle, say they would if they received something in return. (Reciclaje de los españoles, 2015) On the other hand, 6% of people who do not recycle claim ignorance about what to recycle and where. (The Psychology Behind Why People Don't Recycle, 2016)

The analysis of all these data favours the creation of a platform like Recycling Games, since it addresses all the problems for which people do not recycle. On the one hand we have the disinterest on the part of the young, which can be solved with the creation of a mobile application which motivates them to compete among the friends for prizes. On

the other hand we have the disinformation that people claim to not recycle, which can be solved simply by adding a section in the application which explains what elements are recycled in each container. And finally, and probably more importantly, a lot of people claim that if they receive something in return they would recycle, here applies the greatest innovation that Recycling Games brings, the economic compensation.

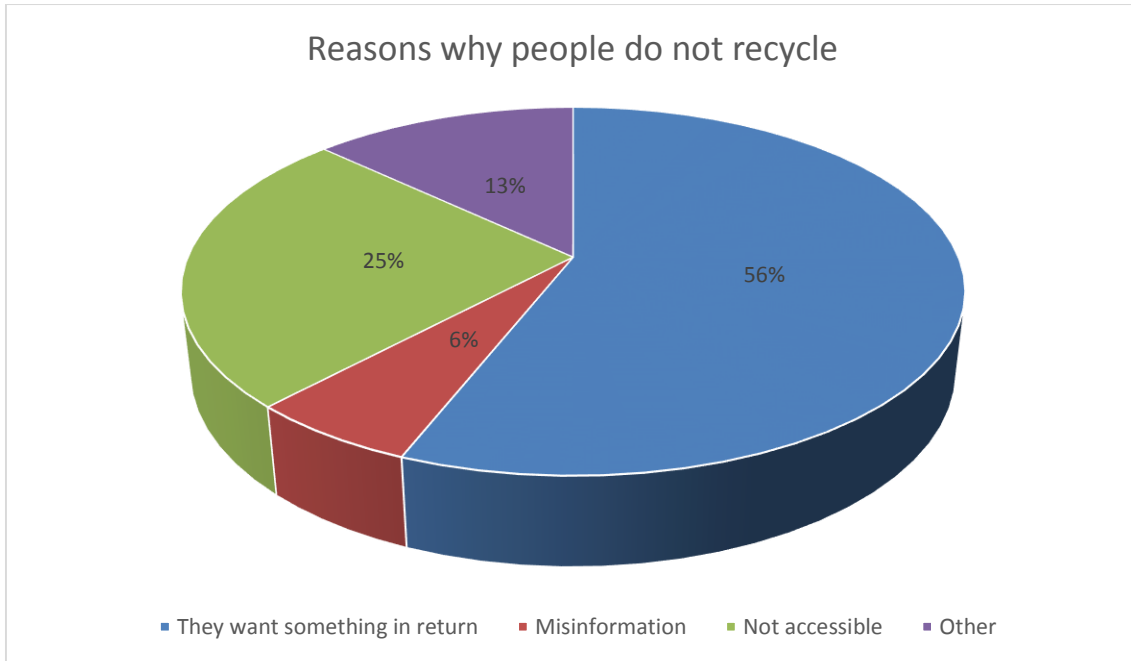


Figure 1. Reasons why people do not recycle.

As can be seen in **figure 1**, Recycling Games provides enough functionalities to make 62% (56% + 6%) of people who do not recycle to think about it.

From everything seen previously, it can be determined that the Recycling Games platform provides a tool that encourages participation in recycling and in general, in search of a more sustainable world.

2.4 Real-world deployment

Although this project is based on the theoretical creation of this smart-recycling platform, it is interesting to analyse how it would be a real-world deployment of this platform.

As we have seen in the previous sections, there are enough reasons to think that the creation of this platform is not only an opportunity but also a necessity. As we have observed in the Motivation (2.3) section, if we do not change the way to promote recycling, it will continue in a downward trend.

Another important aspect to analyse in a supposed real deployment, is what to do with the RFID tags of recycled products. RFID tags are currently made up of aluminium, copper and adhesives, and it is a problem in the recycling process. For example, the recycling of plastic containers is incompatible with these materials, since in this process elements such as caustic soda (NaOH) are usually used, which react negatively with

aluminium, thus precluding a conventional process of recycling the plastic. It is why people are currently conducting several studies related with recycling RFID tags.

One of them is the one made by the Spanish student Carlos Lopez, in his study, he concludes that in broad terms, there are two ways to make possible the recycling of plastic that has RFID tags. (Un español, premiado por su proyecto para el reciclado de etiquetas RFID, 2017) The first would be to change the material with which the RFID tags are made, replacing aluminium or copper with conductive electronic ink (Thin Film Transistors). In fact, there are already studies that seek to make possible this change of material in the composition of RFID tags.

The other solution proposed in the study is based on a small change in the methodology of plastic recycling. This modification is based on the change of the impurities retention meshes in the process of basin of the containers, making the holes in this mesh smaller, giving the ability to retain elements such as the aluminium of the tags.

Given this, although the recycling process of RFID tags can be a problem, there are many studies that work to solve it. So, with a view to the future, this is a point that we should not worry about, since the market itself will adapt to make this possible.

Other aspects that we have to deal with when launching a program or platform to the market, is, for example, cheating. In this case, the solution is very simple, and is given by the characteristics of RFID itself. This is because RFID tags are unique, there cannot be two labels with the same numbering. Thus, the way to avoid the most obvious cheating, deposit multiple times a single package, is as simple as registering the already detected labels in the system and to make them not detectable.

Moreover, with this label registration system, we could have a list of tag numbers already free, in case at some point (unlikely) we must repeat numbers, accessing this record we can decide which identification numbers can be reused.

For all the exposed in this section, we can observe that a display in the real world of this platform would not be impossible at all. It would take advantage of the current state of the recycling and RFID sector, and would take advantage of future improvements, some of them very necessary, such as the recycling of RFID tags.

3. STATE OF THE ART

In the state of the art of this memory will be analysed the possible current competition for this platform, as well as the state of the technology that is used in the development of this project and also the benefit this technology brings to the platform Recycling Games.

3.1 Analysis of current platforms

In this section will be analysed the platforms that have a goal or purpose similar to Recycling Games. Existing platforms are either based on collecting waste information from people in each area, or making more efficient the sorting process.

Most platforms differ from the ultimate goal of Recycling Games, being this a platform that seeks to encourage of recycling to users through economic compensation and competitiveness. Based on this, the most similar platform to the one presented in this project would be RecycleBank.

RecycleBank

The creators of this platform define it as: a platform that seeks to encourage recycling by obtaining rewards. (RecycleBank, s.f.) At this point, you can see how the ultimate goal of RecycleBank is very similar, not to say the same as Recycling Games. What differs between the two platforms is the way to achieve this goal.



Figure 2. RecycleBank (RecycleBank, s.f.)

As can be seen in **figure 2**, the objective of this platform is the same as the one of Recycling Games, but differs both in the absence of competitiveness with other users, and by the absence of the 'Gamification' component. Although it is true that it grants an economic compensation or prize for an activity that normally does not have it, there is no component of competitiveness or collaboration, since it is only you as an individual who participates in this platform.

All this, without taking into account the biggest difference, the absence of technology.

The methodology followed by Recycle Banks to earn points through their platform is following one of the next options:

- Save the waste you want to recycle at home, wait to accumulate a certain amount, and call the platform service to come to your house to analyse the waste for which you want to score and later they will assign the corresponding points.
- Send to the application of the platform a list of the elements that you want to recycle, waiting for the response of the service of the application that determines the amount of points obtained.

As you can see, this is the biggest difference between both platforms, with Recycle Games being a fully automated process based on the use of emerging technologies such as RFID. In addition, having to keep the waste at home can be an inconvenience when it comes to obtaining users. This inconvenience is solved in Recycling Games maintaining the current methodology of recycling, giving the possibility to the users to exchange the wastes by points whenever they wish.

Therefore, the RecycleBank platform can be identified as a Recycling Games competition for its common purpose and way of achieving it, but at a technical and practical level, both platforms are not identified as direct competition. Anyway, the existence of this platform, and the market share it has are good indicators for Recycling Games. The fact that a platform with the same objective, but with a methodology that is much more rudimentary and less automated than Recycling Games has more than 4 million users, shows the potential of this market, which, if exploited correctly can bring great benefits.

Reverse Vending

On the other hand, the process of adapting common containers to smart containers must be analysed. Because of this, we can analyse the Reverse Vending Company, which has designed a system of automated machines that use advanced technology to identify, sort, collect and process used beverage containers. (Reverse Vending, s.f.)



Figure 3. Reverse Vending Machine. (*Reverse Vending, s.f.*)

In this case, the machines created by Reverse Vending identify the beverage containers through the bar code. In the same way, this company offers an economic compensation according to the containers of beverages deposited. Thus, we can see how this initiative is very similar to the Recycling Games platform, in terms of objective and means. However, since they assume the risk of performing in the real world, their scope is smaller. Exchanging only beverage containers for points can be a successful design solution, however, they are losing many other recyclable products. This is why the smart container solution provided by Recycling Games is an adaptation of the current recycling containers, which are already prepared to receive any type of recyclable element.

3.2 Analysis of the main technologies

In this project, a lot of different technologies have been used, but the main technology that can generate some technological risk is RFID. After all, this project is based on integrating RFID to the recycling, a field in which the use of this technology is non-existent in the way that this project uses this technology. This risk is not analysed exclusively as positive or negative. On the one hand, being pioneers in the inclusion of an absent technology in a determined area can make a platform embrace the entire market. On the other hand, this can be a negative aspect, since we would be assuming the lack of acceptance or technological problems that could occur. That is why the design of the platform has sought to be as clear and simple as possible, trying to take advantage of all risks as opportunities.

The applications of RFID in the recycling are based on the detection of residues in the recycling plants for their correct differentiation. And yet, this usage is very recent and not widespread globally. If we compare the recycling with a computer application, the recycling plants would correspond to the back-end of the application, and the containers to the front-end. Following this analogy, the use of RFID in recycling is limited to the back-end, so this project seeks the implementation of technology in the front-end of recycling.

