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Project Report

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Innovative System Design and Development I

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REZES Recycling IoT Application Systems

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Abstract

Environmental pollution is a global issue caused directly by mankind. Almost every inorganic material is in a problem situation for natural recycling. The nature itself cannot easily dispose inorganic materials. Preventing such a cause can only be made of increasing awareness on recycling. REZES project will prevent environmental pollution and provide added value by recycling metal, plastic and glass using IoT (Internet of Things) Technologies, Image Processing, Big Data Analysis and Gamification ideas. The system will include QR code technology, a microprocessor (Raspberry Pi-3), a mini LED display screen, Camera Modules and sensors. As a results of combining all these parts, an automated recycling machine system where the garbage will be converted into reusable materials will be created.

Keywords: Internet of things, image processing, big data analysis, gamification, recycling machine, mobile application, QR code, sensor.

Özet:

Çevre kirliliği, doğrudan insanlığın neden olduğu küresel bir konudur. Hemen hemen her inorganik materyal, doğal geri dönüşüm için problemli bir durumdadır. Doğanın kendisi inorganik malzemeleri kolayca kontrolünde tutamaz. Böyle bir sebebi önlemek, sadece geri dönüşüm konusunda artan farkındalıktan kaynaklanabilir. REZES projesi, IoT (Nesnelerin İnterneti) Teknolojileri, Görüntü İşleme, Büyük Veri Analizi ve Oyunlaştırma fikirlerini kullanarak metal, plastik ve camı geri dönüştürerek çevre kirliliğini önleyecek ve katma değer sağlayacaktır. Kapsamlı bir şekilde, kullanıcıların bir QR kodu, bir mikroişlemci (Raspberry Pi-3), bir mini LED ekran, Kamera Modülleri ve sensörler ile giriş yapabilecekleri bir mobil uygulamada kullanıcı girişi olacaktır. Tüm bu parçaların birleştirilmesi sonucunda, çöpün yeniden kullanılabilir malzemelere dönüştürüleceği otomatik bir geri dönüşüm makine sistemi oluşturulacaktır.

Anahtar Kelimeler: Nesnelerin interneti, görüntü işleme, büyük veri analizi, oyunlaştırma, geri dönüşüm makinesi, mobil uygulama, QR kod, sensör.

1. Introduction

1.1 Problem Statement

Environmental pollution is a global issue caused directly by mankind in the world today and this situation continues to increase rapidly day by day. Plastic, metal and glass bottles are wasted by being thrown into the environment which causes soil, water and air pollutions. Preventing such a cause can only be made of increasing awareness on recycling.

1.2 Solution Statement

We bring a different perspective to help reduce environmental pollution problem; REZES. REZES project will prevent environmental pollution and provide added value by recycling metal, plastic and glass using IoT (Internet of Things) Technologies, Image Processing, Big Data Analysis and Gamification ideas.

1.3 Contribution

We are a group of senior students in computer engineering department who are interested in IoT for recycling machine systems. We aimed to use the fields of IoT, Image Processing, Big Data Analysis and Gamification in this project. In this way, we will create an innovative solution that will include that fields in the rapidly increasing environmental pollution problems.

2. Literature Review

According to study of Jambek et. al, they calculate that 275 million metric tons (MT) of plastic waste was generated in 192 coastal countries in 2010, with 4.8 to 12.7 million MT entering the ocean. Population size and the quality of waste management systems largely determine which countries contribute the greatest mass of uncaptured waste available to become plastic marine debris. Without waste management infrastructure improvements, the cumulative quantity of plastic waste available to enter the ocean from land is predicted to increase by an order of magnitude by 2025 [1].

Rapid urbanization and industrialization is causing an unprecedented rise in the generation of municipal solid waste (MSW) worldwide. MSW is often a rich source of various useful recyclable materials such as metal, paper, plastic, and glass. Effective MSW management can

enable recovery of valuable recyclable materials and reduction of negative environmental impact. Waste sorting is a key step in MSW management for the recycling of materials. Researchers worldwide have been actively exploring automated sorting techniques for efficiently processing increasing quantities of MSW [2].

2.1 Today's Recycling Machine

TOMRA is a one of the important companies that make recycling vending machine. Today, consumers go through almost 1.4 trillion beverage containers every year, representing a vast amount of packaging material that can be collected and reused or recycled. Proper handling of used packaging conserves precious resources like energy, water and crude oil and reduces greenhouse gas emissions.

Users get an instant reward when returning used containers to TOMRA reverse vending machines, motivating repeated use and further raising collection rates. As reverse vending machines are often an integrated part of consumers' routines, everyday recycling is made convenient, efficient and profitable for all stakeholders [3].

Reverse vending machines provide an automated method for collecting, sorting and handling the return of used beverage containers for recycling or reuse. During the 45 years these systems have been utilized, they have proven to be an unmatched success for consumers, businesses and the environment [4].

2.2 Computer Science in Recycling

Nowadays, recycling has an important place because of environmental pollution. With the developing technology, the functional properties of recycling are developing. Thanks to sensors and microprocessors, recycling machines continue to evolve. In our project, new features will be added to the recycling machine systems, so we will inform about the computer science in related sub-headings.

2.3 IoT (Internet of Things)

IoT (Internet of Things) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the

ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.

An IoT ecosystem consists of web-enabled smart devices that use embedded processors, sensors and communication hardware to collect, send and act on data they acquire from their environments. IoT devices share the sensor data they collect by connecting to an IoT gateway or other edge device where data is either sent to the cloud to be analyzed or analyzed locally. Sometimes, these devices communicate with other related devices and act on the information they get from one another. The devices do most of the work without human intervention, although people can interact with the devices -- for instance, to set them up, give them instructions or access the data.

The connectivity, networking and communication protocols used with these web-enabled devices largely depend on the specific IoT applications deployed [5].

2.4 Image Processing

Digital image processing is always an interesting field as it gives improved pictorial information for human interpretation and processing of image data for storage, transmission, and representation for machine perception. Image Processing is a technique to enhance raw images received from cameras/sensors placed on satellites, space probes and aircrafts or pictures taken in normal day-to-day life for various applications. This field of image processing significantly improved in recent times and extended to various fields of science and technology. The image processing mainly deals with image acquisition, Image enhancement, image segmentation, feature extraction, image classification etc [6].

2.5 Mobile Application

Possessing every utility in a day life requires a mobile phone for sure. In our Project, we are trying to ease the process by granting access for all users in order to initiate their recycle process. The UI (User Interface) must be easy to use, fast and practical so that the user would be influenced by the application. Our only aim is to make a simple but qualified application to bring as much users as we can.

Building a different app for each platform is very expensive if written in each native language. An indie game developer or startup may be able to support just one device, likely

the iPhone, but an IT department will have to support the devices that its users have that may not always be the latest and greatest. The performance argument that native apps are faster may apply to 3D games or image-processing apps, but there is a negligible or unnoticeable performance penalty in a well-built business application using Web technology.

What makes things even more complicated are the differences among the actual platform SDKs (software development kits). There are different tools, build systems, APIs, and devices with different capabilities for each platform. In fact, the only thing these operating systems have in common is that they all ship with a mobile browser that is accessible programmatically from the native code [7].

2.6 Gamification

In the past few years, gamification has emerged as a trend within the business and marketing sectors, and has recently gained the notice of academics, educators, and practitioners from a variety of domains. Even so, gamification is not a new concept, having roots in marketing endeavors, such as points cards and rewards memberships, educational structures, most notably scholastic levels, grades, and degrees, and workplace productivity [8].

