DOKUZ EYLÜL UNIVERSITY
ENGINEERING FACULTY
DEPARTMENT OF COMPUTER ENGINEERING

ANDROID-BASED SHOPPING ASSISTANT WITH BLUETOOTH BEACON AND AUGMENTED REALITY

by
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June, 2022
İZMİR

ANDROID-BASED SHOPPING ASSISTANT WITH BLUETOOTH BEACON AND AUGMENTED REALITY

A Thesis Submitted to the
Dokuz Eylül University, Department of Computer Engineering
In Partial Fulfillment of the Requirements for the Degree of B.Sc.

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SENIOR PROJECT EXAMINATION RESULT FORM

We have read the thesis entitled **"ANDROID-BASED SHOPPING ASSISTANT WITH BLUETOOTH BEACON AND AUGMENTED REALITY"** completed by **Kürşadcan AKAY** and **Ümmünur KANDEMİR** under advisor of **Assist. Prof. Dr. Feriştah DALKILIÇ** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of B.Sc.

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ANDROID-BASED SHOPPING ASSISTANT WITH BLUETOOTH BEACON AND AUGMENTED REALITY

ABSTRACT

The capabilities and market of mobile technologies have grown rapidly in the last decade. Despite this growth, the rate of mobile technology usage in traditional shopping is quite low. The rapid spread of supermarkets, which are the contexts of traditional shopping, has brought with it increased product options and larger supermarkets. In this study, it has been evaluated that consumers' access to the ideal product and decision time can be optimized. An Android-based application that consumers will use in traditional shopping has been developed. Bluetooth Beacon technology and versatile algorithms were used to optimize the process of accessing the products in the grocery store. The utilization of Bluetooth Beacon technology was employed to map the inside of the grocery store and create a route for preferred products. Augmented Reality technology has been integrated to increase the user experience of consumers in the navigation process. QR Code technology and Augmented Reality were used together for detailed viewing and filtering of the products on the shelves. In this way, more ideal outputs were obtained from the scanning and filtering processes to be performed by the human eye. It has been ensured that the processes of the consumers in the grocery stores are made more optimal by considering their consumption or economic sensitivities. By using the preferences and route information of the consumers in the shopping process, data that will appeal to the business intelligence units of the grocery stores were obtained.

ANDROID TABANLI BEACON VE ARTTIRILMIŞ GERÇEKLİK DESTEKLİ ALIŞVERİŞ ASİSTANI

ÖZET

Mobil teknolojilerin kabiliyetleri ve pazarı son dekatta hızla büyümüştür. Bu büyümeye rağmen geleneksel alışverişte mobil teknoloji kullanım oranı oldukça düşüktür. Geleneksel alışverişin bağlamları olan süpermarketlerin hızla yaygınlaşması, artan ürün seçeneklerini ve daha büyük süpermarketleri beraberinde getirmiştir. Tüketicilerin kendileri için ideal olan ürüne erişim ve karar süresinin optimize edilebileceği değerlendirilmiştir. Bu çalışmada, tüketicilerin geleneksel alışverişte kullanacağı Android tabanlı bir uygulama geliştirilmiştir. Market içerisindeki ürünlere erişim sürecini optimize etmek için Bluetooth Beacon teknolojisi ve çeşitli algoritmalar kullanılmıştır. Market içerisindeki adresleme ve tercih edilen ürünlerin temini için rota oluşturumunda Bluetooth Beacon teknolojisi kullanılmıştır. Tüketicilerin navigasyon sürecindeki kullanıcı deneyimini arttırmak için Arttırılmış Gerçeklik teknolojisi entegre edilmiştir. Raflardaki ürünleri detaylı görüntüleme ve filtreleme işlemlerinde Karekod teknolojisi ile Arttırılmış Gerçeklik birlikte kullanılmıştır. Bu sayede insan gözüyle yapılacak olan görüntüleme ve filtreleme işlemlerinden daha ideal çıktılar elde edilmiştir. Tüketicilerin market içerisindeki süreçlerinin, tüketim veya ekonomik hassasiyetlerinin gözetilerek daha optimal hale getirilmesi sağlanmıştır. Tüketicilerin alışveriş sürecindeki tercih ve rota bilgileri de kullanılarak marketlerin iş zekası birimlerine hitap edecek veriler elde edilmiştir.

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CHAPTER ONE

INTRODUCTION

1.1. Background Information

Mobile devices have become an indispensable part of today. While mobile devices have been integrated into many areas of life, the number of users has increased rapidly. Statista revealed that the number of smartphones sold to end users has increased from 1.39 billion in 2020 to 1.54 billion in 2021 ("Number of smartphones sold to end users worldwide from 2007 to 2021", 2021). Technological developments, mass production opportunities and global market conditions are increasing the number of mobile device owners day by day. Thus, mobile devices, whose capabilities have increased, have become integrated into many areas of life as they become accessible to large sections of societies. Studies have also predicted that the undeniable increase in the mobile application market will continue rapidly ("Worldwide mobile app revenues in 2014 to 2023", 2019).

The number of supermarkets and the number of products they contain has increased rapidly in recent years. Grocery stores have been globalized, larger supermarkets have been built and a wider variety of products have been placed on the shelves. With technological developments and market conditions, the number of options for consumers has increased significantly. The process of choosing among the options by the consumers has brought with it the necessity of more time and examination compared to the past.

The use of augmented reality is quickly growing. This technology's scope of applicability is continually increasing. While a growth in the usage area boosts expenditures in connected technologies, an increase in the needs of users also increases market demand. It is projected that Augmented Reality technology, which is fast gaining traction in a variety of domains including health, military, and entertainment, will become an integral component of society in the near future (Alkhamisi & Monowar, 2013).

Bluetooth Beacon technology maintains its feature of being the most optimal solution in many areas with the advantage it offers in terms of cost. One of the areas where this technology is used most frequently is indoor mapping and routing. Bluetooth beacons continue to be the optimal solution in indoor routing and mapping processes where GPS technologies are insufficient (Jayananda et al, 2018).

Today, QR Code technology is widely employed. This technology stands out in many goods and processes because of its practical solution and ease of use. Every day, this technology, which has a wide range of applications ranging from products on store shelves to identity verification apps, gains in popularity (Soon, 2008).

In line with the observations made in this study, it has been determined that the grocery shopping process can be optimized by using the mentioned technologies.

1.2. Problem Definition

Problems in grocery shopping:

- People with consumption sensitivities for health, social or religious reasons are not easily informed about the contents of the products on the shelves.
- The inability to easily locate the products to be bought in large supermarkets.
- When a shopping list is made, there is no option in the store that creates the ideal route for the list, and people must search and find these products themselves.
- The lack of detailed information of the store management about the processes of the customers in the market. (For example, there is no information in the store management about the products that customers examine but do not prefer to buy. Or there is no time based information of the busiest customer routes and frequent destinations on the store.)
- Difficulty of making a visual comparison between the prices of products in the same class with the eye.
- Difficulty in learning the shopping price total without going to the cash register.

- Difficulty in choosing the discounted products among the aisles.
- Difficulty of understanding nutritional values of the product directly.
- To take advantage of the benefits of supermarkets, it is not practicable to bring a special card or disclose the phone number. (As it is known, many supermarkets distribute special cards to their customers for their campaigns and these cards are shown at the cashier to benefit from the advantages.)

In this project, effective solutions to eliminate these difficulties have been provided.

1.3. Motivation/Related Works

We are working to prevent difficulties and time losses in supermarket shopping. Especially since the COVID-19 pandemic and afterwards, the tendency to online shopping has increased, the possibility of choosing offline shopping has decreased even more (Watanabe & Omori, 2020). Therefore, we aimed to minimize the time spent in offline shopping and manage this process in the most effective way.

While managing this project, we benefit from many up-to-date technologies. In particular, the main factors driving the growth of the augmented reality market are the increasing demand for AR devices and applications in the healthcare industry, the increasing AR demand in the retail and e-commerce sectors due to COVID-19, the increased investments in the AR market and the increasing AR demand (*Augmented Reality Market with COVID-19 Impact Analysis, by Device Type (Head-mounted Display, Head-up Display), Offering (Hardware, Software), Application (Consumer, Commercial, Healthcare), Technology, and Geography - Global Forecast to 2026,* 2021).

Bluetooth Beacon technology, which is seen as one of the most ideal solutions for indoor navigation today, will be used. Bluetooth Beacon technology gives the most successful results in indoor environments and is often preferred in studies. Another advantage is that it is a simple technology, especially with the advantage of sensitive addressing in indoor environments. With its price performance, it has been evaluated as the optimal technology within the scope of this study.

It has been evaluated that when augmented reality technology in a mobile application is integrated with Bluetooth Beacons and used for product recognition together with QR Code technology, the outputs that will be presented will have a meaningful value proposition.

1.4. Goal/ Contribution

Due to the high usage of android based mobile devices, more people can access the product and these people are enabled to shop easier and smarter thanks to the technological infrastructure.