The only applications of RFID technology in recycling bins remains at the administrative level and control, never looking for user participation. Some of these applications are: the creation of a system that controls the recycling frequency of a user, this system will be applied in Irun, País Vasco. (Txingudi estudiará los hábitos de reciclaje con etiquetas en las bolsas, 2014). Another application of RFID to recycling is happening in Cleveland, in this case, the use of RFID in recycling is based on knowing how and how much each person recycles. (Cleveland uses RFID tags to track who's recycling, 2010)

In each case, the use of RFID is limited to administrative and control functions, so applying RFID to recycling with the participation of the users is an innovative and risky action.

The reason why RFID has not yet been used in applications facing the user, is due to the lack of information about this technology and the lack of use in areas such as supermarkets. Therefore, the end user does not come into contact at any time with this technology. Accordingly, the incorporation of this technology into a user-oriented application must assume several risks such as: lack of acceptance, not getting accustomed, or similar. However, since the current recycling process would not be modified, these risks would be solved with the ease and accessibility of the platform.

3.3 Study of the state of the art

Taking into account both the existing recycling applications similar to Recycling Games and the use of RFID in recycling, we can draw the following conclusions:

- Being paid for recycling is something that people want.
- Competitiveness is a great tool to keep people interested in your application.
- People use this kind of applications even if they change the recycling methodology.
- This platform maintains a similar recycling methodology from the actual.
- The use of RFID in recycling is starting to spread.
- If the administration uses RFID tags in the recycling plants, and other platforms use them in the recycling containers, it is not a problem to use them in the containers in order to give points to the users.
- Being the first in the creation of some platforms or applications is not always good, but in this case, I think that the very first platform that appears with the aim of promoting recycling using economic compensations will obtain the majority of the users.

Those are some of the benefits that Recycling Games has in relation with the actual state of the technology.

The following table contains a summary comparing Recycling Games with the existing platforms.

Platform	Recyclebank	Reverse Vending	Irún - Tags in bags	Cleveland – Tags in containers	Recycling Games
RFID	✗	✗	✓	✓	✓
Economic compensation	✓	✓	✗	✗	✓
Gamification	✗	✗	✗	✗	✓
Recycling Active Motivation	✓	✓	✗	✗	✓
User oriented	✓	✓	✗	✗	✓
Administration oriented	✗	✗	✓	✓	✓

Table 1. Summary of the study of the state of the art.

In conclusion, the technologies used in the creation of this platform benefit the correct development of this and a sustained growth, supported by external research in emerging technologies, such as RFID. And last but not least, the existence of similar platforms that are working and succeeding, even though they are less technologically advanced, provide a favourable future vision for Recycling Games.

4. RECYCLING GAMES PLATFORM

In this section, the whole Recycling Games platform will be explained, including the functional part, the physical components, etc.

4.1 General explanation

As it has been said in the previous sections, Recycling Games is a platform which aims to motivate recycling by giving the users an economic compensation and a feeling of competitiveness. Moreover, this platform can grant information to the public administration and private companies about the recycled elements.

As a conclusion, this platform is both a control and management tool for administration over recycling, and on the other hand, and mainly, this platform is a tool for users who recycle, providing economic compensation for the elements they recycle. Thus generating a platform in charge of motivating the recycling through previously not practiced ways. The ways used consist of the use of an economic compensation (which is a bit extended) and the use of IoT, specifically the RFID technology. Contrary to the first practice, the use of RFID technology is totally new in the field of recycling (at least in the user part or the “front-end” of recycling).

In this platform, the main components will be the smart-containers and a mobile application.

4.1.1 Smart-containers

The smart-containers will be common containers adapted to be used in this platform, adding them two antennas, a RFID antenna and a NFC antenna. The purpose of adding a RFID antenna is to detect and identify the elements that users recycle, being those elements labelled with RFID tags. The aim of the NFC antenna is to let users identify themselves with the mobile application. Also, these containers will be connected to the platform network, sending all the information to the server, saving it in a database.

4.1.2 Mobile application

The users will have a mobile application, with this, they will be able to identify themselves in the smart-containers, using the NFC sensor of their devices.

Using this application, the users will be able to see how many accumulated points they have, and also, they will be able to buy products using these points.

Moreover, the users will be able to see a ranking of the best *players*, both global and local, in order to create this feeling of competitiveness. With the aim of creating this feeling of competitiveness, there will exist a methodology called *Seasons*, these will be periods of time in which users will compete for better rewards, and after a specific period of time the points will be reset to 0 in order to give everyone the chance to win those rewards.

The combination of the smart-containers and the mobile application will create a platform meant to be accessible by everyone and easy to use, ensuring that everyone can enjoy

Recycling Games, altering as little as possible the current methodology of recycling. In fact, this methodology is only altered by the fact that users need to identify themselves with the smartphone in front of the smart-container, something that requires less than 30 seconds, so this change is not identified as an entrance barrier in order to obtain a great amount of users despite their age and technological knowledge. Seen that, the necessary calculations have been made to know how much time of use of the application is required to carry out the whole recycling process. There are two cases, one in which the user is already logged in the application and the case he is not. In case the user is logged in, the process to start recycling is almost instantaneous, since it only requires a tap on a button located on the first screen that appears in the application when opening it. However, if the user is not already logged, the process is longer, because the user must enter his username and password, in that case, performing that type of action on the street, with the bags of products to recycle can be a drawback. For this reason the mobile application is designed to keep the user logged on until the user decides to log off.

4.2 Analysis of the components

As it has been said, the smart-container will be the element of the platform which contains the hardware and all the components like antennas, readers...

Antenna

The RFID antenna used in this project belongs to Keonn Technologies, specifically, it will be used the model Advantenna-p11, which appears in the following **figure**.



Figure 4. Advantenna-p11. (*Advantenna-p11, s.f.*)

This antenna will be in charge of detecting the RFID tags of the products that are recycled, so it will be located protected inside the container. This antenna has a max detection distance of 3 metres, but in this system, the detection range must be very accurate, sacrificing distance, for precision. The operating frequency is 865-868 MHz. And its beam width is 100°, which give the possibility of positioning the antenna like it is showed in the following **figure**. The orange figure corresponds to the RFID antenna, and the black figure corresponds to the container hole.

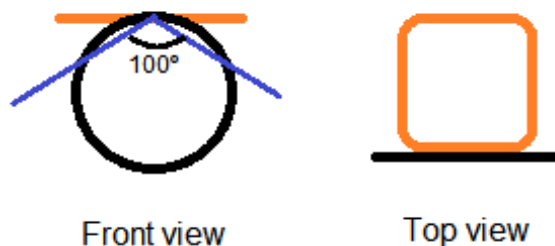


Figure 5. RFID antenna position.

Reader

The RFID reader is the component of the system responsible for performing the communication between the RFID antenna and a computer, translating the signals detected by the antenna into understandable information about the detected tags. The reader used in this project is provided by Keonn Technologies too, the model is AdvanReader-60.

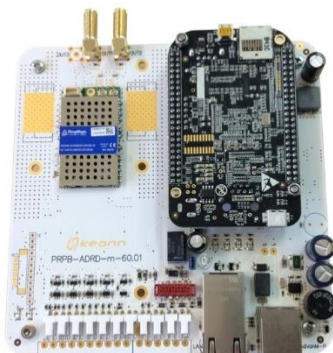


Figure 6. AdvanReader-60. (*AdvanReader-60, s.f.*)

This reader has the possibility to control up to two antennas at a time, giving the possibility of finding an NFC antenna compatible with the reader used.

AvanNet

In order to use this reader correctly, the software/driver AvanNet is needed. This software allows the administrator to check all the information provided by the reader. In this project, the most used functionality has been Monitor. This tab shows the latest RFID tags that have been detected by an antenna. Moreover, this software can generate an XML file with all the information about those detected tags.

5. DESIGN

Once the study of the state of the art has been made with the analysis of the market and the various comparisons in the previous section, we proceed to the preparation of the application itself. For this we must first specify the platform functionalities and define its inner workings.

This section will explain the design of both the global platform and the mobile application.

5.1 Functional Design

This section aims to design a solution that meets the requirements of the platform and the mobile application.

The functional design of the platform and the application will serve to see how future users interact with the system.

5.1.1 Platform functionalities

The functionalities of a platform are the set of attributes that refer to the existence of a set of functions and their specific properties. (UB Glosario Ingeniería, s.f.) In other words, the items defined as functionalities are the different actions that can be performed by the users with the help of the system.

The platform should contain the following functionalities, which will be achieved by the use of different technologies:

Identify	The users need to be identified in order to obtain points from their recycled items. This functionality is achieved thanks to the use of an NFC connection between the container and the user's smartphone.
Detect Recycled Items	The system needs to identify which products is the user depositing in the container. This functionality is achieved thanks to the use of a RFID detection of the tags of the products.
Assign Points	The system must be able to assign points to users depending on the products they have recycled.
Manage Antennas	The platform must be able to manage the antennas of the system, obtaining information from them.

Table 2. Platform functionalities

5.1.2 Application functionalities

The mobile application should contain the following functionalities:

Sign In	The users need to create an account in the application in order to be able to identify themselves in the platform.
Log In	The users need to identify themselves with their username and password to access all the functionalities.
NFC Scanner	The users can start the NFC scanner if they are in front of a smart-container to identify themselves in the system and start winning points.
See the Shop	The users can access the Shop to spend the points earned. All the products will appear to let the user choose which one they want.
Purchase Item	The users can buy the item they want spending the points earned by recycling.
See the Ranking	The users can see the global and local ranking, being able to see who has more points, adding a sense of competitiveness.
See the Profile	The users can access their own profile to see their point's record and edit some information.

Table 3. Application functionalities

5.1.3 Application use case diagram

Depending on the requirements previously specified and the functionalities previously explained, it has been designed a feature map where it can be seen the way that the user will interact with the system. This map or use case diagram also shows the relationship between the different actions that users can perform.