Concept	**Definition**	**Goal**
Gamification	'A process of enhancing a service with affordances for gameful experiences in order to support the user's overall value creation' — Huotari and Hamari (2012).	to support the user's overall value creation by providing gameful experiences (see goal of games)
Games	Free, no material interest, voluntary, uncertain, governed by rules, interesting choices, mastery, flow — Huizinga (1955), Caillois (1958), Avedon and Sutton-Smith (1971)	to create experiences such as flow, intrinsic motivation, achievement and mastery
Loyalty Programme	'Marketing efforts which reward, and therefore, encourage loyal customer behavior in order to increase the profitability of stable customer relationships' —Sharp and Sharp (1997)	to increase customer loyalty

Persuasive Technology	Interactive information technology designed for changing users' attitudes or behaviour — Fogg (2003), Oinas-Kukkonen and Harjumaa (2009)	to change attitudes and behaviours
Choice Architecture	'To nudge people towards the right choices [to make their lives better]' — Sunstein and Thaler (2008)	to help people make better decisions
Decision Support Systems	'A computer based system to aid decision-making [for running organisations more efficiently]' — Sol et al. (1987)	to make decision-making activity more effective

Table 1. Comparison between parallel concepts related to changing attitude and behavior [9].

2.7 Data Analysis

Data analysis is a process of inspecting, cleansing, transforming, and modeling data with the goal of discovering useful information, informing conclusions, and supporting decision-making. Data analysis has multiple facets and approaches, encompassing diverse techniques under a variety of names, while being used in different business, science, and social science domains [10].

2.7.1 The Process of Data Analysis

Analysis refers to breaking a whole into its separate components for individual examination. Data analysis is a process for obtaining raw data and converting it into information useful for decision-making by users. Data is collected and analyzed to answer questions, test hypotheses or disprove theories.

There are several phases that can be distinguished, described below. The phases are iterative, in that feedback from later phases may result in additional work in earlier phases [10].

- Data requirements
- Data collection
- Data processing
- Data cleaning
- Exploratory data analysis
- Modeling and algorithms
- Data product

2.8 Machine Learning

Machine learning is an application of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed. Machine learning focuses on the development of computer programs that can access data and use it learn for themselves.

The process of learning begins with observations or data, such as examples, direct experience, or instruction, in order to look for patterns in data and make better decisions in the future based on the examples that we provide. The primary aim is to allow the computers learn automatically without human intervention or assistance and adjust actions accordingly [11].

2.9 Raspberry Pi

A Raspberry Pi is a credit card-sized computer originally designed for education, inspired by the 1981 BBC Micro. Creator Eben Upton's goal was to create a low-cost device that would improve programming skills and hardware understanding at the pre-university level. But thanks to its small size and accessible price, it was quickly adopted by tinkerers, makers, and electronics enthusiasts for projects that require more than a basic microcontroller even arduino.

The Raspberry Pi is slower than a modern laptop or desktop but is still a complete Linux computer and can provide all the expected abilities that implies, at a low-power consumption level [12].

2.10 Sensors

There are two distinct ways for recognizing a material, one is sensors and the other one is image processing however they both have their own trade-offs. Determining the best option requires a test on both platforms. Testing on sensors requires a choice; we may use some infrared sensors, motion sensors or directly material recognizing sensors.

The simultaneous detection and quantification of physical, chemical, and biological information from the ambient with mobile/autonomous/remote sensing systems is easier accomplished when using complex platforms that integrate several dissimilar sensors; ideally all those required by a specific application. The first step towards flexible multi-parametric sensing platforms should be, and actually was, the development of different kinds of sensors on plastic substrates [13].

The kinetic response was studied by continuously monitoring the colored complex spectra of cage sensors after the addition of analyte ions at varying times.

Chemical sensors are molecular receptors that transform their chemical information into analytically useful signals upon binding to specific guests. These sensors are attracting attention owing to their potential for easy detection and quantification of the pollutant species in many fields of application, such as waste management, environmental chemistry, clinical toxicology, and bioremediation of radionuclides. The kinetic response was studied by continuously monitoring the colored complex spectra of cage sensors after the addition of analyte ions at varying times.

Different brands of motion sensors detect steps differently; therefore, caution must be used when comparing step counts between studies that have employed different brands of motion sensors. Taking into consideration the results of both studies and the initial walking test used for instrument screening purposes, it appears that, of the three pedometers tested, the YAM pedometer is most consistently accurate under both controlled and free-living conditions. Future research must consider presenting motion sensor accuracy in absolute terms so that the magnitude of error is not underestimated [13].

2.11 Future Work

As a future work, we plan to design our recycling machine systems (REZES) using computer science technologies such as IoT, Machine Learning etc. By making these components a new generation smart recycling machine concept, we aim to recycle waste more efficiently and systematically.

3. Software Requirements Specification

3.1 Introduction

3.1.1 Purpose

The purpose of this document is to describe REZES Recycling IoT Application Systems project. Environmental pollution is a global issue caused directly by mankind. Almost every inorganic material is in a problematic situation for natural recycling. The nature itself cannot easily dispose inorganic materials. Preventing such a cause can only be made by increasing awareness on recycling. REZES project will prevent environmental pollution and provide added value by recycling metal, plastic and glass using IoT (Internet of Things) Technologies, Image Processing, Big Data Analysis and Gamification ideas. This document includes detailed information about requirements of the project. It reflects the identified constraints and proposed software functionalities. Moreover, the SRS document explains how people interact with this project.

3.1.2 Scope of Project

The purpose of REZES project, is to increase awareness on recycling. The REZES project consists of two main components. The first component is the recycling machine and the second component is the mobile application. Users will login to the system after registering with the mobile application. There will be a QR code carrying the user ID in the application. The user approaches the machine to discard the waste, the QR code that will be in the mobile application will be scanned by the camera on the machine. If the entry is successful, the name of the user is written along with the "Welcome" message on the touch screen on the machine. The user can

start throwing the waste. Each of the wastes such as plastic, metal and glass bottles is detected by the sensors inside the machine. After user completes the work, s/he gains points because of recycling which will be added to the user account. The earned points will be calculated in real time on user's mobile application. For example; user decides to recycle a waste by using the next generation smart recycling machine. This waste is detected by the sensors inside the machine. Assume that 10 wastes are disposed, assuming 5 points for each waste, the person who throws waste will gain 50 points in total. The calculated 50 points will be reflected on the touch screen by Raspberry Pi and will be reflected to the user's account after the person has completed the transaction. As a result, 50 points can be used in a part of the shopping in the shopping centers and markets. Waste will be sent to recycling center locations. Some of the revenue generated from the wastes will be given to the shopping centers or groceries where the points can be spent. Thus, REZES will promote recycling significantly.

Moreover, it is aimed to increase the motivation of users by adapting gamification elements in the mobile application. In addition, data analysis will be performed and an intelligent waste-based score system will be developed by analyzing region or specific time of the day parameters. Thus, by means of data analysis, it is aimed to increase and motivate the waste recovery in each region.

3.1.3 Glossary

Term	Definition
REZES	Renewable Energy Zero Energy Squandering
User	The user who use the REZES Recycling IoT Systems. Generally users are the aged between 12-65.
Stakeholders	Recycling center locations, shopping centers and groceries that are supported the project.
Recycling Machine	Recycling machine where the waste is

	collected systematically.
IoT (Internet of Things)	The Internet of Things is called the communication of data transfer between devices like mobile phones, computing devices, objects are connected to the network [5].
Image Processing	Image processing is a method to perform some operations on an image for extracting useful information from it [6].
Machine Learning	It is a data analysis method that automates analytical model creation using the data set.
Big Data Analysis	It processes raw data and converts to useful information for decision-making by stakeholders.
Gamification	It encourages to user for reward, achievement, competition, and status.
Raspberry Pi	It is a small-sized computer.
Sensors	It is a device that to recognize an object.
Points	Users will rewarded when they recycling.
Database	It is an organized collection of data, generally stored and accessed electronically from a computer system [14].