Making the best of people's time while shopping traditionally, making the most suitable indoor navigation for shopping list which they do before or during the shopping, providing access to the desired products without contacting the store employees, makes it much more autonomous and easier to compare products in the same class according to their contents and prices , checking whether the specified limit is exceeded before shopping, easy access to discounts that people can be benefited are provided. Thanks to being able to get details of product, customers who has sensitivity for health, social or religious etc. reasons will be able shop more confidently.

The store management will be able to view the density of customers on which shelves in which time period in the store. According to the time periods of the day, the customers will be able to determine which routes they pass the most in the store. He will be able to know which products he has examined but not bought. Thus, meaningful outputs for CRM will be available to store management and business intelligence units.

With the technologies used, the person can realize these situations in the most convenient and easy way, and in-store navigation is enhanced and the in-store experience is improved.

1.5. Project Scope

Even though a shopping list is prepared while shopping for the market, it is very difficult to reach the desired products, to find the most ideal ones as soon as possible, to fully comply with the determined budget, to select and evaluate the discounts directly, to learn the stock status of the products directly, and to do them without communicating with anyone. The aim of this project is to eliminate all these problems and to optimize market shopping for both customers and supermarket owners by using today's technologies.

It will be a service that takes into account the sensitivities of customers regarding their diet or health. Customers will be able to set limits for any nutritional value prior to shopping. This nutritional value is determined by the customer also can be adjusted dynamically. It will be able to do the same limit determination for the total amount of the shopping. When this limit is reached during shopping, the person will be informed.

There will be a special interface for people with consumption sensitivity, and people will be able to enter their diseases or sensitivities from this interface. People with allergies will be able to add whatever food or nutrient content they are allergic to (lactose, gluten, some fruits and vegetables, nuts etc.). Customers who are sensitive to consumption for religious reasons can also buy halal food, kosher food, etc. can add their preferences. Consumers who are sensitive to shopping for special reasons will also be able to add their preferences to the system (vegetarian, vegan, pescatarian, cruelty-free, etc.).

Product data to be used in this project will be produced and used as mock data. Campaigns and opportunities will be created by replicating the processes of real markets. Customers will be able to create their shopping lists from the interface where the products are displayed. A shopping route will also be created for these products. While creating the route, addressing will be done with Bluetooth beacons. Symbols for navigation of people will also be displayed on the screen.

Thanks to integration of multiple QR Code scan technology, customers will be able compare products in the same class or shelf depending on selected criteria. Thanks to AR, comparison results will be visualized on the screen.

In the payment step, to take advantage of some discounts, customers will use the personal QR Code that generated from the application. Thanks to this step program will be able to understand amount of payment and details of customers which is also needed for improving CRM output for the project.

There are basically 3 types of users: customers, store employees and store managers. Firstly, the above-mentioned services will be offered to customers. Secondly, store employees, will use this application to make revisions only when the location of the products or information changes. QR Codes will be updated on the basis of the product to be produced by the store management, and the store employees will put this updated QR Code on the shelf. Afterwards, the location update will be carried out thanks to the application that contacts the Bluetooth Beacons by scanning this QR Code from its own interface. So the store employees will only use the application when the location or content of the product will be updated. Lastly, store manager accounts, will only have access to in-store customer logs kept in raw format. This data will be served by the application in raw format.

In conclusion, customers will be able to shop much more smart and sensitive way, easily. All mentioned services will be implemented within an android application. It will be easy to use and will has only several interfaces for whole mentioned processes. Also, the store managers will be able to manage the shopping process more properly and provide the best service to the customers.

1.6. Methodology/Tools/Libraries

By dividing the project into several stages, improvement is aimed at each stage. In other words, the Agile methodology has been discussed. It is aimed to carry out work with planning, execution and evaluation processes. It is decided to create physical representations of the tasks with Kanban boards and manage the project. By looking at the progress of the tasks, it is decided whether they are in accordance with the plan. The project will be managed with the agile approach, by following the errors and progress using Jira developed by Atlassian.

During the project, Figma will be used to design the product. The designs that will be created more effectively in this way become clear before the product was started. GIT technology will be used for an interactive work.

IntelliJ IDEA will be also used as the IDE. The application will be built using React Native, an open-source UI software framework, and Node.js, an open-source, cross-platform, back-end JavaScript runtime environment. MongoDB, which is a NoSQL database, will be used as the database. Using the Expo platform, it will be checked how the application works on Android devices.

Open source frameworks will be used for Bluetooth Beacon part.

CHAPTER TWO

LITERATURE REVIEW

Although the Global Positioning System (GPS) technology for outdoor navigation is very advanced, it is insufficient for indoor positioning due to lack of signal that caused by construction materials. Therefore, alternative methods are being tried. There are many technologies used in indoor positioning. Examples of these are infrared, ultra sound, WLAN, Wi-Fi and RFID. However, these solutions are often difficult or costly to implement (Bekkelien, Deriaz & Marchand-Maillet, 2012). Also, techniques as Wi-Fi and RFID are less accurate than Bluetooth technology (Jayananda et al, 2018). For these reasons, especially in recent years, using Bluetooth technology for indoor navigation has become preferable with the increase in Bluetooth-enabled devices.

The Nokia Research Centre is the first one to develop Bluetooth low energy (BLE) as a technology. Since the iPhone 4s, Apple has included Bluetooth Low Energy in its products. A continuous broadcast data stream and a collection of receivers are present. The speed with which mobile devices get data is determined by their proximity to a network node. A MAC address is assigned to those Bluetooth Beacons. These MAC addresses can be used to generate UUIDs. A Bluetooth node, in other terms, is a tag (Namiot, 2015).

The IoT device is always looking for Bluetooth devices in the area. Continuous scanning ensures that the localization algorithm receives more data points. More data points equals more precise location. Because beacon signals are inconsistent, fewer data points are available for the localization algorithm to offer an accurate location estimate. It is important to take note of this issue. Additionally, the distance estimate model proposed by Texas Instruments can be used to determine beacon proximity, which is critical for the localization method. Interpolation techniques include 3-Dimensional Trilateration, 2-Dimensional Trilateration, Generalized 2-Dimensional Lateration, Filtering found beacons, and Last Estimated location algorithms (Chen, 2019).

Bluetooth Beacon technology can be used in a very large area of our lives such as health and educational institutions, public spaces, transportation, museums. In addition to these, it is also used to optimize the shopping process. Bluetooth Beacon technology can be used to increase the satisfaction of grocery shoppers. It can increase the service that customers receive from shopping. Automatic payment, indoor navigation, instant coupon and discount information can be used. By transferring these improvements directly to the customer's phone, maximum efficiency can be obtained from shopping. It can also be seen as an innovation for the relations between the grocery store owners and customers, so that the customer experience is improved and the grocery store owners are also positively affected by this situation (Thamm et al, 2016). The Bluetooth Beacon can be used to detect the location of products in the grocery store. The customer can create a shopping list before they start shopping. According to this list, a path can be created for the customer in the grocery store. In this way, it can save time from shopping time. In this way, the store owner can directly convey his offers about these products to the customers, and can also easily follow the stock information of the products (Kelkar et al, 2018).

While shopping in the grocery store, obstacles in the store (e.g., walls, items in the store) can interfere with the signals. The identity, signal strength and distances of Bluetooth beacons interacting with customers during shopping should be recorded. In this way, sufficient number of Bluetooth Beacons and Bluetooth Beacons' positions can be determined for optimal indoor positioning (Stavrou et al, 2019).

Augmented reality technology is a technology that offers digital add-ons to the physical environment. Sound, image and graphics can be added to the physical world with augmented reality. It is presented by combining the real and virtual worlds to increase the experience of the users. Images created in the virtual world with AR are reflected in the real world, thus providing help or entertainment to the users with the virtual world. 2D/3D environments and models can be created by using software development kits such as Unity and Vuforia to perform these operations (Martin et al, 2021).

The user's location information is used when navigating indoors. Augmented reality is also one of the technologies used for indoor navigation. A high-quality augmented reality app can be delivered for a specific environment, but in this case a specific location is handled. When moving beyond the environment, location-based systems are more preferable. The most suitable example for this situation is GPS technology working in the open field. However, the accuracy and update speed may decrease with the preference of GPS technology. Based on these, it would be more accurate to prefer AR technology for a high quality navigation system indoors (Reitmayr & Schmalstieg, 2003).

After users determine a specific destination they want to go or reach, a path to that destination can be created with the camera of their phones. This path can be followed using AR technology with the help of camera (Matuszka, Gombos & Kiss, 2013). Smartphones are one of the best devices that can be used with AR technology for indoor navigation. The location of the user can be determined by the location information of the device or directly by the camera. After the location is determined, the user is expected to select a target. When the target is selected, the closest path to the target is reflected on the user's phone screen via the camera. In this way, the most ideal path determined can be easily followed on the way to the destination (Çalık & Gülgen, 2021). Additionally, AR technology provides a detailed, quality impression to the system, while navigation can be provided with a technology other than AR technology. By adding information points to the routes, it can ensure that the path is formed more accurately and properly and the errors are reduced (Mulloni, Seichter & Schmalstieg, 2011).