The following **figure** corresponds to the use-case diagram of the Recycling Games application:

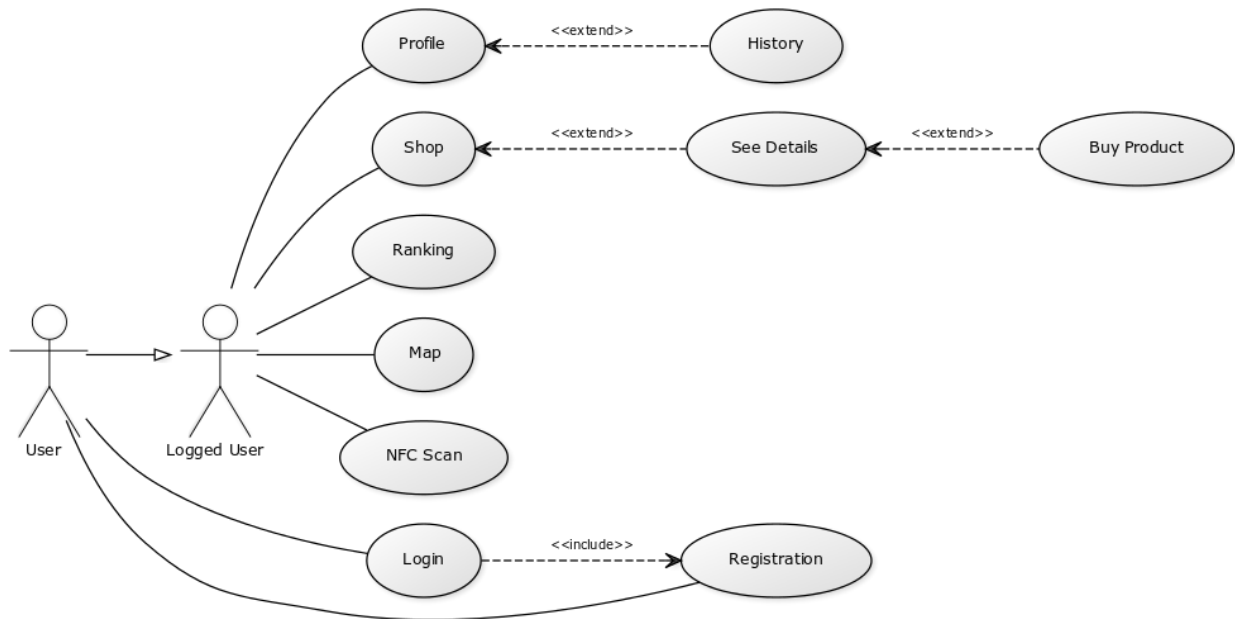


Figure 9. Application use case diagram

As it can be seen, **figure 9** shows the use-case diagram of the mobile application developed in this project.

First of all, users need to create an account (Registration), after this they will be able to identify themselves (Login) and enter the application being a Logged User. Login and Registration have a *include* relationship because the user cannot identify himself via Login if he has not created an account using the Registration form. In order to create and account, users must choose a username that is not already in use, and a password that will be used to access the application, with this information, the Login form will be able to give access to the users if they give correct information.

All the Logged Users can access directly from the Home screen the following functionalities: Profile, Shop, Ranking, NFC Scan and Map.

From the Profile screen the Logged User can see his own information, such as Recycling Points, name, email,... and also he can access from this screen his Points Record (History), this is why a *extends* relationship joins History and Profile, because History adds an extra functionality to the Profile screen.

In the Ranking screen, the Logged User can see both the global and local ranking, being able to see which user has more points and which position in the ranking is he. The main purpose of this screen is to create a sense of competitiveness between users.

The Map functionality lets the Logged User know where he is, and also it shows the nearest smart-containers to his position.

The NFC Scan functionality activates the NFC functionality of the smartphone, and starts looking for a NFC antenna near. If a smart-container is near to the smartphone, it will identify the user in the system, causing the points to be added to the identified user. This functionality will keep the user identified in this smart-container until the user stops the NFC scanner or after 10 seconds of inactivity.

Finally, the Shop is a screen where all the purchasable items appear, letting the Logged User choose which item to buy, spending his Recycling Points. From this screen, the Logged User can access the details of any product (Product Details) and buy the item from this screen (Buy Product). The Logged User, logically, needs to have more Recycling Points accumulated than the cost of the product he wants to buy. A *extends* relationship joins these three functionalities because, first of all, Product Details cannot exist without a Shop, and in the same way, the Logged User cannot buy an item if it is not located in the Shop and its details are accessible.

With this use-case diagram, we can see how it has been tried to reduce the complexity of using the application as much as possible, reducing the application to the only functions of obtaining and spending points, facilitating the accessibility to users with little technological experience.

5.1.4 Application mock-up

Depending on the requirements specified in previous sections, we have designed a prototype mock-up used to define an interface that meets these requirements.

In the **figure 10** appears the mock-up of this application, as has been said in the previous section, it has been tried to keep a simple and easy to understand design, giving everybody the possibility to use this application, regardless their technological knowledge.

Having the NFC Scan button and the Map on the main screen provides easy access to the most recurrent functionalities. Being able to use both, easily and quickly in the middle of the street.

Having the rest of functionalities together in a sliding menu facilitates the navigation, making easier to find anything. Also, having only one way to access a final screen like the product details of any item gives a straight and quick navigation.

In conclusion, this mock-up has been designed with all types of users in mind, trying to guarantee the qualities that every application must have: usability and intuitiveness.

Usability understood as the degree to which a software can be used by a user to achieve the application objectives with effectiveness, efficiency and satisfaction. (ISO 9241-11:1998 - Ergonomic requirements for office work with visual display terminals, 1998)

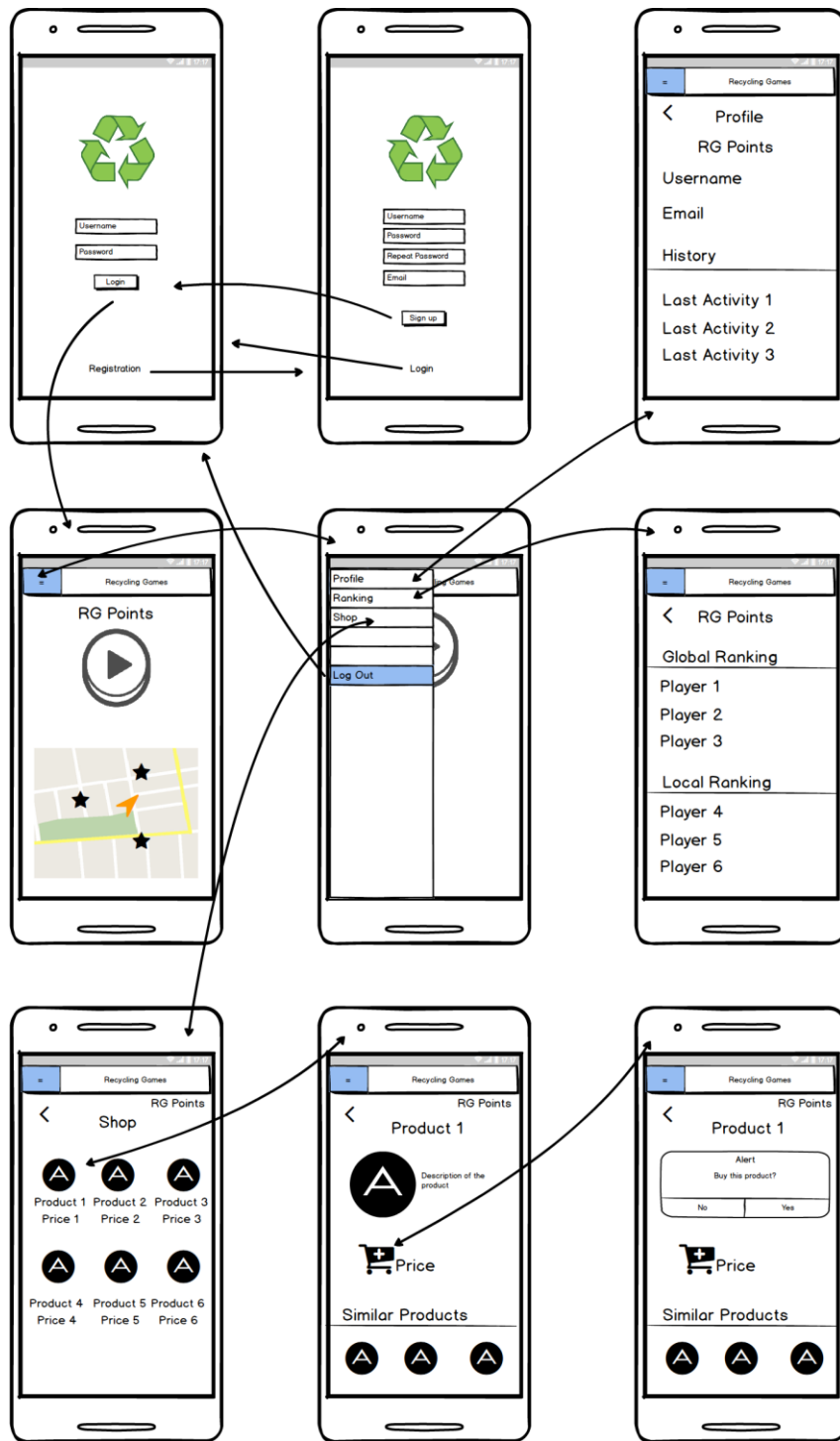


Figure 10. Application mock-up

a) Login screen

This screen will be displayed when the application starts. This screen will allow a user already registered in Recycling Games to access by his username and password.

This screen should also provide access to the Register screen to sign up.

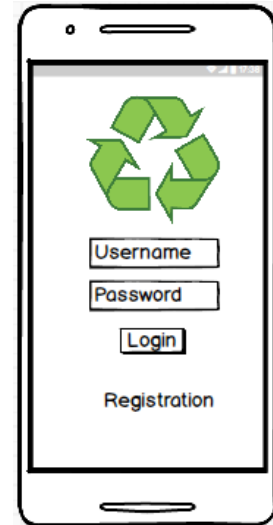


Figure 11. Login screen

b) Register screen



Figure 12. Signup screen

This screen allows the user to make a sign up, in other words, to register on the platform and thereby be able to access the application.

This register will be implemented through a username, email and password. The inserted username cannot be already in use by anyone else, and also it will be necessary to repeat the password to prevent access errors.

Once the user has completed the registration, and all the information is correct, the account will be created, and the user will be sent to the login screen to access the application with his just created account.

The information given in this screen by the user, will be stored in a private database allocated in a server. The only part that may be visible to other users will be the username if it appears in the ranking screen.

c) Home screen

This will be the main screen of the application, from this screen, all functionalities are accessible. The user can check his Recycling Points at the top of this screen.

The two visible functionalities in **figure 13** are the NFC Scan button and the map. In the map will appear the position of the user and the location of the nearest smart-containers. Pressing the NFC Scan button an alert will appear to tell the user that the device is now looking for an NFC antenna to identify the user with his username. Pressing again the NFC Scan button will make the device stop looking for any NFC antenna.

In **Figure 14** appears the Home screen in addition to the slide menu. This menu is accessible from any other screen to navigate to application easily.