3.1.4 Overview of the Document

The second part of the document describes functionalities of the REZES Recycling IoT Application Systems. System requirements are described in the Requirement Specification chapter where the details of the functionality of the project are described in technical terms.

3.2 Overall Description

3.2.1 Product Perspective

REZES is a recycling machine project that aims to decrease environmental pollution and increase the awareness on recycling. The REZES project consists of two main components. The first component is the recycling machine and the second component is the mobile application. REZES project will prevent environmental pollution and provide added value by recycling metal, plastic and glass using IoT (Internet of Things) Technologies, Image Processing, Big Data Analysis and Gamification.

3.2.2 Development Methodology

For developing the project, we have planned to use Kanban methodology. Because Kanban methodology supports incremental development [15]. We will start incremental development as there are more than one component related to the software. We will perform the tests after the software components are ready.

An incremental process is one in which software is built and delivered in pieces. Each piece, or increment, represents a complete subset of functionality. The increment may be either small or large, perhaps ranging from just a system's login screen on the small end, to a highly flexible set of data management screens. Each increment will be fully coded and tested, and the common expectation is that the work of an iteration will not need to be revisited. By taking into consideration of these facts, these are the most suitable methods for our project.

3.2.3 User Characteristic

3.2.4 Participants

- User are aged between 12-65.
- User must create an account.
- User must do their responsibilities during the process.

3.2.5 Admin

- Admin must be an employee of REZES.
- Admin must manage the security of user account systems.
- Admin must know how is the machine situation.

3.3 Requirements Specification

3.3.1 External Interface Requirements

3.3.1.1 User interfaces

User must have a mobile phone running on an Android operating system where the QR code of the user is generated. The system will be operational no matter what the screen size is. There are several items in menus for users to feel the importance of what they are doing.

Since the system has a user age interval of 12-65, a beginner mobile phone user shall use it without any training.

3.3.1.2 Hardware interfaces

There are three main branches of hardware in the system; Raspberry Pi3, RASPBERRY Pİ-3 Camera Module and Sensors. Python will run through the interconnection between the camera module and RASPBERRY Pİ-3.

Various sensors are being used in the system depending on the current phase of a material:

- Weight sensor
- Motion detection sensor
- Metal detection sensor
- Proximity sensor

These sensors will be used to determine the type of the material however the size is another issue to be dealt with so, weight sensor will be used to weigh the material during the process.

3.3.1.3 Software interfaces

First part of the system includes a local network only therefore, MSSQL Database Management Studio will be used to design a proper data management system.

Application systems runs on operating systems which vary on the brand. For the first release, the OS chosen is indicated below;

- Android, Version 8.0 Oreo

Several statistical libraries and machine learning algorithms are needed to implement gamification ideas into the system. Some of them are:

- Logistic Regression: Which is used for statistical modelling of relevant data.
- Naïve Bayes Classification: System should suggest performance upgrades where as it works with the algorithm to define the probabilities.
- Statmodels, MIpy and SciPy libraries in python for statistical modelling.

3.3.1.4 Communication interfaces

Raspberry pi's on different machines need to communicate for the statistical algorithms. In order to handle such a problem XRF Modules by Ciesco or Xbee Radios modules can be used.

3.3.1.5 Memory constraints

Memory usage is not significant in compared to other applications running on the background for the software part.

For the hardware part, raspberry pi3 is a board computer which runs on low memory usage so, no memory constraints.

3.3.1.6 Site adaption requirements

The product owner is supermarket business, the name of the company must be given to the system before first launch in order to avoid payment failure.

3.3.2 User characteristics

3.3.2.1 End-User characteristics

Anyone who can use a simple mobile phone application must handle the system. Age gap is 12-25. No educational requirements except reading and writing.

3.3.2.2 Support team characteristics

Support team members must have a driving licence, Hardware knowledge on REZES machines and members should be young-adult age.

3.4 Constraints

On the general design part of the machine, designs should be kept as small as it can be. It will not be possible to make room for the machines on every platform.

- Electrical connection must be close to the machine.
- Network should be available on mobile phones.
- Materials must be empty before dropping.

3.5 Functional requirements

3.5.1 Use-Cases

3.5.1.1 Login Page Use Case

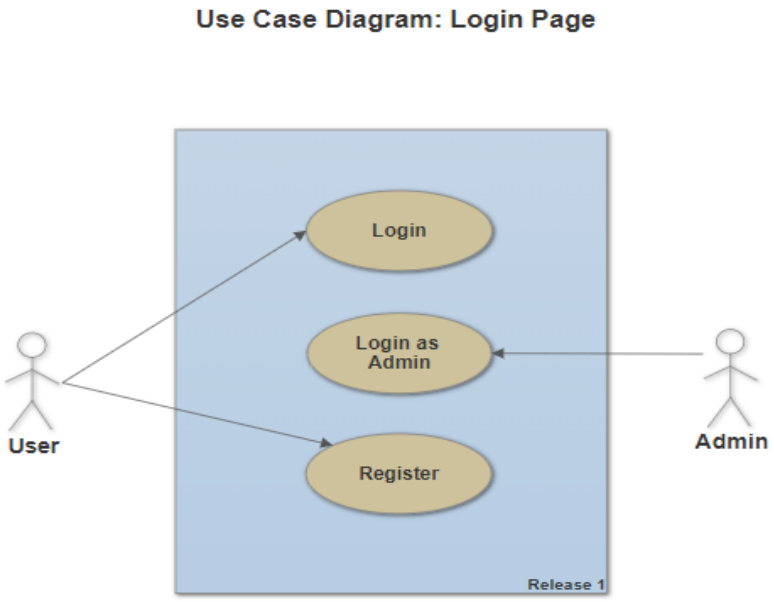


Figure 1: Login Page Use Case Diagram

Actors: Admin, User

Brief Description: Figure 1 shows the possible interactions for a user and an admin. Users are able to use two functions; Login and Register. Register function takes information on personal information. Admins are registered manually. Login function is linked to the homepage where user has to authorize ID, password.

Initial step by step description

- User shall select login method to authorize themselves. If no records exist, user shall register to save relevant information.
- Admin shall select Login as Admin method to authorize themselves. Admins cannot register.