With the Pokemon Go game, which was released for the first time in 2016, AR technology became the focus of attention. However, AR technology is not just a technology used in the entertainment industry. This technology, which is also discussed in subjects such as education, tourism and health, is also used in the shopping process (Gutiérrez et al, 2019). Today, digitalization and technologies have become an important step for retail grocery businesses. Retail stores can become smart stores with digitalization. In this way, customers' shopping efficiency can be increased. Technologies that can be used are the internet of things, virtual reality, artificial intelligence and augmented reality. By using AR technology in retail stores, customers can help their decision making process and make the shopping process smart. With the increase in the use of mobile devices, this process can be easily presented to customers as a mobile application (Fagerstrøm, Eriksson & Sigurdsson, 2021).

Augmented reality can be an important aid in healthy eating. When people want to buy a healthy product, they can make better decisions during grocery shopping with AR. Thanks to AR technology, they can access the nutritional information of the products. Augmented reality filters products based on diet or allergic foods to avoid. Information such as price, content, stock, location of the products in the grocery store are kept in the database of the market. And using this database, this information is transmitted to customers via AR. In this way, the probability of reaching the desired product increases, while the duration of shopping is reduced. In addition, matching products that are similar to the products the customer chooses or the filters they choose leads to more options and therefore more sales (Ahn et al, 2015).

When customers hold their mobile devices to the shelves while browsing the store, they can reflect the products on the shelf to their device with the AR marker that is prominent on the shelf. And by tapping on a product, customer can access its information. Customers can use the arrows that appear on their screen thanks to AR to reach the products they want to examine. When the customers search for a specific product on their device, the boundaries of this product are specified with AR and transferred to the customers (Rashid, Peig & Pous, 2015).

With AR technology, products can be labeled to prevent unhealthy nutrition and obesity. Thus, users reach more healthy products and their confidence in shopping increases. Products are offered according to customers' diets or calorie preferences. According to these filters, the products that can be preferred or not are specified to the customers. Thanks to this proposition, the time to find healthy products is reduced and it helps to avoid unhealthy products (Gutiérrez et al, 2019)

CHAPTER THREE

REQUIREMENTS

Functional and non-functional requirements are included in the requirements. The features and functionalities of a product are defined by functional requirements. Non-functional requirements are the general properties of a system.

3.1. Functional Requirements

Functional requirements will be explained in two sections. In the first one, common functional requirements will be explained for each type of user. In the second one, functional requirements will be explained depending on type of user.

3.1.1. Common Functional Requirements

- Each type of user (Customer, Grocery Employees and Grocery Manager) must be able to sign-up and sign-in to application.
- Each type of user must be authenticated with the method of e-mail authentication.
- Each type of user must be able to reset their passwords in the case of security reasons or forget password.
- Each type of user will be able to fill personal information as name, surname.
- Application permissions will be asked and there will be a illuminating text for each user depending on type of information.

3.1.2. User Type Oriented Functional Requirements

3.1.2.1. Customer Based Functional Requirements

- Customers will be able to create a shopping list. This shopping items will be listed from the supermarkets stocks information.
- Shopping lists route will be created thanks to Bluetooth beacon and customers will be navigated thanks to augmented reality.
- Customers will be able to add product sensitivity criteria such as vegetarian,

vegan, pescatarian, cruelty-free, gluten-free, halal, kosher etc.

- Customers will be able to determine limit for specific gradient of cost of total products that bought (For example maximum calory limitation). And when limit exceed the application will warn the customer.
- Customers can select the discount tour of supermarket which routes the customers to discounted products in the supermarket.
- Customers can display total amount of shopping thanks to scanning each products QR Code.
- Customers will be able to scan QR Code of product that located at the shelf and they will get detailed information of the specific product.
- Customers will be able to make multiple QR Code scan and add some filters to scanned items. Customers will be able to sort the items in ascending order depending on selected criteria such as protein, fat or carbonhydrate content or price.
- Customers will be able to search a product and application will navigate that customer to searched product.

3.1.2.2. Grocery Employee Based Functional Requirements

- Grocery Employee will be able to use their interfaces to update products location.

3.1.2.3. Grocery Manager Based Functional Requirements

- Grocery managers will be able to take activity report of grocery depending on customers. This information will be formatted as csv. Grocery managers will be able to download this file by demanding from SESA.

3.2. Non-Functional Requirements

- **Accessibility:** The application will be accessible from the mobile app market.
- **Availability:** Application will be reachable for most of people because of that it is a mobile application for Android devices. Amount of Android users will contribute the criteria of availability. Android-based devices like mobile phones,

tablets etc. will be able to run this application.

- **Capacity:** Application will be able to support several thousands of users simultaneously per grocery stores.
- **Extensibility:** Application will be able to integrated by lots of sub-modules depending on versatile requirements of related groceries. Thank to this modular structure, application will be able to support new sub-modules. Also, structure of REST will provide easily integration with new back-ends.
- **Maintainability:** Thanks to autonomous services which are supporting maintainability of application, maintainability will be much more effective. Also, clean code and clean architecture based design will contribute maintainability process of application. Well-defined relations and business rules will satisfy the requirements of understanding software workflow process for developers.
- **Performance:** Application will be fast enough for satisfying real shopping circumstances. While users are using the application, they will have no extra waiting periods to complete related task in their shopping. Navigation and calculations will be completed in milliseconds which is not recognizable for human eye.
- **Reliability:** Generally accepted standards will be applied while writing the code and designing the entire project. One of the most important criteria for reliability is that software testing, such as both white box and black box testing, will be implemented.
- **Reusability:** Front-end and back-end components will be separated very clearly. Instead of monolithic structure, loosely coupled structure will be applied. Micro service structure will be applied. Also, in design phase front-end components will be used again and again to increase reusability without sacrificing design.
- **Testability:** Thanks to REST structure, we will be able to make black box testing techniques with the end-point that written in the back-end. Front-end components also will be able to tested by the structure of design of application with labeled component. End-to-end test will be applied for application too thanks to previously defined use case scenarios. Back-end classes will also include test replicates for applying unit tests. In the back-end, there will be some

end-points for the only purpose of testing.

- **Usability:** UI/UX concerns will increase the usability of application. There will be a easy user interface and user friendly components. Thanks to previously created wire-frames, user experience will be increase sharply. Because use cases will determine wire-frames structure.

CHAPTER FOUR

DESIGN

4.1. Architectural View

Figure 4. 1 displays main architectural structure of application. User assigns customers and grocery employees that interacts with Bluetooth beacons and the application server. Grocery manager displays customers' analytics. Checkout structure supported with the QR code technology for detected purchased products.

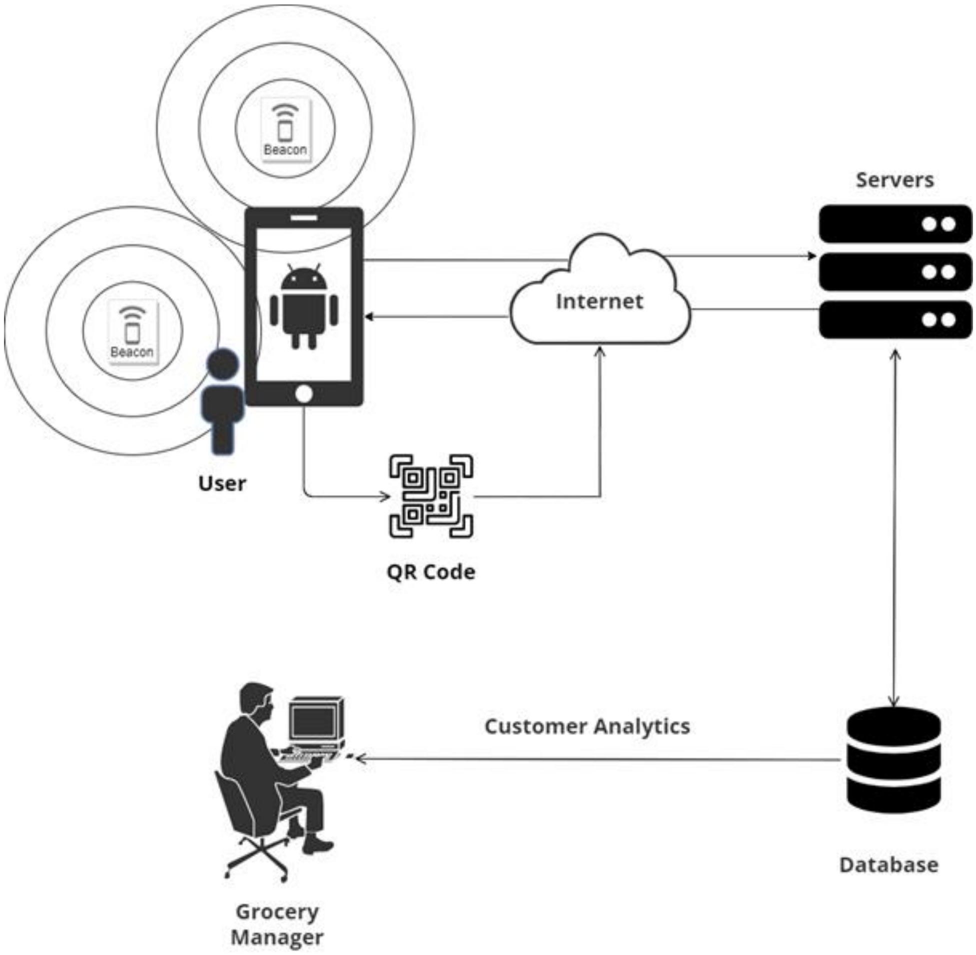

Figure 4. 1 Architectural view

4.2. Database Design/ER Diagram

Figure 4. 2 displays relations between entities. In fact, those relations are based on business rules. Because in this project, non-relational database is used. Customer can create shopping list. Also, customer has behaviours as scanning product, routing samples etc. Customer behaviours are based on products. Grocery manager displays customers' behaviours. Also, grocery employee can edit products.