Using the buttons in this menu the user can navigate to any of the following screens: Profile, Ranking, Shop and also it will let the user Log out, closing his session and returning to the Login screen.

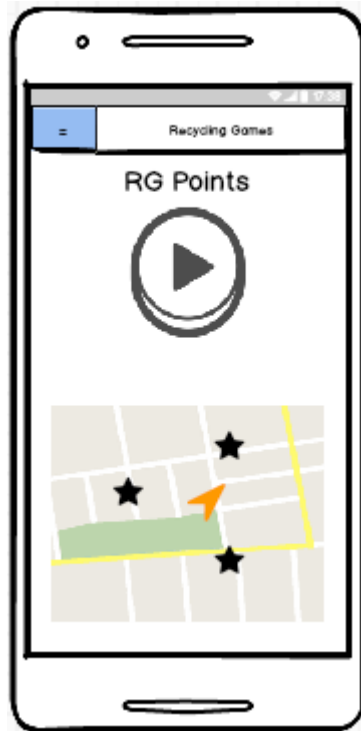


Figure 13. Home screen

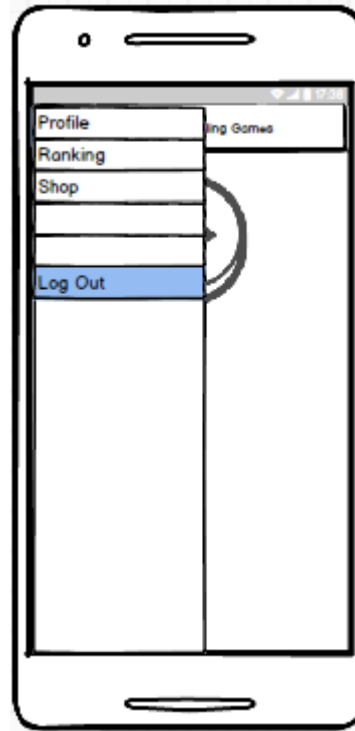


Figure 14. Home screen with slide menu

d) Profile screen

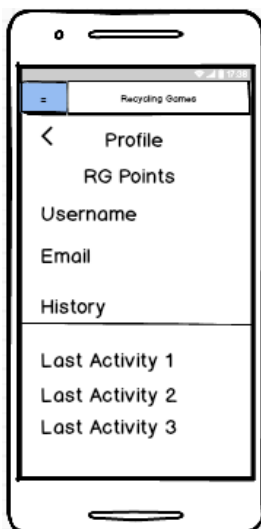


Figure 15. Profile screen

In the Profile screen, the user can see information about himself, such as: Recycling Points, Username, Email... and also he has access to his point's record.

In the History part of the screen will appear the most recent point's movements (Obtained points and Spent Points).

The user has two ways to return to the Home screen, one by clicking the Back button (represented as an arrow pointing left) and the other by clicking the title of the screen.

e) Ranking screen

In this screen, the user will be able to see “the best players”, those players are the ones that generate more points.

The screen is divided by Global and Local ranking. Understanding Global as showing the players with more points regardless of where they are. And understanding Local as showing the players with more points in your area, in order to have a bigger sense of competitiveness with users who are maybe friends or familiars.

In the future, this screen will become more important as it is planned to grant users rewards according to their ranking, creating *seasons*, in which the points counters will be reset when the *season* ends after some weeks, thus giving opportunities to everyone to win better prizes.



Figure 16. Ranking screen

f) Shop screen

The shop screen (**Figure 17**) is one of the most important ones, because in this screen, the users will be able to select which product they want to buy.

The user will be able to see his Recycling Points in the top right corner of the screen. The rest of the screen will be a grid of all the available products, with their name and price.

If a user taps on any product, he will be sent to another screen with the details of this product (**Figure 18**). In the Product details screen, the user will be able to see a description of the product and similar products suggestions, in addition to the possibility to buy this product by clicking the shopping cart.

Once the user clicks the shopping cart to buy a product, an alert will appear (**Figure 19**) to let the user confirm his purchase. The user will only be able to buy a product if he has enough Recycling Points accumulated.



Figure 17. Shop screen

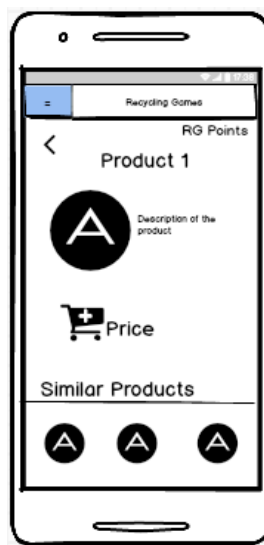


Figure 18. Product details screen



Figure 19. Purchase alert

5.2 Technical Design

Once defined the solution at the functional design section, we now proceed to define an architecture, analysing both hardware and software, that gives support to the solution previously proposed.

Here will appear the architecture design of the platform, also we will see how the internal parts of the platform are related, as well as the relation between the database and the application and the operating system.

5.2.1 Architecture

In the **Figure 20** appears de Architecture Diagram, it shows how the platform works internally.

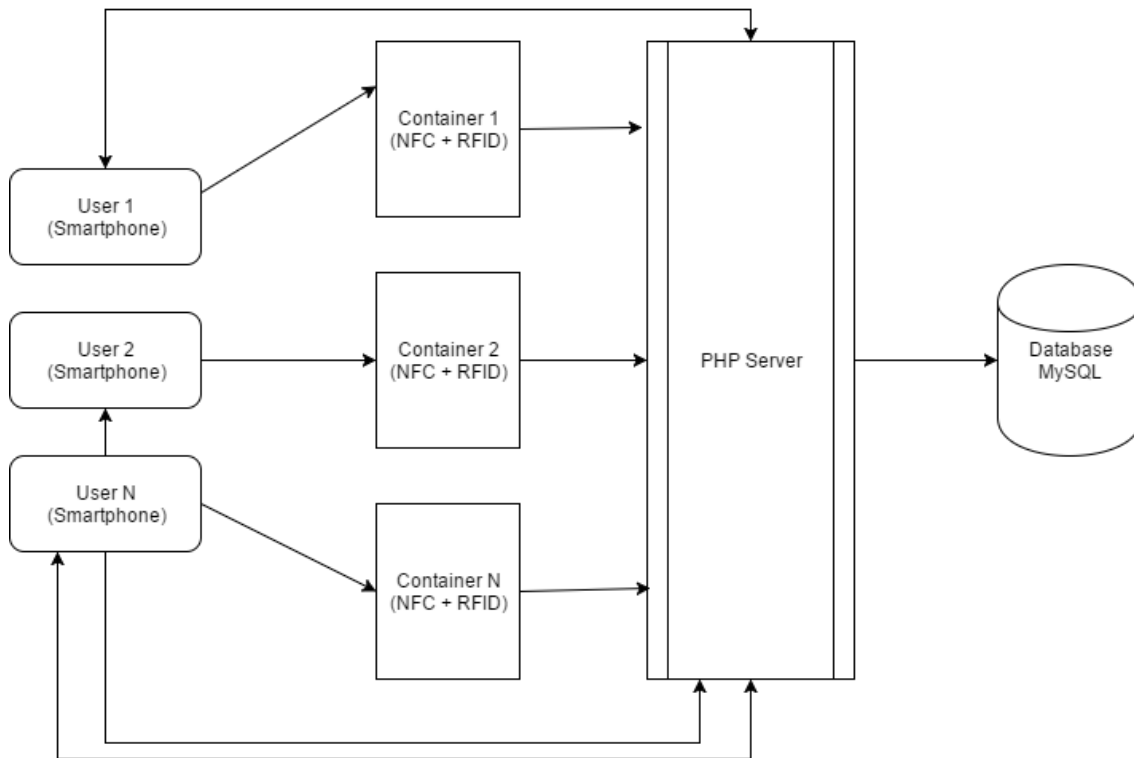


Figure 20. Architecture Diagram

It can be observed how each user that connects to a smart container, generates a connection with the server. In this server there is allocated a database, which contains all the data of the system. The database is both accessible from the smart containers, and from the mobile application, through the server.

As it can be observed, the connection between the mobile application and the container is made through an NFC connection. The container detects the recycled products via RFID and connects to the database using the PHP connection provided by the server. The database is based on MySQL, which works perfectly with PHP servers.

RFID Architecture

The RFID system has its own architecture, being this one of the main parts of the project. In the following picture appears the global architecture diagram.

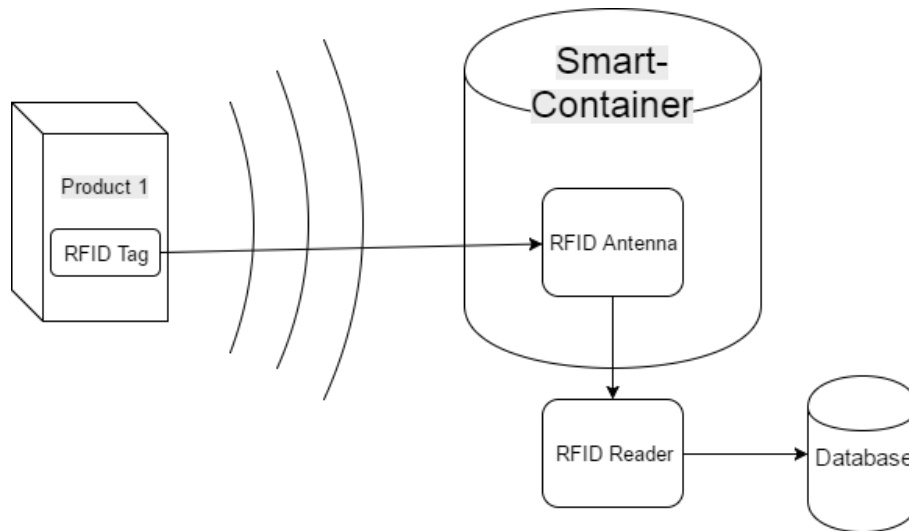


Figure 21. RFID Architecture Diagram.

It can be seen how the recyclable product identified with a RFID tag is detected by the antenna located in the smart-container. After a product is detected, the smart-container sends the information to the database.