3.5.1.2 Home Page Use Case

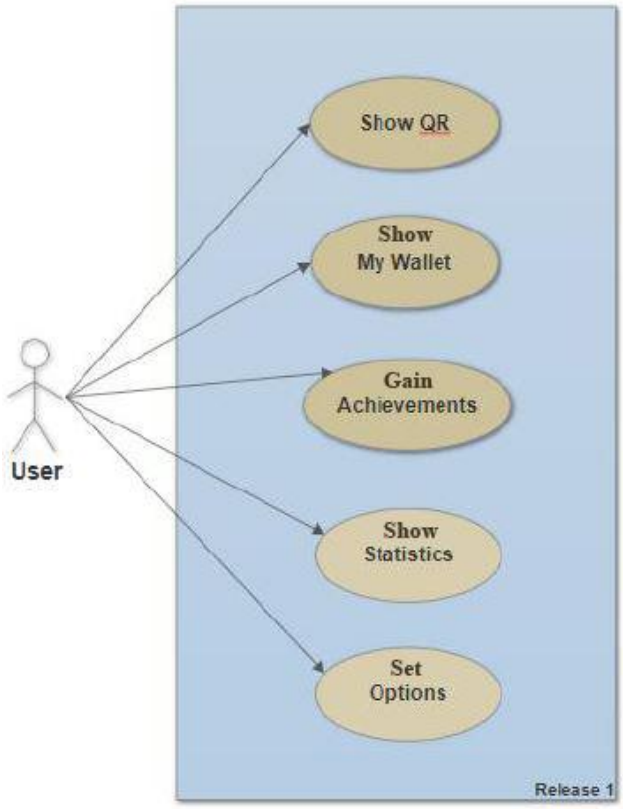


Figure 2: Home Page Use Case Diagram

Actors: User

Brief Description: Homepage contains the main functions of the application. Users can preview their;

- QR-code where the camera can recognize
- Transaction history of user including details
- Achievements and badges earned
- Statistic of the system

Also, the options menu is available to modify settings.

Initial step by step description

- User shall select Show QR method to see their identity on the screen. Identity frame includes; user name, surname, QR-code, points.
- User shall select My Wallet method to control all their past processes. My Wallet window displays location, date, time, total points earned, and the total number of materials recycled for a specific transaction.
- User shall select Achievements method. A new screen pops up with a trophy table design where all past records are shown.
- User shall select trophies, badges and medals to see what those items are for.
- Users are given bounties as pay checks in supermarkets or badges on the application. There is also a ladder on the app for a small competition where people can see who recycles the most.
- Statistics are shared with users on demand so that users may give feedback with statistical inspection.
- User shall select options to modify personal information or app settings.

3.5.1.3 Admin Home Page Use Case

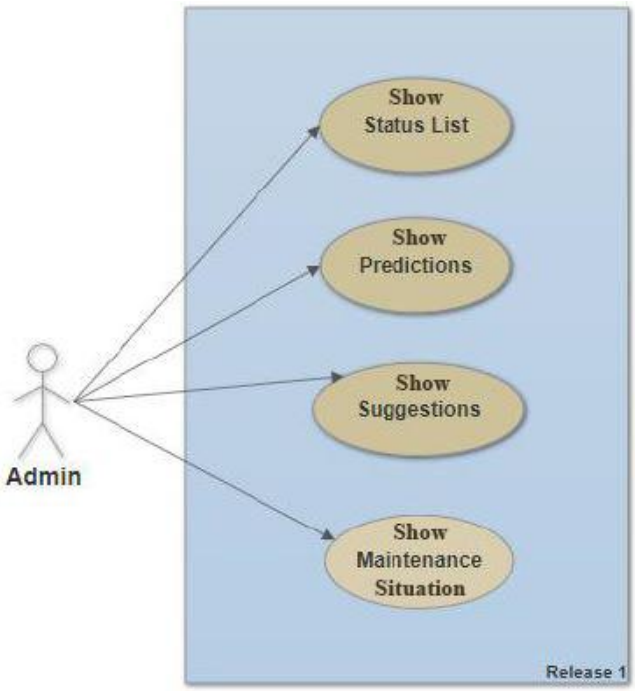


Figure 3: Admin Home Page Use Case Diagram

Actors: Admin

Brief Description: Admins are needed to control the system running. There is a support team patrolling between machines to control any kind of failure. Admins are on duty about checking machines remotely on both web and mobile platforms. Status list gives information about the machines. This entire system is a hub-like on its own where machines communicate with each other. System should generate a report for Admin which includes predictions to increase performance of the network. According to these predictions, if user selects suggestions method, the system may suggest operations. Maintenance method is for forwarding support team to a destination in case of a problem in any machine. All machines have a heart point to indicate their precedence on maintenance need.

Initial Step by Step Description

- Admin shall select Status List method to preview a list where machines are displayed in an order of heart point.
- Admin shall press “put into maintenance list” button if the situation is critical (This is determined by selecting the lowest health point machine).
- Admin shall ask for predictions where the system analyses the data gathered from all the machines. These predictions contain age predictions of the target area, daily density predictions and monthly income predictions.
- Admin shall ask for suggestions from the system. The system prints out a report that has instructions; directing the admin to change methods or strategies about rewarding systems and commercials. These strategies depend on populational results.
- Admin shall process their list of maintenance by selecting maintenance method. This method forwards support team to the relevant machine on such errors; storage full, cover stuck, low power, no sensor response and Raspberry Pi-3 stuck.

3.5.1.4 **Recycling *Process Use Case***

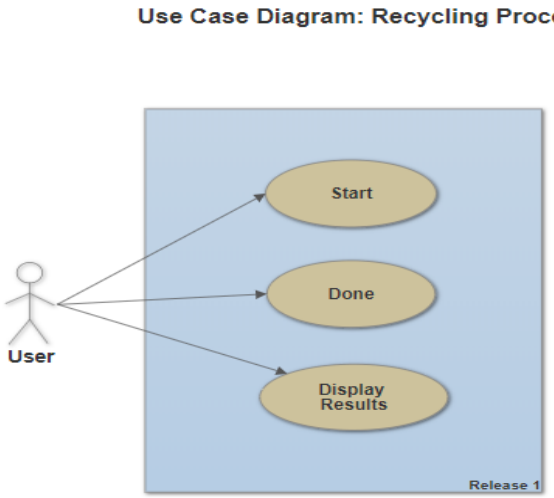


Figure 4: Recycling Process Use Case Diagram

Actors: User

Brief Description: Default page is the standby mode visual of a machine. On this phase, machine consumes the least energy. Once the system senses an interrupt it wakes up. Camera module is on. If QR code is recognized and matched, Recycling screen turns on.

Initial step by step description

- User shall touch the LED on the machine on any spot between the frame to wake the machine up.
- Once the machine is up, user opens the application on the mobile phone.
- User shall handle the login.
- After successfully logging in, user should press start button and then begin dropping materials.
- Material counts are displayed on the LED in a distinct table.
- Total count of material is displayed
- User shall click “Done” after the dropping part is over.
- User shall use display results to see the current transaction only. It gives information about the details.

3.6 Non-Functional requirements

3.6.1 Availability

- The system must be operating and online as long as the environment (shopping mall, supermarket etc..) is operating.

3.6.2 Performance

- Materials that are not recognized should be discarded otherwise this may cause wasting of recycled materials.
- Recognition should be at highest possible level.
- Application page switches should be as fast as possible
- Database modification should be fast.

3.6.3 Usability

- Every operation handle error.
- Users are leaded.
- No waste data transfer.

3.6.4 Adaptability

- The system should be implemented clearly and delicately.
- Easy reading brings easy change

3.6.5 Scalability

- Since data transfer sizes are not significant, system could be used by crowded populations without any problems.

4. Software Design Description

4.1 Introduction

4.1.1 Purpose

The purpose of this document is describing design details of project which is called REZES Recycling IoT Application Systems.

The purpose of REZES project, increase the awareness on recycling. The REZES project consists of two main components. The first component is the recycling machine and the second component is the mobile application. Users will login to the system after registering with the mobile application. There will be a QR code carrying the user ID in the application. The user gets close to the recycling machine to discard the waste, the QR code in the mobile application will be scanned by the camera on the machine. If the entry is successful, the user can start throwing the wastes which can be plastic, metal or glass bottles to be detected by the sensors inside the machine. After the adding this waste to the recycling machine, user will gain points which can be used as money in shopping centers.
REZES system design will be explained in the following parts.