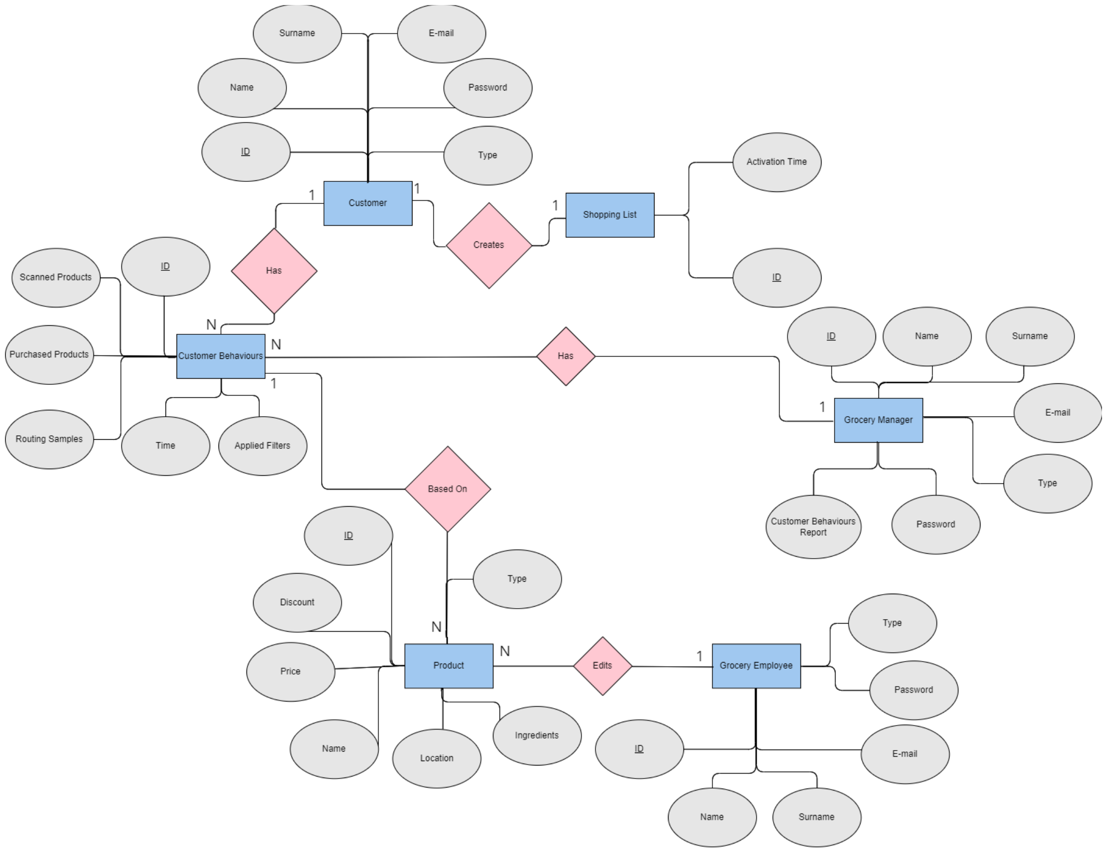

Figure 4. 2 ER diagram

4.3. UML Class Diagram

Figure 4. 3 displays classes of application for frontend and backend.

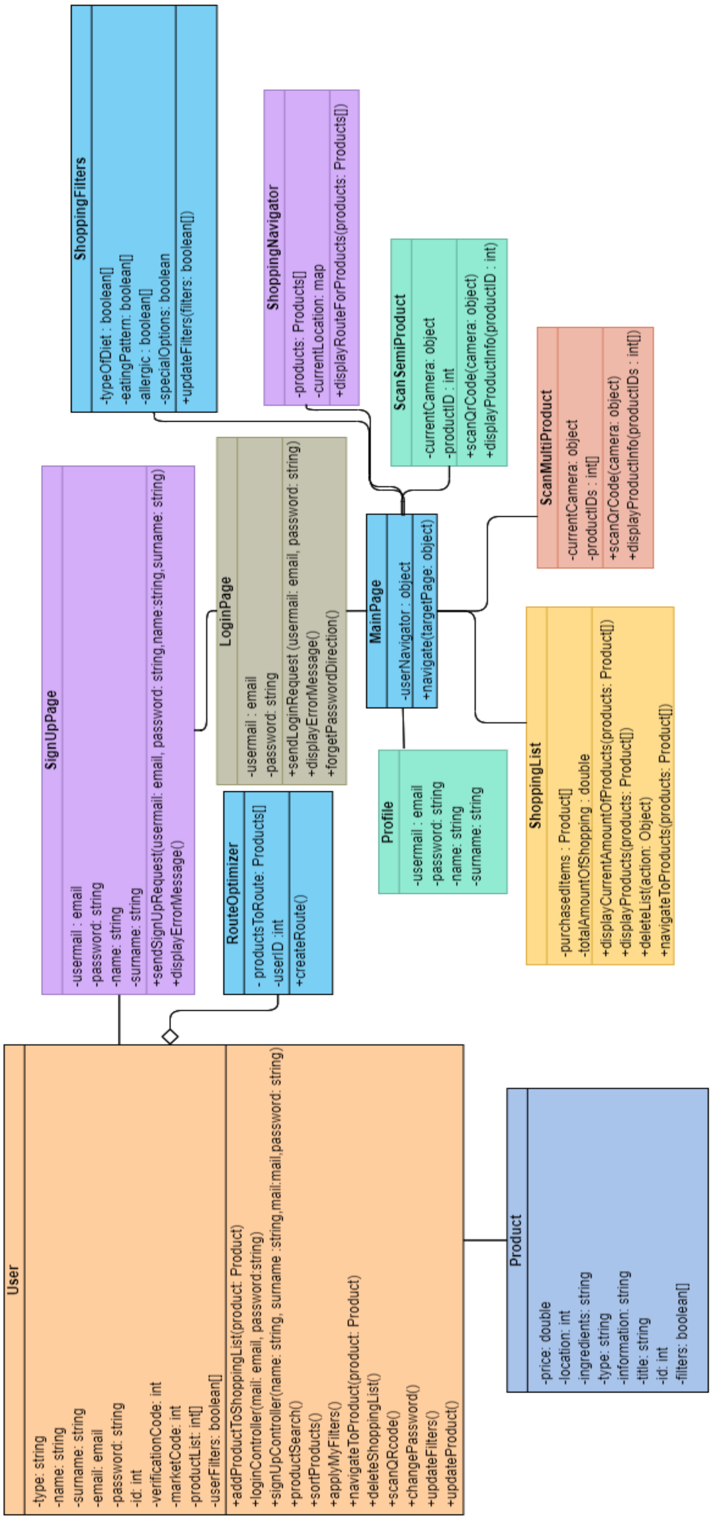

Figure 4. 3 Class diagram

4.4. UI Design

Figure 4. 4 displays sign up screen for application called “sesa” (which is an abbreviation of ‘Smart and Effective Shopping Assistant’ that found by developers of this project).