To have a better idea of every component used, they will be explained separately:

- **RFID Tag:** It will be used passive RFID tags, it means that this tags does not need any power supply, this type of RFID tags react to the radiofrequency signal emitted by the antenna. They are cheap, recyclable and power efficient.
- **RFID Antenna:** It will be used an antenna provided by Keonn Technologies. As it was explained previously, this antenna will emit a radiofrequency signal, which will be received by the tags, and the signal rebound will contain the information about this tag. In order to be able to understand the received data it is necessary the following component.
- **RFID Reader:** It will be used a reader provided by Keonn Technologies. This component is needed to create an understandable file containing the information of the detected tags. This component is in charge of the connection between the antenna and the computer used to manage the information.

5.2.2 Block diagram

In the **figure 22** appears the Block Diagram of the **mobile application**. This diagram shows how the different elements that make up the application are related and how the different parts of the system are needed in the whole platform.

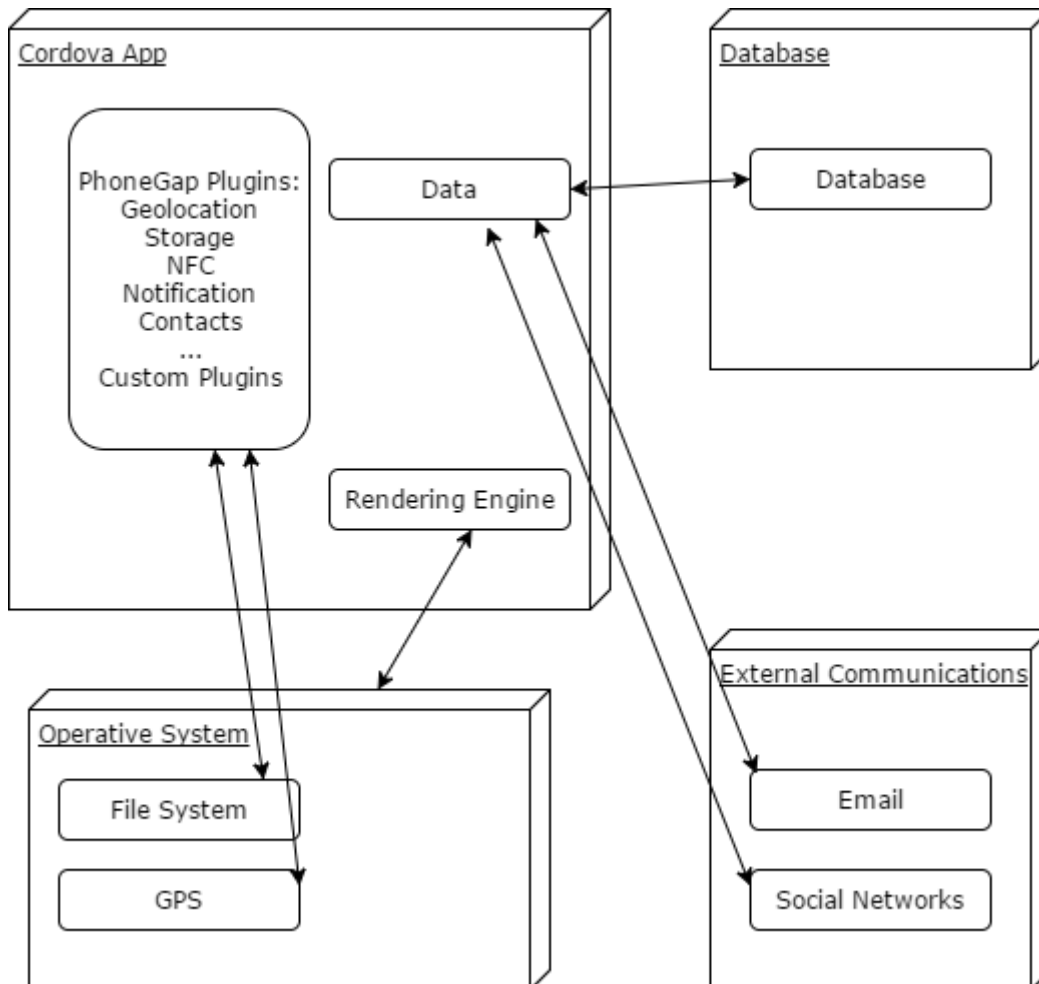


Figure 22. Block Diagram

The first thing that we can observe, is that the mobile application has been developed using Cordova/PhoneGap, ensuring that the application can be build up for different operating systems, guaranteeing the maximum distribution. This development environment has its own plugins (geolocation, NFC, storage...) which can take benefit from almost all capabilities of the smart device. Moreover, this environment grants the possibility of connecting the application with a PHP server, via AJAX. In order to use correctly al the Cordova plugins, the application needs to use three operative system functionalities: GPS for the geolocation plugin, File System for the local storage plugin, and it also uses a rendering engine, so the application needs the GPU of the smart device.

As it was explained in the architecture section, the mobile application gets the data from the database allocated in a server. In addition, some of this data can be shared via email or social networks, such as the products that a user has purchased.

The application is quite autonomous, excluding some extra features, it would work properly just installing it on a device with internet connection, ensuring that the application does not need devices with high features or very complex environments to operate.

5.2.3 Final solution

In the final solution applied to the platform, different technologies and multiple architectures have been joined, so each part of the solution will be explained separately.

Server and Database

The server is allocated in a laptop, therefore, in order to perform the simulation, the mobile device with the application, must be on the same subnet as the laptop, using a Wi-Fi access point.

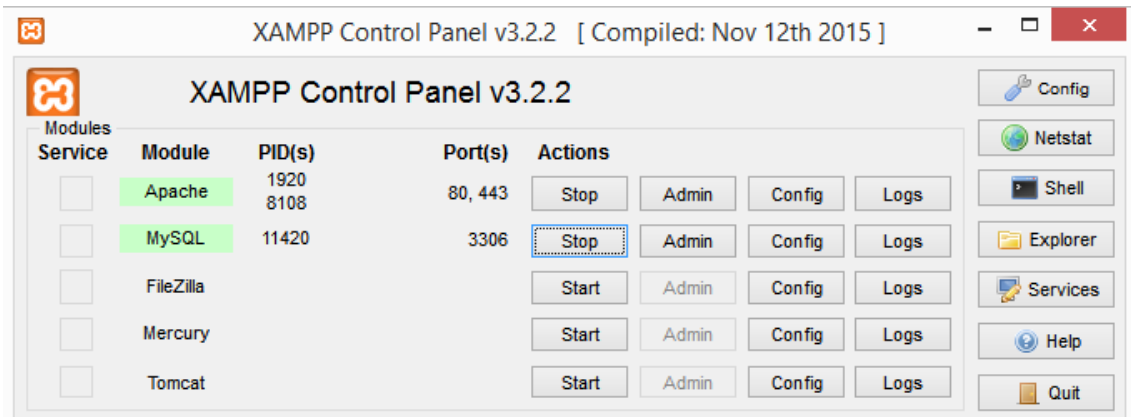


Figure 23. XAMPP Server

The server is deployed over an Apache distribution, using a PHP language interpreter. Moreover, XAMPP allows to create a MariaDB database, which is a distribution of MySQL database.

It is possible to manage this database via *phpMyAdmin* or MySQL Workbench.

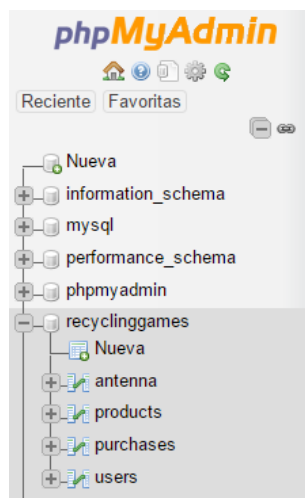


Figure 24. phpMyAdmin Control Panel

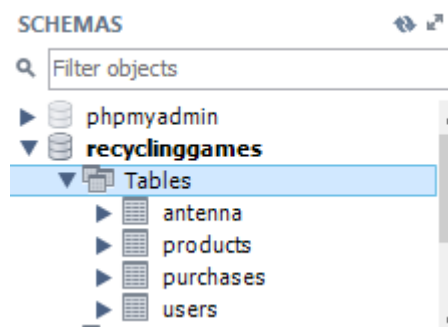


Figure 25. MySQL Workbench Control Panel

Application

As discussed above, the mobile application has been developed using Cordova/PhoneGap. This development environment is based on mixing HTML5, JavaScript and CSS, instead of using native APIs of Android, iOS or Windows Phone.

Cordova allows to create a simulation of the application in localhost, which works perfectly with our solution used, because our server is allocated in localhost.

```
C:\Users\Alejandro\Desktop\TFG\RecyclingGames>cordova run browser
Running command: cmd "/s /c "C:\Users\Alejandro\Desktop\TFG\RecyclingGames\platforms\browser\cordova\build.bat"
```

Figure 26. Cordova creating a localhost environment

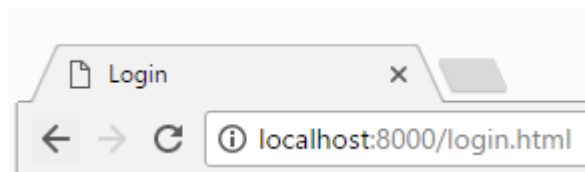


Figure 27. Cordova localhost environment created

Cordova contains some plugins that offer the possibility to use all the capabilities of the smart device. In this solution, it has been used the following plugins: geolocation, storage, NFC, notifications, contacts and more.

This environment allows to connect the mobile application with the rest of the platform with ease. These are some examples:

- Connection with the database: using Cordova, and specifically JavaScript, it can be used AJAX (Asynchronous JavaScript And XML), this technology is based on an asynchronous communication between the server and the client, it is really helpful to create a communication between the application and a PHP server.
- NFC connection: in order to identify the user in the smart-containers, it is used a NFC connection, to make it possible it has been used the NFC Cordova plugin.
- Local storage: users can set an image in their profile, it is possible using the local storage Cordova plugin.

In conclusion, Cordova/PhoneGap is a great choice to use in this solution, because it allows to build up the application for different operative systems with ease, ensuring an easy distribution. It allows to connect the application with all the parts of the platform fitting perfectly with the architecture of the system. Making other intermediate software not necessary.

RFID

As it was mentioned before, one of the main objectives of the platform is to incorporate the RFID technology to recycling. The RFID technology is capable to identify objects from a distance thanks to radiofrequency signals emitted from an antenna which is able to detect tags with a microchip. As it can be seen in the next **figure**, the antenna emits a radiofrequency signal, which is answered by the microchip inserted in the tag. In this project it has been used passive tags, it means that the tags only react to the signal emitted by the antenna, they are unable to emit any signal by they own, and in addition, they do not need any power supply.