4.1.2 Scope of Project

This SDD document includes a full description of the design of REZES Recycling IoT Application Systems.

The Raspberry Pi 3 is a mini computer and it is a suitable device for making prototypes [16]. It supports various Linux operating systems and Windows IoT Core operating system. Thanks to Wi-Fi feature, there is internet access. The Raspberry Pi 3 device will play an important role in the IoT part of our project. Raspberry Pi 3 supports applications written in various programming languages. Raspberry Pi touch screen component will be used to ensure that the application written in Raspberry Pi has a user interface.

Visual Studio is a very good platform to develop applications. WPF can be developed on this platform [17]. WPF will be used for the application to be developed in Raspberry Pi 3 which has the features of WPF user-friendly and functional visual design.

Another component that will have an important role in the IoT, data analysis and Gamification part of the project is the mobile application section. Firstly, we will develop the mobile app for mobile phones which have Android operating system. Android Studio for developing Android application will be preferred [18]. Android Studio has a rich library and is widely used. Android Studio supports Java and Kotlin programming languages. The mobile application will be developed in Java in this project. Java is a free and open source programming language [19]. Because it has a very large community network, it is possible to find solutions to problems that may arise related to Android.

4.1.3 Glossary

Term	Definition
SDD	Software Design Document
User	The user who use the REZES Recycling IoT Systems. Generally users are the aged between 12-65.
Recycling Machine	Recycling machine where the waste is collected systematically.

IoT (Internet of Things)	The Internet of Things is called the communication of data transfer between devices like mobile phones, computing devices, objects are connected to the network [5].
Gamification	It encourages to user for reward, achievement, competition, and status.
UML Diagram	It is a modelling language which is used in Software Engineering.
Block Diagram	The type of schema which the components in the system are displayed in blocks.

4.1.4 Overview of the Document

The remaining chapters and their contents are listed below.
Section 2 is the Architectural Design which describes the project development phase.
Section 3 is Use Case Realization. This section related to block diagram of the system.
Section 4 is related to Environment.

4.1.5 Motivation

We are a group of senior students in computer engineering department who are interested in IoT for recycling machine systems. We aimed to use the fields of IoT, Big Data Analysis and Gamification in this project. In this way, we will create an innovative solution that will include the Internet of Things, Gamification and Big Data Analysis in the rapidly increasing environmental pollution problems. Thus, we aim to minimize environmental pollution by extending recycling for a better future.

4.2 Architecture Design

4.2.1 Simulation Design Approach

Agile methods are the most suitable ones for REZES Project. Two of them are Scrum and Kanban. On Scrum, there is a scrum master to predefine the roles of the team members however, on kanban, a Project manager exists and define roles on the planned date. These two models bot hare iterative which reduces the waste of time. On kanban, products are delivered upon requirement not as sprints. This provides the team to work only when needed. The team is composed of university students so ideas may be subject to change any moment spent on the Project. On scrum, changes are not really couraged during sprints however on kanban, changes are available any time. Productivity of the Project is measured by recording the cycle time of a part to be completed. Figure 1 shows a kanban board including the Works handled, are being handled and to be handled. All these Works takes less time than a sprint length so, Kanban is the best choice for our Project. Works that are existing in the "Done" part are ready to be deployed.

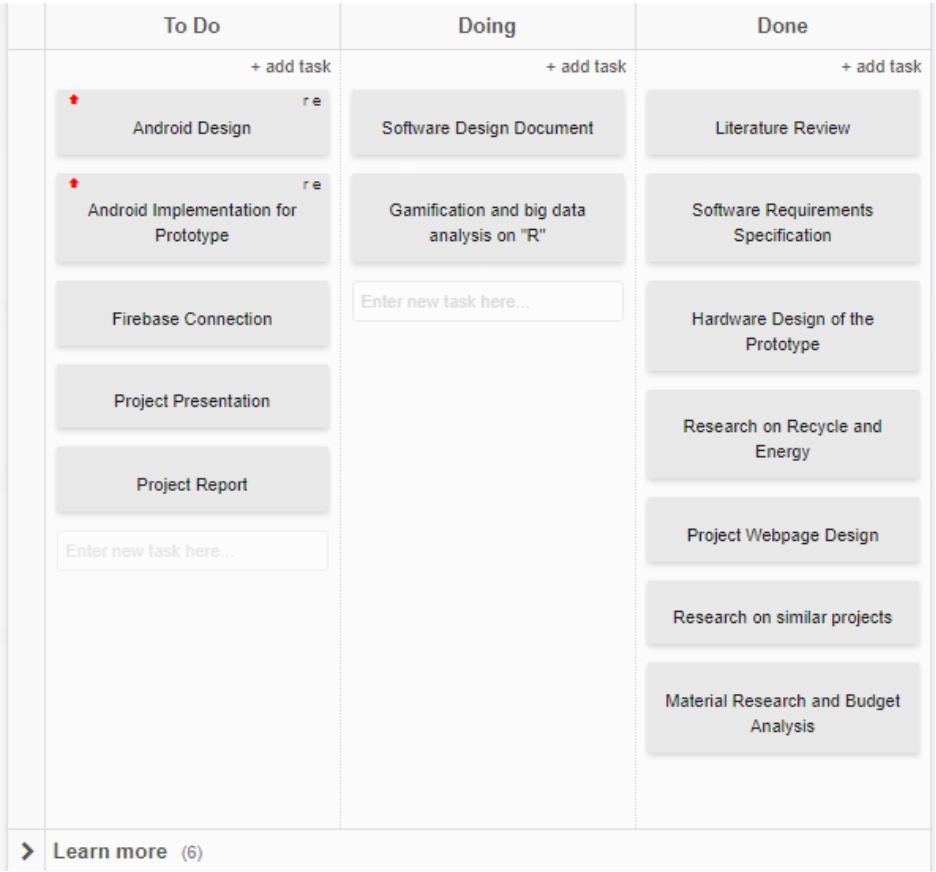
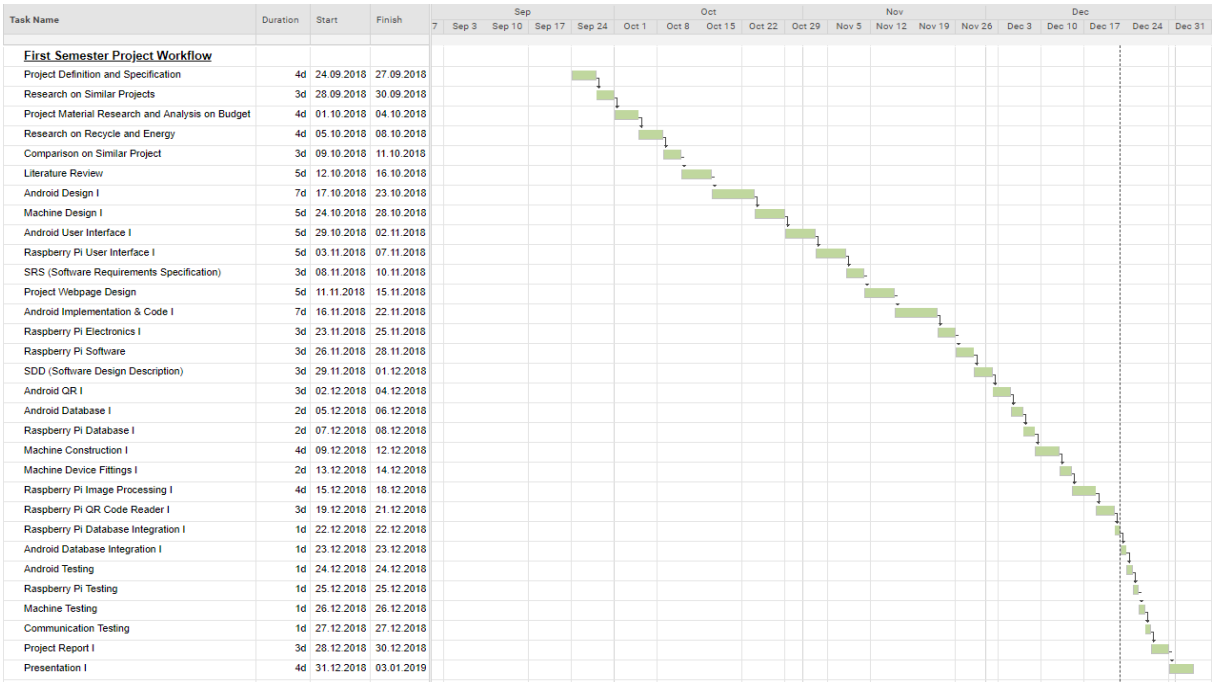