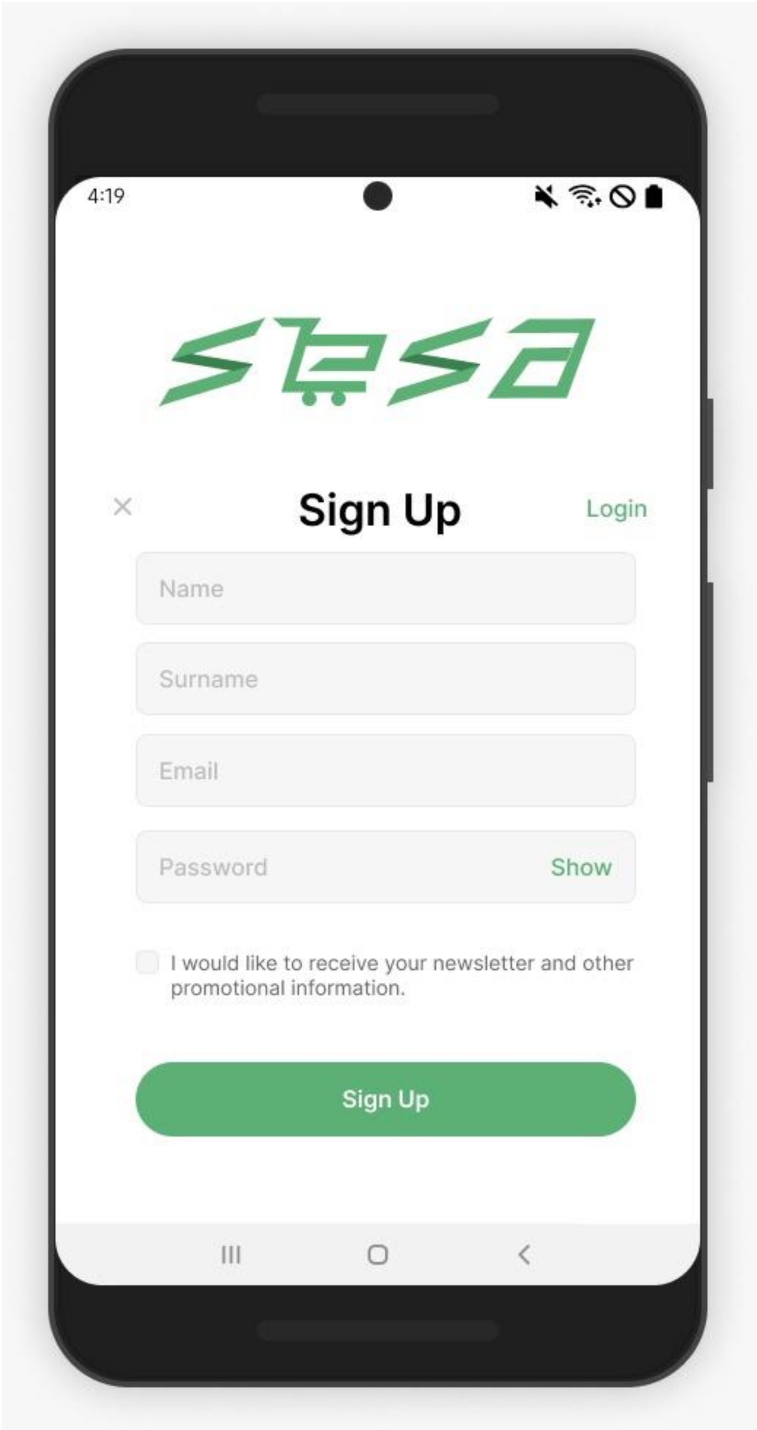

Figure 4. 4 Sign up screen

Figure 4. 5 displays log in screen of application.

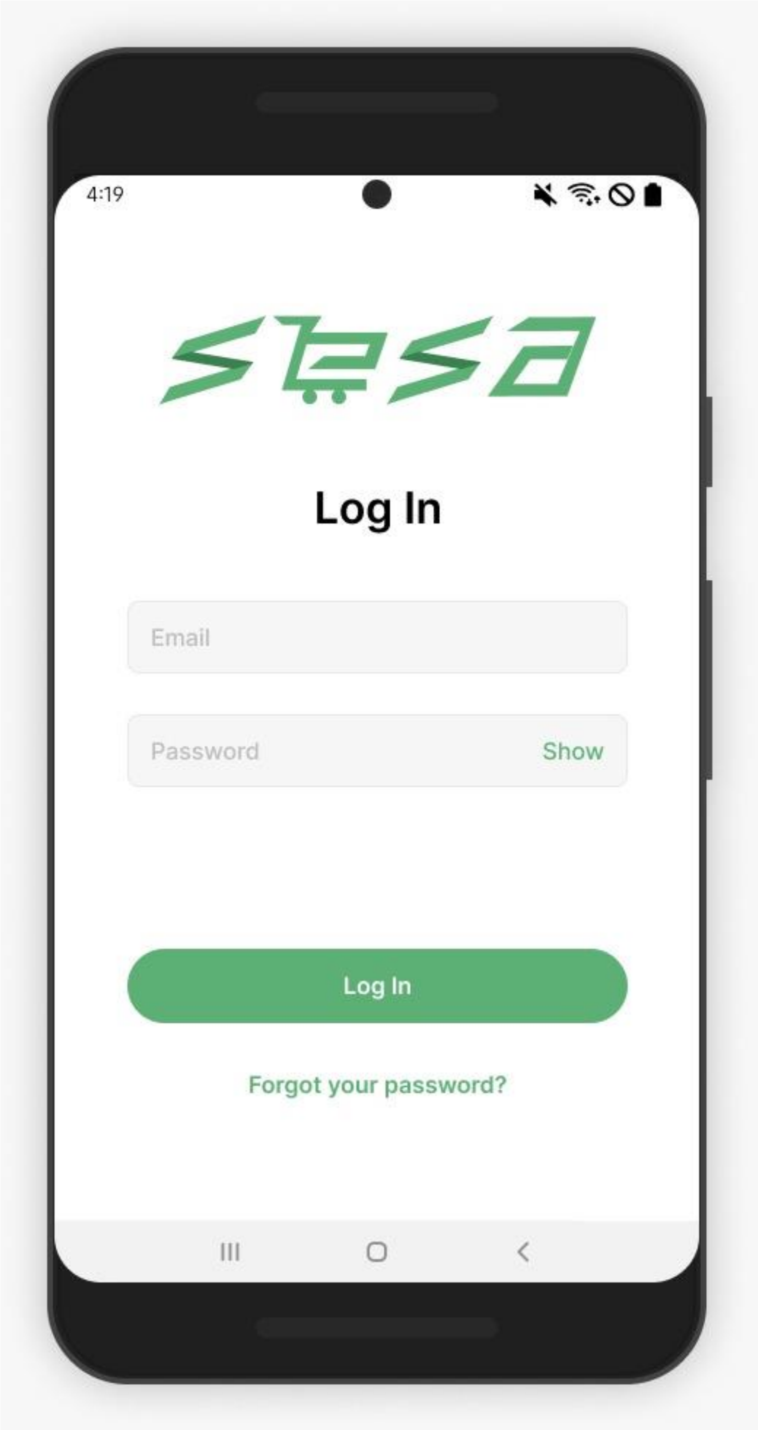

Figure 4. 5 Log in screen

Figure 4. 6 displays main screen of application.

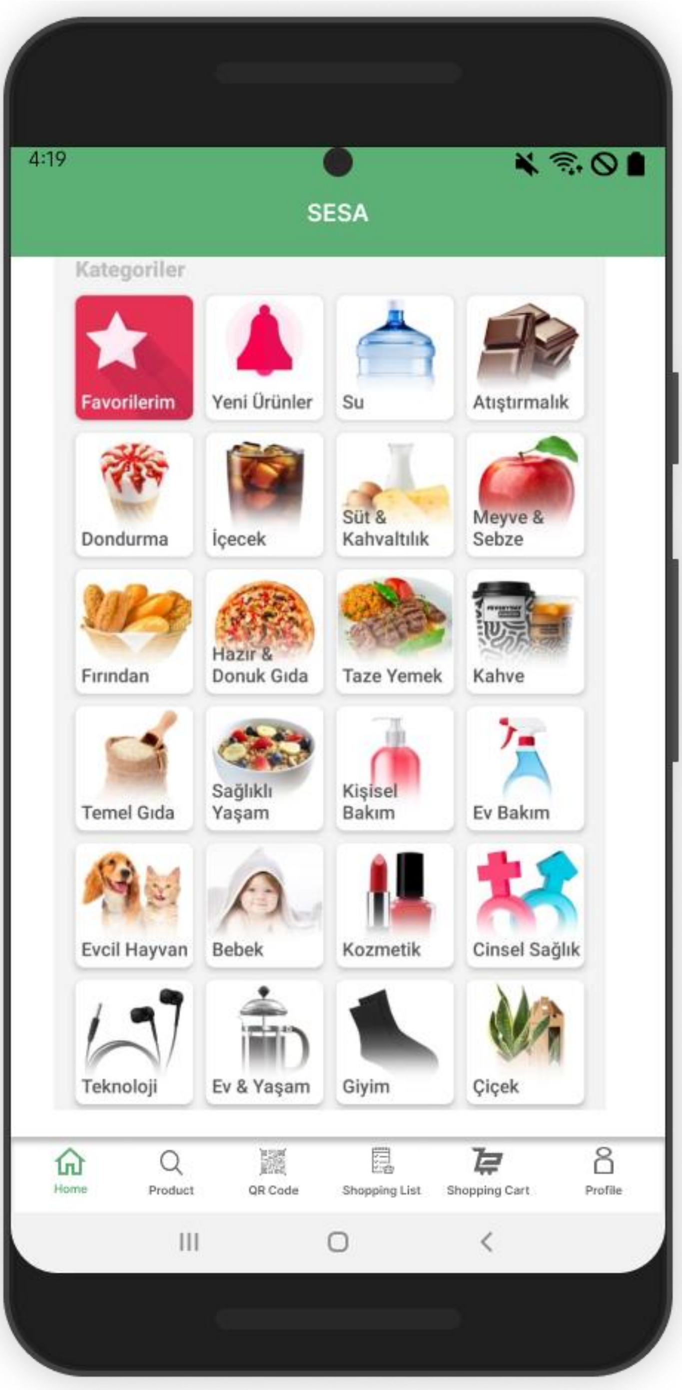

Figure 4. 6 Main screen

Figure 4. 7 displays navigation for a product in grocery store.