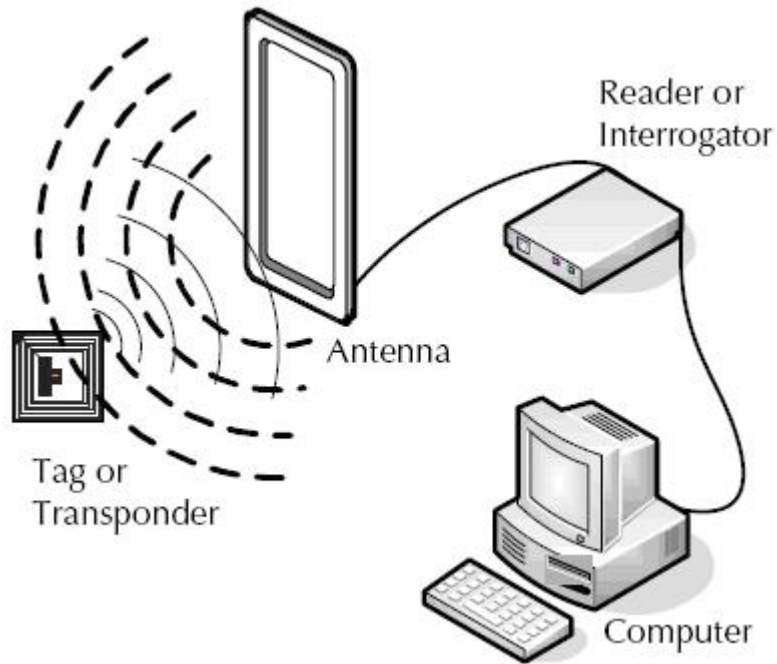


Figure 28. RFID Scheme

6. IMPLEMENTATION

In this section, we will follow the steps to create the prototype of the platform proposed in this final, it will be shown how the structure of the database, and also it will be explained via a class diagram the different classes and entities that make up this project.

6.1 Database creation

As it was explained in the design section, the database is based on MySQL, specifically on MariaDB. In the following image appears the structure of the database and how the different tables are related.

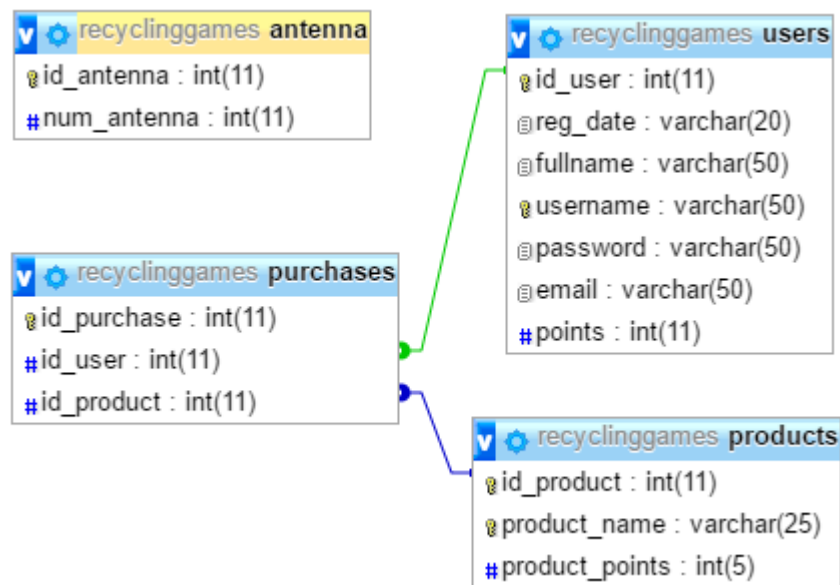


Figure 29. Database structure

The database is composed of four tables: users, products, purchases and antenna.

- Users: This table contains all the information referred to the users: a unique id, the date of registration, their full name, a username (which cannot be repeated), a password, an email and the points that this user has available.
- Products: This table contains all the information referred to the products: a unique id, the public name of a product (it cannot be repeated) and the cost of this product in points.
- Purchases: This table is used to join the users and products tables, this table links each user to the products that he has purchased in the past, using both the user id and the product id.
- Antenna: This table contains all the information referred to the antennas, this table is used to control the amount of points that an antenna is detecting. This table has only control purposes.

6.2 Control Panel

In order to manage the database in a simpler and visual way it has been created a control panel as a desktop application using Java. In the following image appears the class diagram of this application, showing the classes and the functions used to create this visual interface to manage the database.

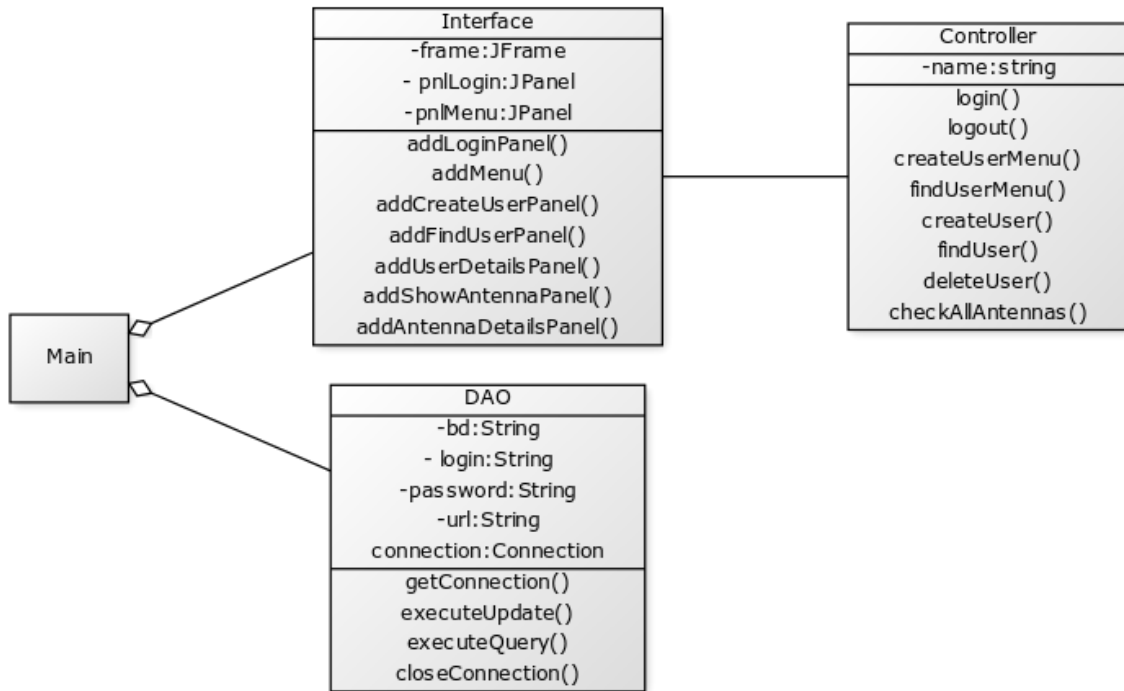


Figure 30. Control Panel Class Diagram

In order to create this desktop application it has been used a kind of MVC (Model-View-Controller) methodology applied on Java.

This application is composed of the following parts:

- Main: Using this methodology, the Main class is used only to create the connection with the database and to start the first screen of the application.

```
public class Main {
    public static void main(String[] args) {
        final DAO dao = new DAO();
        dao.getConnection();

        Interface.addLoginPanel();
    }
}
```

Figure 31. Main Class code

- DAO: This class is used to create the connection with the database, it needs the url of the server, the name of the database and the credentials to enter this database, with the higher privileges if it is possible.

```

static String url = "jdbc:mysql://localhost/" + bd;
Connection connection = null;
/**
 * DbConnection Constructor
 */
public DAO () {
    try {
        //We obtain the driver to use MySQL
        Class.forName("com.mysql.jdbc.Driver");
        //We obtain the connection
        connection = DriverManager.getConnection(url, login, password);
    }
}

```

Figure 32. DAO Class code

- Interface: This class would be identified as the View part of the MVC model. This class is responsible for displaying the different views of the application on screen. This class is closely linked to the following one, the Controller. It could be identified the Interface class as the "face" of the application. As it can be seen in the following image, the Interface class is composed of all the functions which create the visual part of the different screens of the application. It is possible to create a visual interface with Java using the Swing Library, it contains objects such as JFrame, JPanel and JButton which create visual elements with the standard Windows format.

```

public class Interface {

    private final static JFrame frame = new JFrame("Recycling Games");
    final JPanel pnlLogin = new JPanel();
    final JPanel pnlMenu = new JPanel();

    public static void addLoginPanel() {...92 lines }

    public static void addMenu() {...73 lines }

    public static void addCreateUserPanel() {...117 lines }

    public static void addFindUserPanel() {...64 lines }

    public static void addUserDetailsPanel(String username, String userPoints) {...56 lines }

    public static void addShowAntennaPanel(String num_antenna[]) {...44 lines }

    public static void addAntennaDetailsPanel(String num_antenna[]) {...44 lines }

}

```

Figure 33. Interface Class code

- Controller: This class is the Controller part of the MVC model. As it was said before, this class is responsible for making decisions and performing calculations and queries. Using the analogy previously mentioned, this class would correspond to the "brain" of the application. As it can be seen in the following image, this class contains all the functions used to make calculations and queries, and also call to Interface's functions to change the screen showed in the application.

```
public class Controller {  
  
    public static String name;  
  
    public static void login(String username, String password) {...23 lines }  
  
    public static void logOut () {...4 lines }  
  
    public static void createUserMenu () {...3 lines }  
  
    public static void findUserMenu () {...3 lines }  
  
    public static void createUser(String username, String password) {...20 lines }  
  
    public static void findUser(String username) {...26 lines }  
  
    public static void deleteUser(String username) {...3 lines }  
  
    public static void checkAllAntennas () {...17 lines }  
  
}
```

Figure 34. Controller Class code

6.3 Mobile Application

In this section will be explained the implementation and development of the mobile application. As it was explained in the design section (5. DESIGN) the mobile application has been developed using the Cordova/PhoneGap environment. This means that it has been used HTML, JavaScript and CSS in order to create this multiplatform application, and as external resources it has been used AJAX, jQuery and Bootstrap.

The HTML pages used are: index, login, signup, home, profile, ranking, shop and product. Those are the different screens or views that the application has. Being the HTML part the "skeleton" of the application.