Figure 5 Kanban Board of REZES

Figure 2 describes the Work Plan within time boxes. The Work Plan includes 2 parts. One is for the first semester period of the project and the other is for the second semester. First semester work mostly contains documentation and design however, second semester is about implementation and testing. If there is an obligation to categorize them, they can be developed by waterfall model only.



Task Name	Duration	Start	Finish
First Semester Project Workflow			
Project Definition and Specification	4d	24.09.2018	27.09.2018
Research on Similar Projects	3d	28.09.2018	30.09.2018
Project Material Research and Analysis on Budget	4d	01.10.2018	04.10.2018
Research on Recycle and Energy	4d	05.10.2018	08.10.2018
Comparison on Similar Project	3d	09.10.2018	11.10.2018
Literature Review	5d	12.10.2018	16.10.2018
Android Design I	7d	17.10.2018	23.10.2018
Machine Design I	5d	24.10.2018	28.10.2018
Android User Interface I	5d	29.10.2018	02.11.2018
Raspberry Pi User Interface I	5d	03.11.2018	07.11.2018
SRS (Software Requirements Specification)	3d	08.11.2018	10.11.2018
Project Webpage Design	5d	11.11.2018	15.11.2018
Android Implementation & Code I	7d	16.11.2018	22.11.2018
Raspberry Pi Electronics I	3d	23.11.2018	25.11.2018
Raspberry Pi Software	3d	26.11.2018	28.11.2018
SDD (Software Design Description)	3d	29.11.2018	01.12.2018
Android QR I	3d	02.12.2018	04.12.2018
Android Database I	2d	05.12.2018	06.12.2018
Raspberry Pi Database I	2d	07.12.2018	08.12.2018
Machine Construction I	4d	09.12.2018	12.12.2018
Machine Device Fittings I	2d	13.12.2018	14.12.2018
Raspberry Pi Image Processing I	4d	15.12.2018	18.12.2018
Raspberry Pi QR Code Reader I	3d	19.12.2018	21.12.2018
Raspberry Pi Database Integration I	1d	22.12.2018	22.12.2018
Android Database Integration I	1d	23.12.2018	23.12.2018
Android Testing	1d	24.12.2018	24.12.2018
Raspberry Pi Testing	1d	25.12.2018	25.12.2018
Machine Testing	1d	26.12.2018	26.12.2018
Communication Testing	1d	27.12.2018	27.12.2018
Project Report I	3d	28.12.2018	30.12.2018
Presentation I	4d	31.12.2018	03.01.2019

Figure 6 Gantt Chart of Work Plan

Task Name	Duration	Start	Finish
Second Semester Project Workflow			
Gamification and Big Data Analysis I	7d	18.02.2019	24.02.2019
Android Design II	8d	25.02.2019	04.03.2019
Gamification and Big Data Analysis II	4d	05.03.2019	08.03.2019
Machine Design II	5d	09.03.2019	13.03.2019
Android User Interface II	7d	14.03.2019	20.03.2019
Raspberry Pi User Interface II	7d	21.03.2019	27.03.2019
Android Database II	3d	28.03.2019	30.03.2019
Raspberry Pi Database II	3d	31.03.2019	02.04.2019
Android Implementation & Code II	8d	03.04.2019	10.04.2019
Raspberry Pi Electronics II	4d	11.04.2019	14.04.2019
Raspberry Pi Software II	3d	15.04.2019	17.04.2019
Machine Construction II	3d	18.04.2019	20.04.2019
Android QR II	4d	21.04.2019	24.04.2019
Raspberry Pi QR Code Reader II	4d	25.04.2019	28.04.2019
Raspberry Pi Image Processing II	7d	29.04.2019	05.05.2019
Machine Device Fittings II	3d	06.05.2019	08.05.2019
Android Database III	2d	09.05.2019	10.05.2019
Raspberry Pi Database III	2d	11.05.2019	12.05.2019
Android Database Integration II	1d	13.05.2019	13.05.2019
Raspberry Pi Database Integration II	1d	14.05.2019	14.05.2019
Final Android Testing	3d	15.05.2019	17.05.2019
Final Raspberry Pi Testing	3d	18.05.2019	20.05.2019
Final Machine Testing	3d	21.05.2019	23.05.2019
Final Communication Testing	3d	24.05.2019	26.05.2019
Project Webpage Design	3d	27.05.2019	29.05.2019
Final Presentation	4d	30.05.2019	02.06.2019