Figure 4. 7 Navigation screen

Figure 4. 8 displays user’s filters.

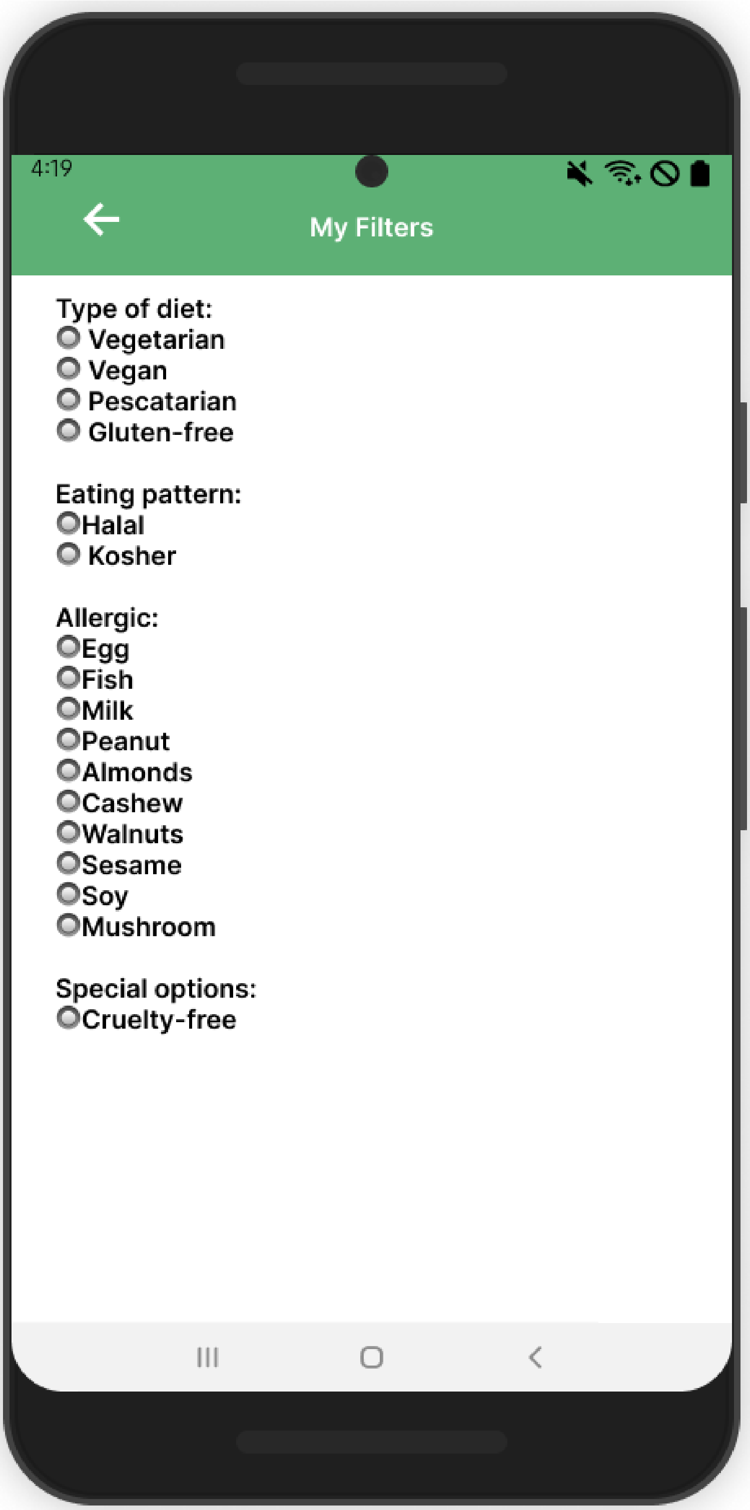

Figure 4. 8 Filters screen

Figure 4. 9 displays QR code scanning screen. There is an applied filter as sort items in ascending order depending on prices.

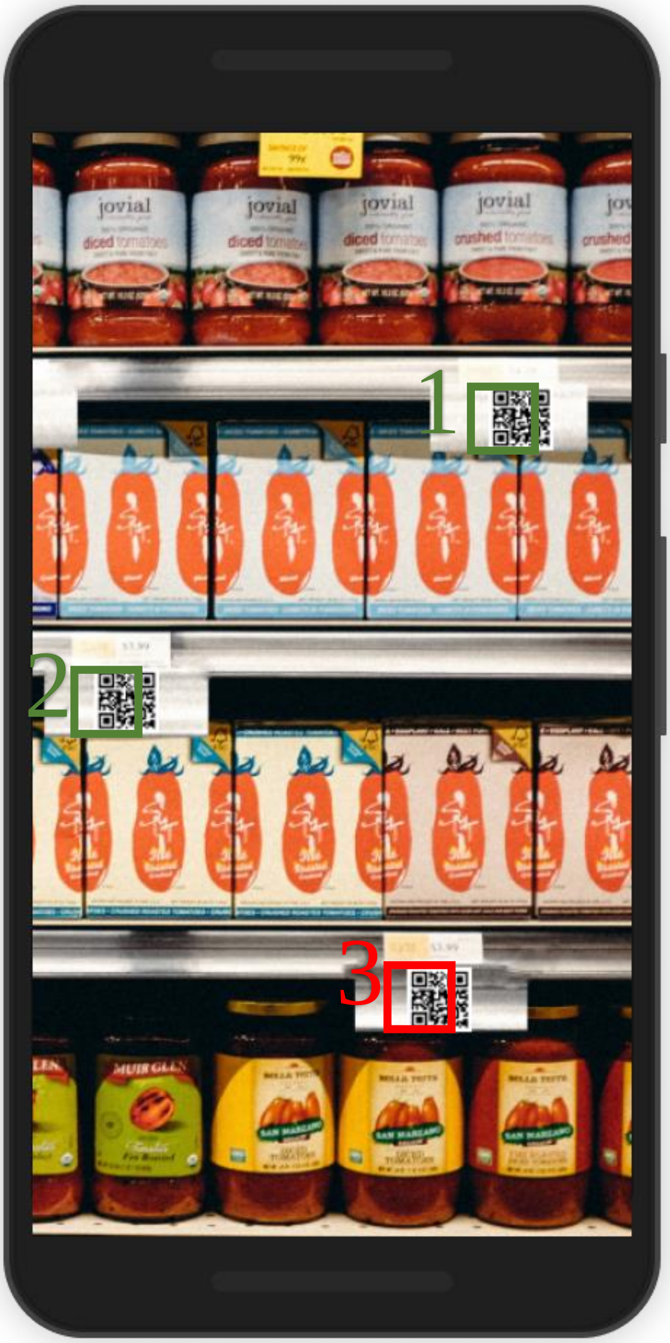

Figure 4. 9 QR codes of products

4.5. Use Cases

Figure 4. 10 displays use cases diagram. Application has 3 types of users as customer, grocery employee and grocery manager.