The HTML part is closely linked with the CSS, being the CSS the "skin" of the application. It used to make the application look like we want. In order to have a simpler manage of the CSS it has been used Bootstrap framework.

In the following image appears an example of the combination of HTML and CSS using Bootstrap.

```
<div id="page" data-role="page">
  <div data-role="panel" id="myPanel" data-display="overlay">
    <p id="shop" style="font-family: Lato"> Shop </p>
    <p id="profile" class="element_panel" style="font-family: Lato"> Profile </p>
    <p id="ranking" class="element_panel" style="font-family: Lato"> Ranking </p>
    <p id="logout" class="element_panel" style="font-family: Lato"> Log out </p>
  </div>

  <div data-role="header">
    <a href="#myPanel" class="ui-btn-left ui-btn ui-btn-inline ui-mini ui-corner-all ui-btn-icon-left ui-icon-bullets"></a>
    <h1 id="goToHome" style="font-family: Lato">Recycling Games</h1>
  </div>

  <div class="row" style="margin-top: 10px">
    <div class="col-xs-12 col-md-12">
      <p align="center" style="font-size:25px; font-family: Lato"> Home </p>
      <p align="center" style="font-size:20px; font-family: Lato" id="points"></p>
    </div>
  </div>
</div>
```

Figure 35. HTML + CSS Example

All the functionalities of the applications are managed using Javascript, being the “brain” of the application. This language allows us to insert other languages within the HTML code, besides performing their own functions. Using Javascript we can also use AJAX and jQuery.

As it was explained in the design section (5. DESIGN), AJAX is used to make possible a connection between the application and the PHP servers, using JSON packets. In the following image appears an example of an AJAX call:

```

if($.trim(username).length>0 & $.trim(password).length>0)
{
    $.ajax({
        type: 'POST',
        url: 'http://192.168.137.1/myplaces/login.php',
        dataType: 'json',
        data: {username: username, password: password},
        crossDomain: true,
        cache: false,
        success: function(response){

            if(response=="noexist")
            {
                alert("This username doesn't exist.");
            }
            else if(response=="success")
            {
                sessionStorage.setItem("user", JSON.stringify(username));
                window.location = "home.html";
            }
            else if(response=="failed")
            {
                alert("Incorrect password");
            }
        }
    });
}

```

Figure 36. AJAX call example

This concrete AJAX call is used to check the login function of the application. Here will be explained the different fields used in the AJAX call separately.

- type: In this example the type of the call is POST, this type of call is usually used when this function has to change any information in the server, but it is not the case, in this example, it is used POST because the login action cannot accidentally happen, this functionality should not be accessible via URL, as it would be if the type GET was used.

- url: In this field appears the PHP file addressed in the server, in this example, it is login.php, because in this file it is defined how the Login action must work.

- dataType: In all the AJAX calls used in this application the dataType is JSON. It is an open-standard file format that uses human-readable text to transmit data objects consisting of attribute–value pairs and array data types. (A Modern Reintroduction To AJAX, s.f.) In other words, using JSON grants us (as developers) the capability of reading the information transmitted between the server and the client without any encryption.

- data: This field contains the information that will be sent to the server in the JSON file. It relates the name of the variable that the server will receive and the variable name or information in the application. In this case, as we are trying to log in, the username and the password introduced by the user are sent to the server to check if those are correct or not.

- crossDomain: This field set to True grants us the capability of sending requests to a server that is in a different domain or network.
- cache: Setting the cache field to False makes the browser or the application not saving any information of the request, it uses a timestamp instead, it is a way to save space, since many Login request will be made.
- success: This field is used to set the action of the application depending on the server response. In this example, the action is separated in three different responses because of the Login action definition in the PHP file.

In the following **figure** appears how the Login action is defined in the PHP file:

```

if(mysqli_connect_errno())
{
    echo "Failed to connect to DB";
}
$username = mysql_real_escape_string(htmlspecialchars(trim($_POST['username'])));
$password = mysql_real_escape_string(htmlspecialchars(trim($_POST['password'])));
$q1 = "SELECT * from `recyclinggames`.`users` where `username`='". $username. "'";
$result1 = mysqli_query($con, $q1);
$numrows1 = mysqli_num_rows($result1);
if($numrows1==0)
{
    echo json_encode("noexist");
}
else
{
    $q2="SELECT * FROM `recyclinggames`.`users` WHERE `username`='". $username. "' AND `password`='". $password. "'";
    $result2=mysqli_query($con,$q2);
    $numrows2 = mysqli_num_rows($result2);

    if($numrows2!=0)
    {
        echo json_encode("success");
    }
    else
    {
        echo json_encode("failed");
    }
}
echo mysql_error();

```

Figure 37. Login action definition in login.php

Now that we have the Login action definition in the PHP file login.php, we can understand why the AJAX success action is divided in three different responses. As it can be seen in the PHP code, the server sends three different responses depending on the result of the request.

The server gets the username and password values and creates a query addressed to the MySQL database looking for a result matching the username written by the user. If this username does not exists in the database, the server will send a “noexist” message, this I the first response case. If the username exists in the database, the next step is checking if the combination of the username and the password is correct. If the information is correct the server will send a “success” message, and in the negative case, the server will send a

“failed” message. With these three responses we can figure in the Javascript code which was the problem.

Other examples of PHP definitions are: signup, points, buy, history and ranking. In conclusion, every action that requires a request to the database needs a PHP file which makes this connection between the Javascript code and the database.

Once seen all the modules that are part of the mobile application, it is shown in a diagram the complete operation of this one.

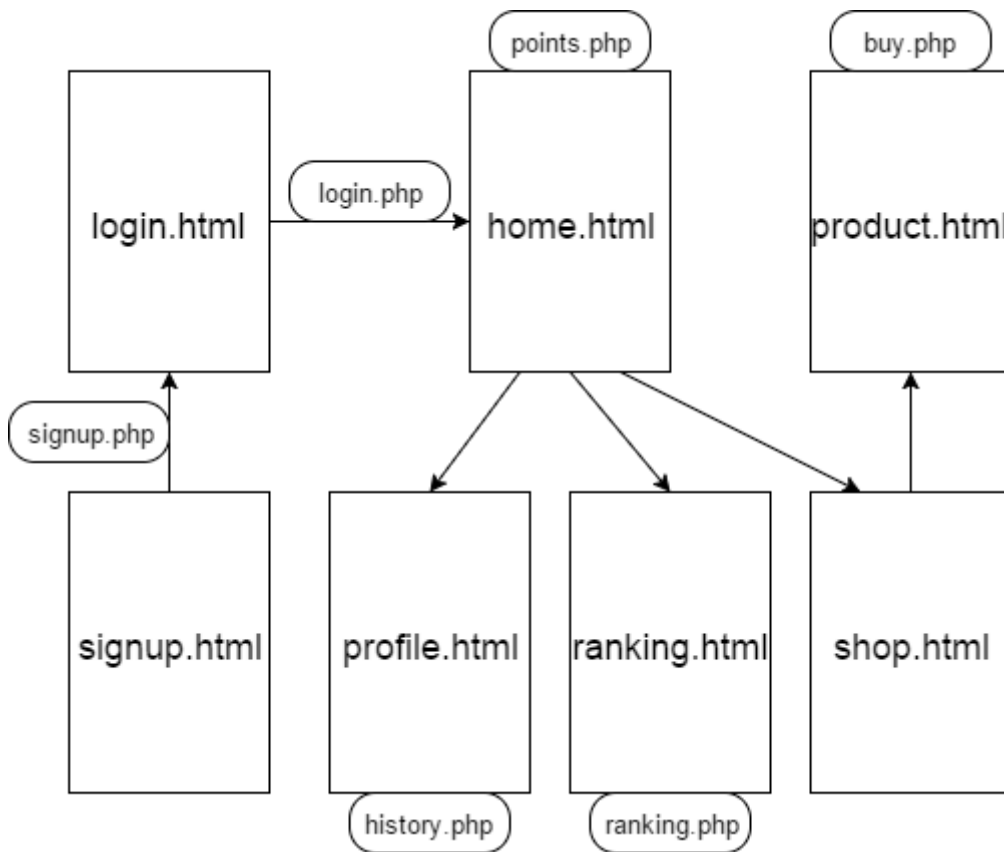


Figure 38. Application work-flow

In the **figure 38** appears how the HTMLs and the PHPs are connected. The work flow of the application would be the next one:

- In the Signup screen (signup.html) the user can create an account entering a valid combination of username and password.
- Signup.php will check if the data entered is valid and will create the account, saving this credentials in the database.
- In the Login screen (login.html) the user must enter a valid combination of username and password.
- Login.php will check with the database if the data entered is valid and will move the user to the Home screen if it is correct.
- In the Home screen (home.html), points.php will be called, saving in the session storage the amount of points that the user has in this moment, requesting it from the database.

- In the Profile screen (profile.html), history.php will be called, requesting from the database the last ten points movements of the user, printing them in the Profile screen.
- In the Ranking screen (ranking.html), ranking.php will be called, requesting from the database the first ten users with more accumulated points, and printing them in the Ranking screen.
- For the demo, in the Shop screen (shop.html) the products that appear are no dynamic, this is why no PHP file is called.
- In the Product screen (product.html), once the user tries to purchase an item, buy.php will be called, checking if the user has enough points to buy this item, and subtracting them from the database if he has enough.

6.4 Application prototype

In the following figures, it will be shown the result of the first prototype of the application. It has a temporal design, but all the requested functionalities work.

First of all we can check that the user “test2” does not exist in the database:

	id_user	reg_date	fullname	username	password	email	points
<input type="checkbox"/>	1			admin	admin		500
<input type="checkbox"/>	2			test	test		5642
<input type="checkbox"/>	4	23-03-17 06:01:38	test1	test1	test1	test1@gmail.com	1333

Figure 39. Users table in the database.

First of all, we must create the user “test2” in the Signup screen.

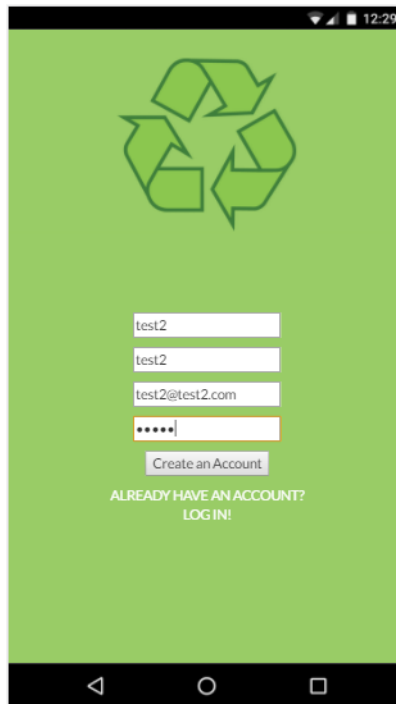


Figure 40. Creation of “test2” user.