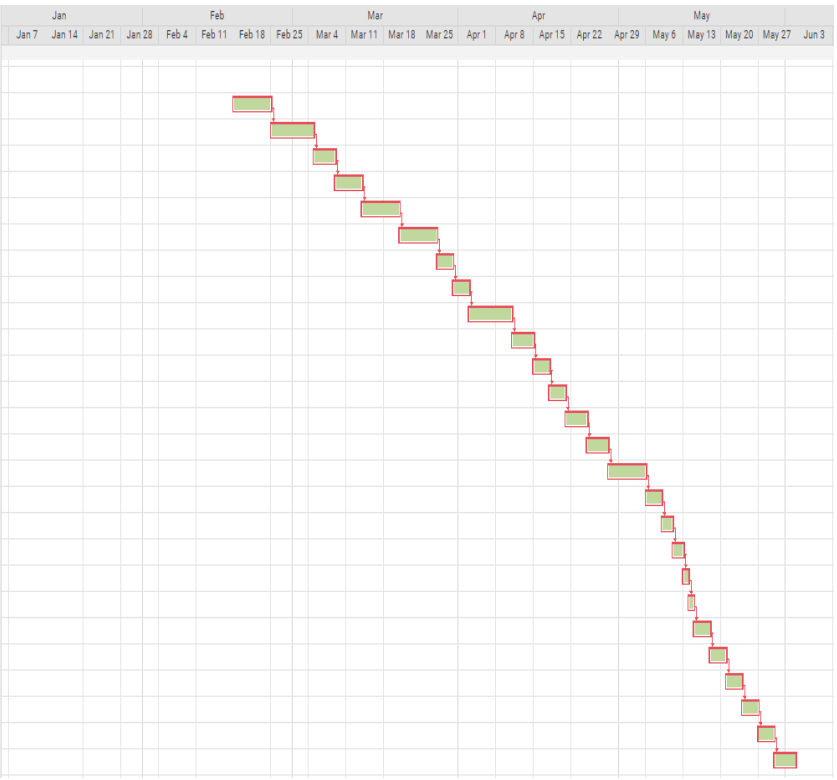


Figure 7 Gantt Chart Continued

4.2.2 2.1.1 Class Diagram of REZES

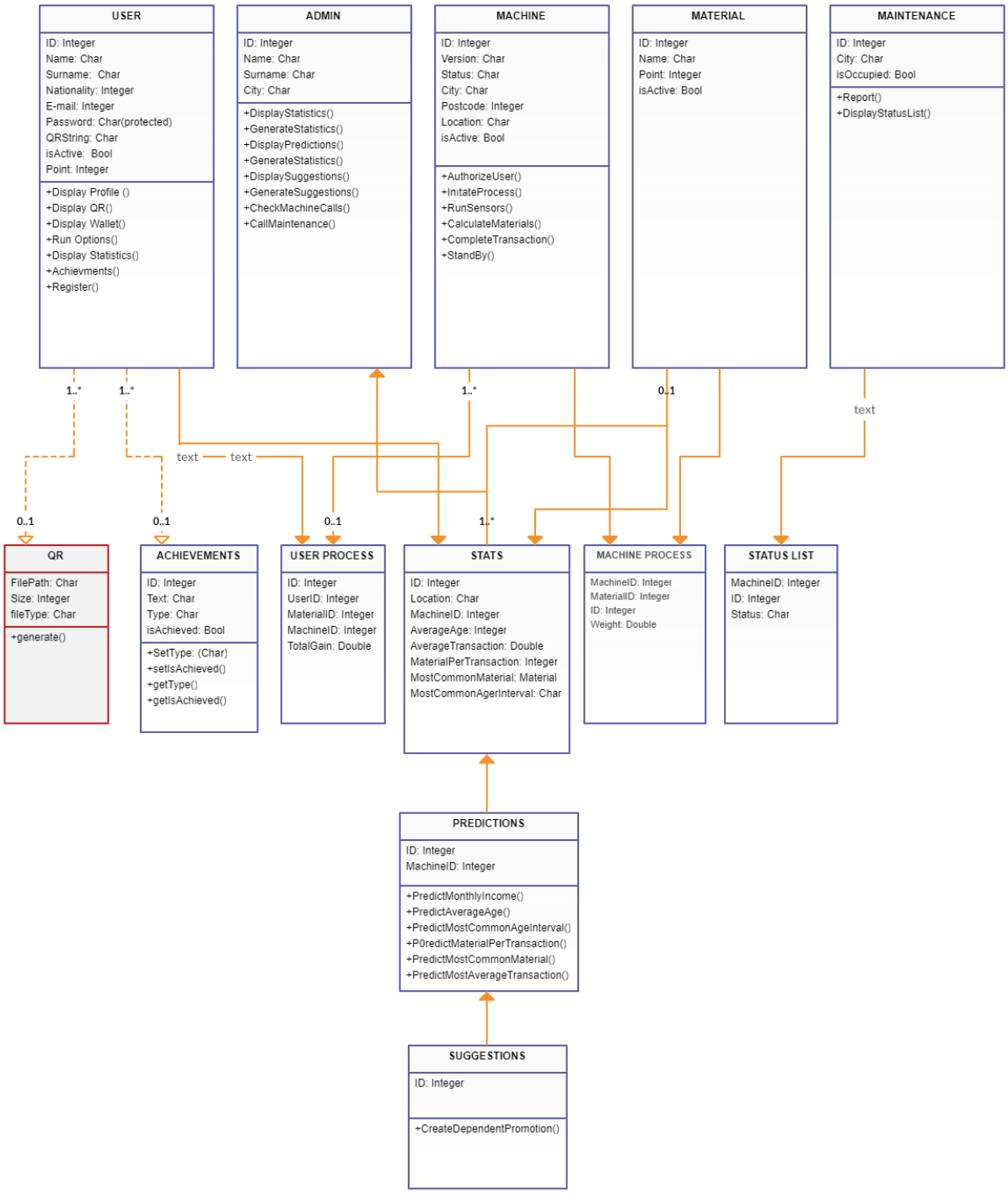


Figure 8 Class Diagram of REZES

Figure 3 shows the bonds between modules in the entire system. The system is branched under 5 main subjects. As the system contains 3 different actors in total, there are several different environments for distinct actors. Users are able to operate under recycling only although, admin and maintenance actors are responsible for both user experience and system experience. Their main task is to maintain the entire system in order to keep it operational. There may be errors or problems in the machines which needs to be taken care of. In such situations, machines change their status on to "needs maintenance". Admins have a function to list the status of every machine. Machines may be located in different cities, even different time zones. This brings a problem on maintenance where a crowded staff is needed. There will be several different materials to be recycled so a class for material is needed to indicate distinct materials. Gamification is a part of the system which requires deep analysis on statistics. System gathers statistics from different machines do determine such as the age interval or the average material per process. According to these statistics, the system shall predict future transactions or processes. These predictions results in improvement of attention. How? It is known that the previous age interval is "30-42", depending on this, system may predict that the target audience is going to be between 30 and 42. This helps us to create promotions for the interval which would increase their interest on recycling.

4.2.3 Profile Management

Summary: User can login, register, display QR code and update personal information and exit from the system. In addition, admin can create new admins.

Actor: Participant, admin

Precondition: User must run the program.

Basic Sequence:

1. User should register dependent on the existence of an account.
2. User shall login entering personal information if step 1 is checked.
3. In the profile section, user shall select update button to edit personal information.
4. Admin shall create new admins if needed.
5. User shall exit the application by clicking the menu button.

Exception: Access to database may fail.

Post Conditions: None

Priority: Low

4.2.4 Account Management

Summary: User can preview their score, their transaction history, their achievements and badges.

Actor: User

Precondition: User must be logged in.

Basic Sequence:

1. User shall select preview score function to display their total “Green Score”
2. User shall select transaction history function to display all their previous transactions. This method contains; location of transaction, total material recycled, green points earned and the date of the transaction.
3. User shall select Achievements method to preview their success rate on recycling which contains the number of distinct materials, the number of beaten competetors and the badges such as “The most green among us”.

Exception: Internet connection may be interrupted.

Post Conditions: None

Priority: Low

4.2.5 Process Management

Summary: User shall initiate the process.

Actor: User

Precondition: User must be logged in. User must compare their QR using the camera module on the system.

Basic Sequence:

1. User should login to the mobile application and select display QR method.
2. QR displayed in the app must be scanned by the camera on the machine. If it matches the record in the database for the current user, system should open the cover.
3. User shall drop materials to be recycled.
4. Whenever the system's recogniton is over, LED screen will display the amount recycled in details(Including the material types and distinct quantities).
5. After the process is over, user shall display the most recent transaction in the mobile application.

Post-conditions: None

Priority: High

4.2.6 System Management

Summary: The system is maintained, changes in the system are handled.

Actor: Admin, Maintenance Team

Precondition: Admin and Maintenance Team must be introduced into the system.

Basic Sequence:

1. Admin shall display status list where all the machines are listed. Upon this listing, admin may direct maintenance team to the related machine (Errors are displayed on the list).
2. Maintenance team shall display status list where all the machines are listed. They can send warnings to admins if there are machines to be taken care of.
3. Maintenance team shall send a report after an intervention on a machine if the process was succesful.

Post-conditions: None

Priority: High

4.2.7 System Improvements

Summary: The system developes itself by using machine learning

Actor: Admin

Precondition: Admin must be introduced into the system.