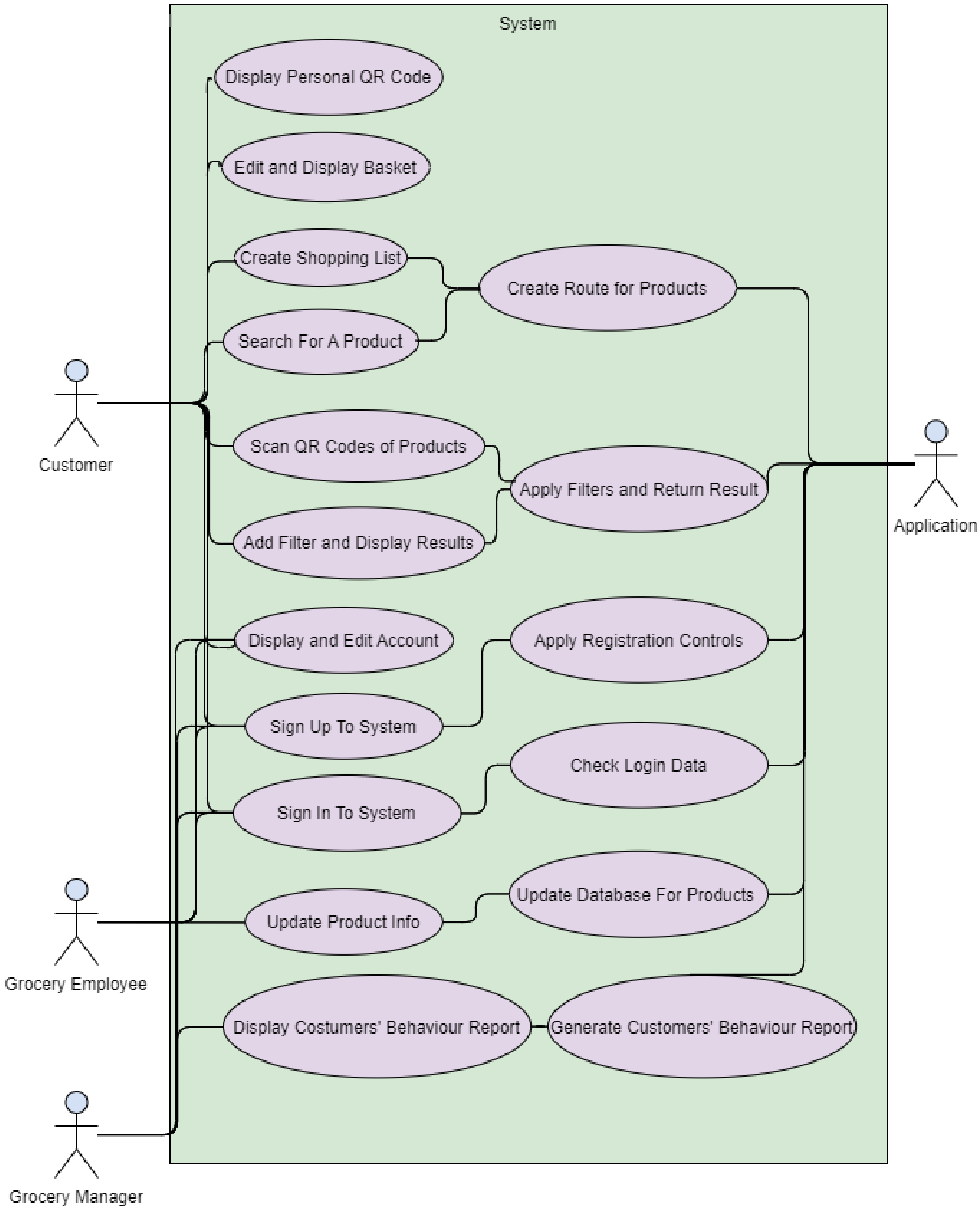

Figure 4. 10 Use case diagram

4.6. Sequence Diagram

Figure 4. 11 displays a sequence diagram of application. After customer log in successfully, customer create shopping list. Then, application navigates him along to shopping list.

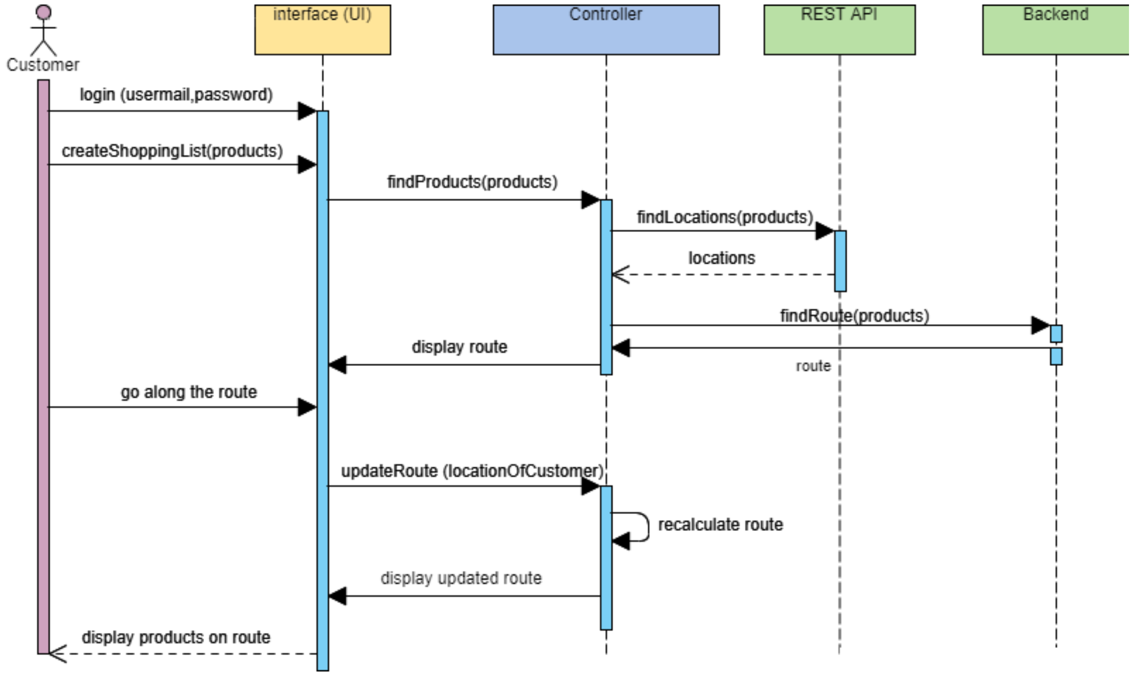

Figure 4. 11 Sequence diagram

4.7. Activity Diagram

Figure 4. 12 displays an activity diagram of application. After customer log in successfully, customer searches a product. Then, application navigates him along to product if it exits in grocery store.

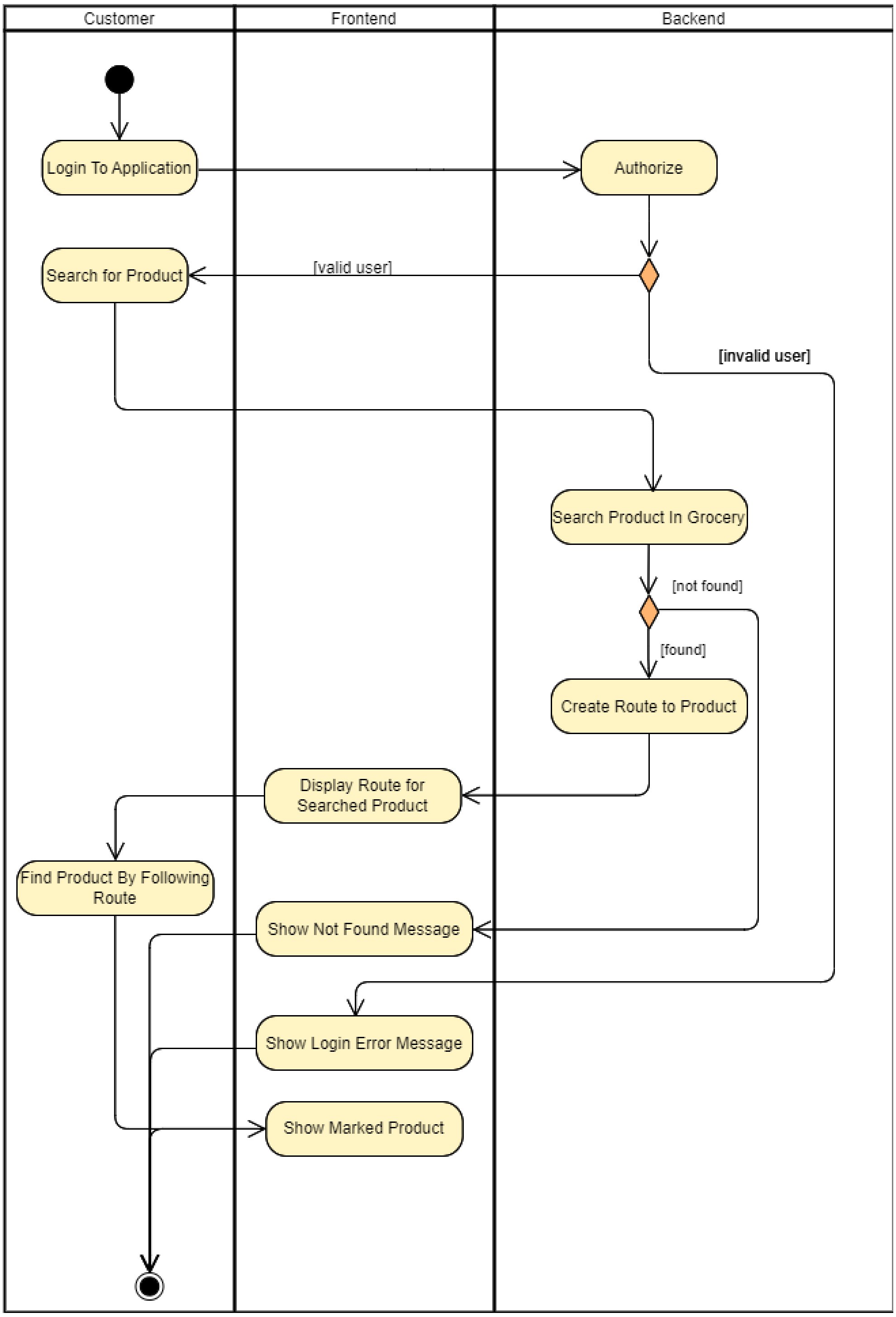

Figure 4. 12 Activity diagram

4.8. Deployment Diagram

Figure 4. 13 displays deployment diagram of application.