Now the user is correctly created in the database:

		id_user	reg_date	fullname	username	password	email	points	
<input type="checkbox"/>	Editar	Copiar	Borrar	1		admin	admin	500	
<input type="checkbox"/>	Editar	Copiar	Borrar	2		test	test	5642	
<input type="checkbox"/>	Editar	Copiar	Borrar	4	23-03-17 06:01:38	test1	test1	test1@gmail.com	1333
<input type="checkbox"/>	Editar	Copiar	Borrar	16	10-06-17 11:55:24	test2	test2	test2@test2.com	0

Figure 41. New Users table in the database.

Now that the user is created, we can log in using the credentials introduced before, then the application will show the Home screen of the user “test2”.

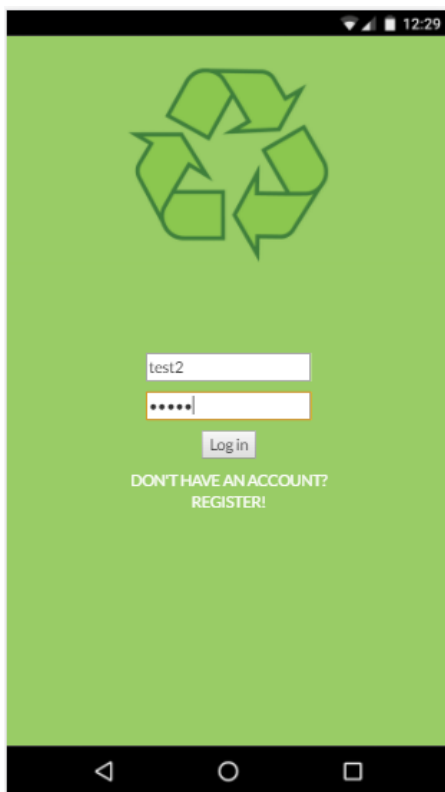


Figure 42. Login screen.

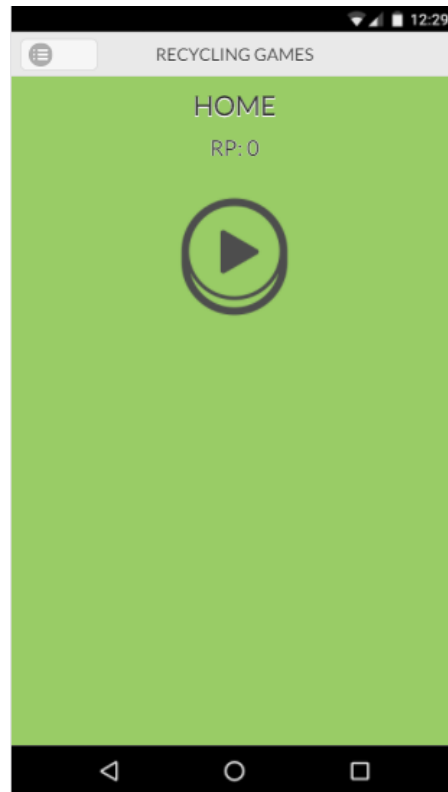


Figure 43. Home screen.

As it can be seen in the previous **figure**, the user “test2” has 0 Recycling Points, as it is a fresh created account. The Play button that appears in the Home screen is the one used to start the NFC sensor to let the user identify himself in the smart-container.

In the following **figure** appears the Ranking screen, showing the best players, it can be confirmed by looking at **figure 44** that these are the players with the most accumulated points.

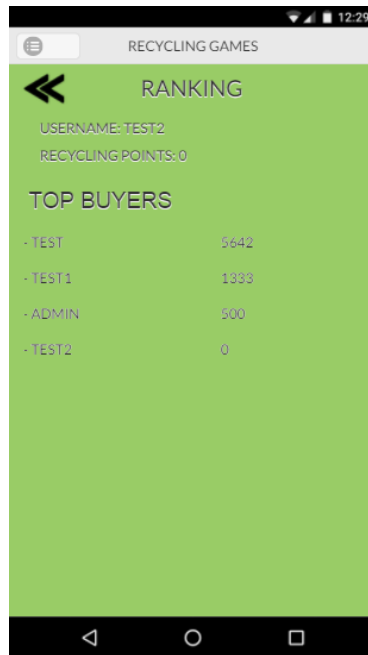


Figure 44. Ranking screen.

In the following figures it will be shown a purchase example, showing that in the very start, the user has no previous purchases. After, I will give some points to user “test2” to let him buy some products, refreshing by this the last purchased items of the user in his Profile.

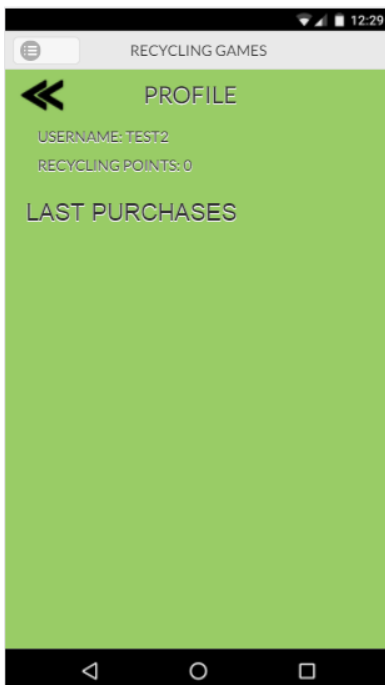


Figure 45. Profile screen with no Last Purchases.

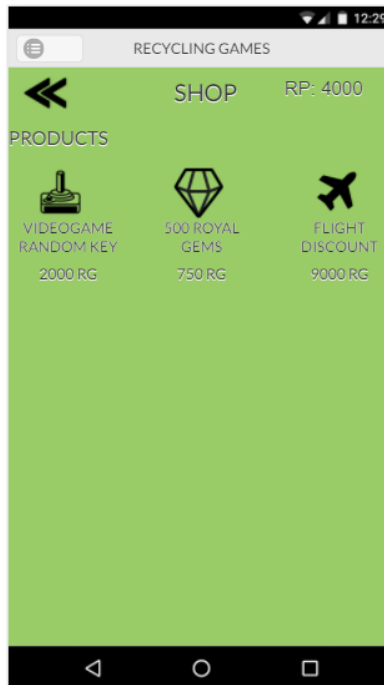


Figure 46. Shop screen with updated Recycling Points.

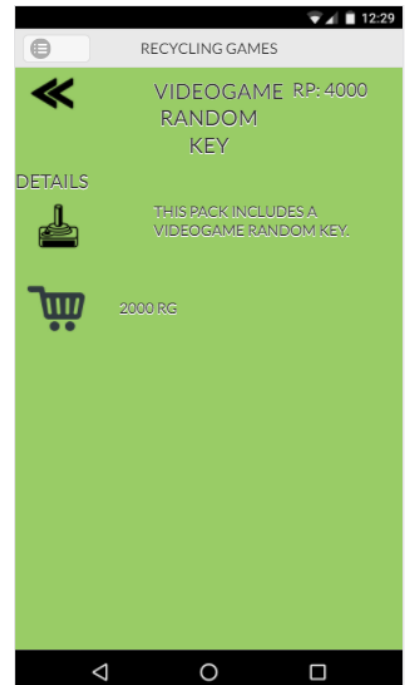


Figure 47. Product 1 details.

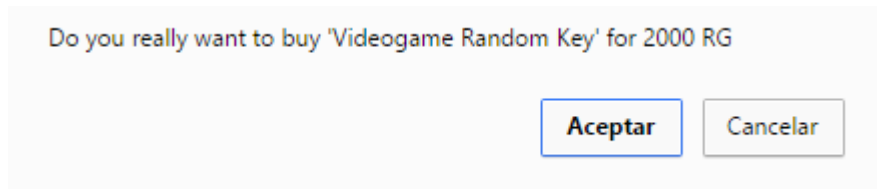


Figure 48. Purchase confirmation alert.

As it can be seen in the following **figure**, the user “test2” has now 2000 Recycling Points (4000-2000 of the previous purchase) and it appears the last item purchased in the Profile screen.



Figure 49. Profile screen with Last Purchased items.

In this section has been showed the complete natural flow of the application, which consists on:

- Creating an account.
- Log in with this account.
- Earn Recycling Points by recycling some elements.
- Look for any item in the shop that you can afford.
- Buy it.
- As extra functionalities: check your position in the Ranking and check the Last purchases.

7. CONCLUSIONS

As a conclusion to close this report, it is concluded that the established objectives have been fulfilled, these being the creation of all the platform parts, creating a functional prototype of the platform.

With the development of this project I have discovered even more the potential of RFID technology, and in general, the IoT potential. I have also discovered that with the right amount of money and time, the creation of such a platform could be a great market opportunity, therefore, the efforts dedicated to the realization of this project have not been in vain, and thanks to this I now have a greater knowledge on all the technologies used, and a greater vision on the realization of a project that starts from an own idea.

The main actions to be taken in order for this platform to succeed if it exists, are the creation of an application with a design that people like and the realization of a powerful advertising campaign. This is because the current methodology of recycling is not modified with the use of this platform, and therefore, there are no major barriers to the use of this platform. All the actions taken looking for the success of this platform must be based on obtaining a good image of the brand facing the customer and on obtaining agreements to offer more and more products in the application store.

As it has been mentioned previously, the use of RFID technology favours the success of this platform, since being an emerging technology with a view to the future, this technology will be improved more and more by the technicians, which offers the possibility of updating the technology used in this platform periodically, offering a better quality of service in terms of speed of response and ability to detect recyclable elements easily.

In addition, I clearly know what the following steps would be for the correct development of the platform, leaving for future tasks:

- The adaptation of the system for the possible identification of users with NFC elements different from the smart-phone, such as a key ring. With the intention of guaranteeing greater accessibility.
- Conduct a market study and cost analysis to study the feasibility of the project.
- Improvement of the mobile application, both in design and optimization.
- Deploying the database to a server in the cloud.
- Search for investors for the final deployment in a pilot city.

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