Basic Sequence:

1. Admin shall display statistics of the entire system where age intervals of the users, total count of recycles and most used machines are the statistics.
2. According to statistics, admin shall generate predictions for the future transactions.
3. Admin shall generate suggestions making the system use predictions.

Post-conditions: None

Priority: High

4.3 Use Case Realizations

4.3.1 REZES Project

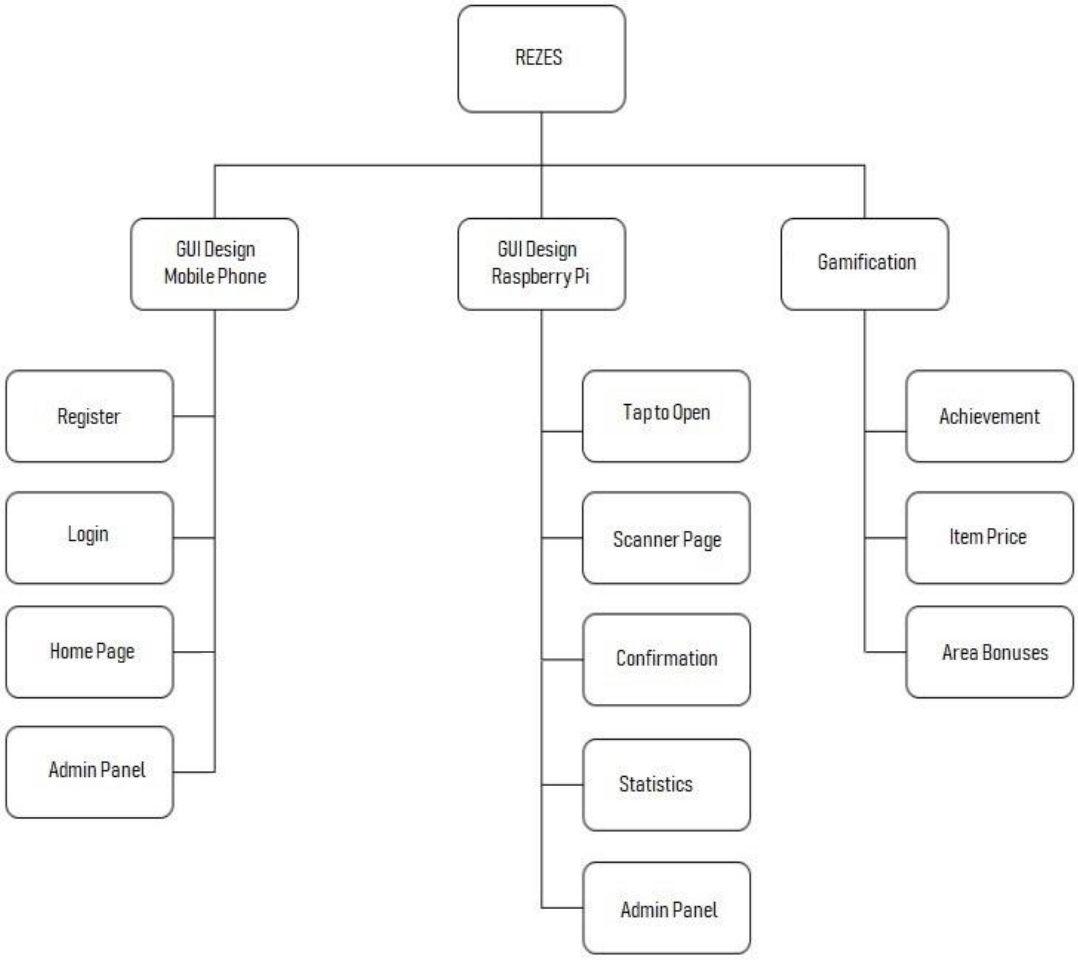


Figure 9 Project Components of REZES

4.3.2 GUI Design – Mobile Phone

There are two different start screens for the application used in the phone. The first is the registration screen this page is for people who will use the application for the first time. The reason we are recording is that if the application is deleted and then redownloaded and of course to keep the information in the database. Here, the user will see the name, surname, e-mail, location and telephone number such as special information will be required.

If the user has already registered need to enter the login screen. Here user can log in with their own email and password, and of course, if they forget the password, "Forgot your password?" will be included in the phrase. If this option is selected, the email address will be requested. After the user logs in a non-mixed home screen will appear. Here are the subheadings that will be taken: Show QR, My Wallet, Achievements, Statistics, Options. In the show QR section, the person is expected to enter the application with the special qr code. In my wallet tab, the user can see how much money has in the application. The part of Achievements is an addition that we add in the name of gamification. User follow badge and rank wins. The statistics tab is made for the user to see the history of the products, scored and how much collected point. In the settings menu, the user will be used to turn on and off notification, changeing theme and to sign out the account.

4.3.3 GUI Design - Raspberry Pi

To prevent the sensors from deteriorating the application is not constantly turned on. Therefore, the screen will wait for message with "click to login". After the click operation, the machine will be active. After that, the "Scan your QR code" section will appear. Here, only the user is expected to read the qr code. And there is the exit button at the bottom. User has logged in and disposed of waste confirmation screen with the points won on the screen will appear.

The last screen that can be used is the statistics section. Here the user will be able to see the points collected by regions, points collected by gender, and so on. The earnings may change here in the periods we set. This is because people will be encouraged to recycle. For example If the waste collected in a region is scarce, the number of wastes point in that region may be doubled. In this way, incentives can be provided for recycling in that area.

4.3.4 Gamification

Achievements have been created to support users to use the machine. In this section, active users gets the more success will be achieved. They want to see their names on the top of the list, and accordingly, they will be in the top of the rank. Example of these achievements "You put 100 pet bottles.". With these achievements, they will be able to win a badge and display them.

Item prices will be arranged by past months. The value of the discarded product will remain constant or decrease. The lesser product will be valued for further disposal in the next month. This will keep the average earnings constant.

Area bonuses vary according to districts. If recycling wastes are used in the region less, incentive will be increased.

4.4 Environment

We will create two components for the environment. One of these components is mobile application and another is Raspberry Pi application. Using these components, we will build a link and finally we will create our IoT and Gamification environments.

5. Conclusion

On such a project as we are dealing, just a single scope on a specific matter is never enough. It should be handled in parts. Among all these parts, recognizing the material that was dropped by the user was the most crucial one. Sensors are named as hardware and they have a raw cost no matter what. On the other hand, image processing does not. Until the testing part with two distinct methods comes up to a conclusion, it is not easy to pick a method. Another matter was the QR code generation and matching codes. In this issue, Raspberry Pi-3 is the actor; it is not an appropriate way to put a huge desktop right next to a box taking waste materials as input. Raspberry Pi will act as a computer in our project. The process does not need great properties in a computer. Some simple operations will be enough. Another part of the project is mobile application for users. It seems as we will develop an application on an Android platform first however in the future, it will also be implemented. As indicated in the survey, a startup company may not be funded enough to afford two mobile platforms at the same time. Some other surveys shows us that on a project like ours, we shall definitely have a user-friendly interface to keep them linked with the application. Increasing the attention is another problem on the project. Gamification is a solution for advertisement. Reaching out to an audience requires analysis of the audience. REZES is designed to operate in huge scales, so; analyzing such data would not be

so easy. Big data analysis includes attributes for grouping on common platforms. For determining the correct audience on a specific spot is only possible by data analysis. On the other hand, there are several different ways for applying gamification. All these ways improves the quality of the project. In a nutshell, when all these parts are handled and gathered together, there will be an incredible result as in making the World a cleaner and healthier place thanks to produce REZES recycling machine systems.

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