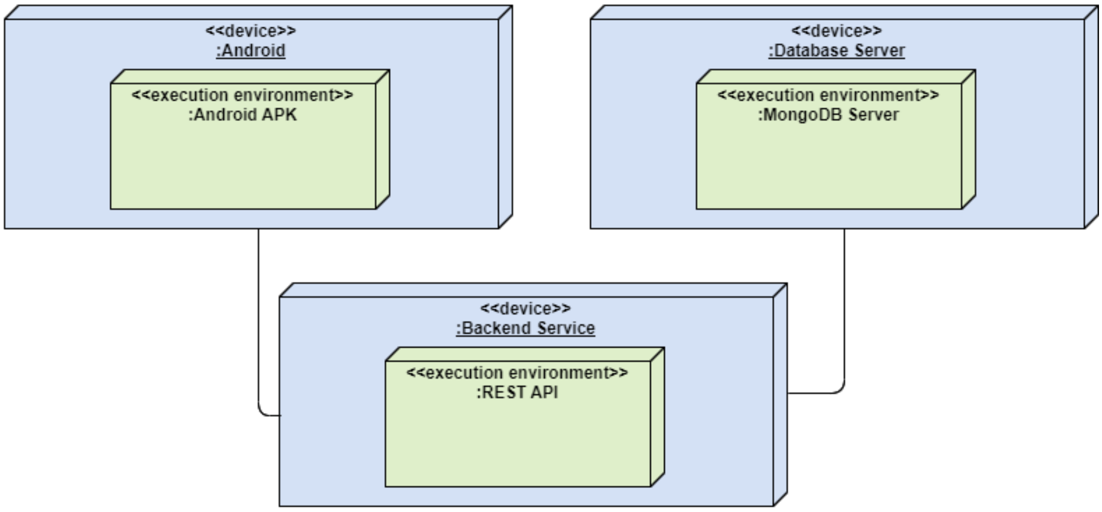

Figure 4. 13 Deployment diagram

CHAPTER FIVE

IMPLEMENTATION

5.1. Database

MongoDB was chosen as the database. A test database was created via MongoDB. The user model and product model have been implemented to the MongoDB. These models are created by Mongoose framework. Database access policy managed by MongoDB Web platform to allow and restrict user's access. Developers' IP addresses are added to system to ensure access permissions. CRUD operations on the database triggered by Postman in versatile steps on the development.

User model (given in Figure 5. 1 with a sample record) contains required information for users as following: oid, name, surname, mail address, password, type (customer or employee), verification code, market code (it's mandatory for employees), product list (includes ids of products that added to shopping list), filters (type of diet, allergic, eating pattern, special option).

Product model (given in Figure 5. 2) contains product information as following: oid, product id, title, price, ingredients, extra information, location (a numeric value that describes the location in market), type, product filters (type for special diets, the information for allergic issues etc.). To satisfy real market environment situations, needed product dataset created manually with the Postman technology as 200 different products under 20 categories.

```
{
"_id":{"$oid":"6266ad034e3a19ec0b5d2da4"},
"userName":"Ümmünur",
"userSurname":"Kandemir",
"userMail":"ukummu@gmail.com",
"userPassword":"hisesa",
"userType":{"$numberInt":"1"},
"userVerificationCode":"2049324",
"userMarketCode":{"$numberInt":"10000"},
"userProductList":[
    {"$numberInt":"92"},
    {"$numberInt":"102"},
    {"$numberInt":"111"},
    {"$numberInt":"124"},
    {"$numberInt":"41"}],
"userFilters":[{
    "isVegetarianSelected":true,
    "isVeganSelected":false,
    "isPescatarianSelected":false,
    "isGlutenFreeSelected":false,
    "isHalalSelected":true,
    "isKosherSelected":false,
    "isEggSelected":true,
    "isFishSelected":false,
    "isMilkSelected":false,
    "isPeanutSelected":true,
    "isAlmondSelected":false,
    "isCashewSelected":false,
    "isWalnutSelected":false,
    "isSesameSelected":false,
    "isSoySelected":false,
    "isMushroomSelected":false,
    "isCrueltyFreeSelected":true,
    "_id":{"$oid":"62780bde930f4ecf8ba39563"}}],
"__v":{"$numberInt":"0"}
}
```


Figure 5. 1 A sample record from database for user model

```
{"_id":{"$oid":"6264494f670215681fee2f30"},
"productId":{"$numberInt":"15"},
"title":"Oreo Biscuits 110g",
"price":{"$numberDouble":"11.15"},
"ingredients":
    "Wheat flour (contains gluten),
     sugar,
     vegetable oils (palm,
     canola),
     reduced-fat cocoa powder (4.3%),
     wheat starch (contains gluten),
     glucose-fructose syrup,
     leavening agents (ammonium carbonates,
     potassium carbonates,
     sodium carbonates) ),
     salt,
     emulsifier (soy lecithin),
     acidity regulator (sodium hydroxide)",
"location":{"$numberInt":"15"},
"productType":"Snack",
"extraInformation":
    "Energy: 476 kcal,
     Fat: 20g,
     Saturated Fat: 5g,
     Carbohydrates: 68g,
     Sugar: 38g,
     Protein: 5g,
     Sodium: 0.73g",
"productFilters":[{
    "isVegetarian":true,
    "isVegan":true,
    "isPescatarian":true,
    "isGlutenFree":false,
    "isHalal":true,
    "isKosher":true,
    "isEggIncluded":false,
    "isFishIncluded":false,
    "isMilkIncluded":false,
    "isPeanutIncluded":false,
    "isAlmondIncluded":false,
    "isCashewIncluded":false,
    "isWalnutIncluded":false,
    "isSesameIncluded":false,
    "isSoyIncluded":true,
    "isMushroomIncluded":false,
    "isCrueltyFree":false,
    "_id":{"$oid":"6264494f670215681fee2f31"}}],
"__v":{"$numberInt":"0"}}
```


Figure 5. 2 A sample record from database for product model

5.2. Backend

Node.js framework is used for backend operations. For REST API design, necessary auxiliary libraries, especially axios, express.js and mongoose technologies, have been integrated.

In the first phase of project, the endpoints required for 2 different types of user registration and login processes were written and tested. Node-mailer technology was used for e-mail verification during new user registration. A corporate information e-mail is opened to inform the relevant new user at the time of registration, and e-mails are sent to the users via this address.

Kitty-route technology is preferred for routing route-based transactions. Async structures are preferred in server-client communication over the relevant endpoints. Exceptional situations that will occur during the related processes are handled with appropriate responses.

On the backend side for the user-based requirements, user's registration and login to the application, password reset, e-mail verification, get and update of user filters, get and update of user’s product list operations have been completed. The necessary control queries for error situations that may occur while performing the relevant operations have also been successfully implemented.

Product based requirements as: adding new product and retrieving product from database handled by the endpoints that associated with products.

Previously mentioned operations handled by the endpoints are given in the Figure 5. 3.

```
const transporter = nodemailer.createTransport({service: 'gmail'...});
app.put("/updatePassword", async (req, res) => {...});
app.post('/resendVerificationCode',async (req, res) => {...});
app.post('/addNewUser', async (req, res) => {...});
app.post("/getUserByMail",  async (req, res) => {...})
app.post('/login', async (req, res) => {...});
app.post('/changePassword', async (req, res) => {...});
app.post('/getUserFilters', async (req, res) => {...});
app.post('/updateUserFilters', async (req, res) => {...});
app.post('/addNewProduct',  (req, res) => {...});
app.post("/getProductByType",  async (req, res) => {...});
app.post("/getProductById",  async (req, res) => {...});
app.post("/getProductByIdSync",  (req, res) => {...});
app.post('/getUserProductList', async (req, res) => {...});
app.post('/updateUserProductList', async (req, res) => {...});
app.post('/deleteUserProductList', async (req, res) => {...});
app.post('/getAllProducts', async (req, res) => {...});
module.exports = app;
```

Figure 5. 3 Endpoints

5.3. Bluetooth Beacons

Bluetooth Beacons to be used for indoor positioning and navigation in the project were supplied by Orema Inc. Totally 13 Bluetooth beacons of four different types were supplied. Beacons are powered and their signals are tested. Successfully received signals from all beacons. It was decided to work with 3 NRF51822 Eddystone iBeacons (given at Figure 5. 4). By using the LightBlue application (from Android Market), the UUID, Minor and Major information of the relevant beacons have been successfully tagged. Signal tests continue to be performed externally before integrating them into the application. Official permissions have been obtained to use Dokuz Eylül University Computer Engineering Lab7 to demo the related market environment.

Figure 5. 4 NRF51822 Eddystone iBeacon

5.4. Indoor Positioning

Trilateration algorithm preferred to detect location of user. BLE signals that received from 3 different positioned Bluetooth Beacons are used by their RSSI (Received Signal Strength Indicator) values from mobile devices. To increase accuracy of location detection, position of beacons located as separate as possible. Because Trilateration approach uses previously known positions of beacons with the axis and ordinate values in the equations. When axis and ordinate values of at least two beacons are so close, mathematical result deviates because of divide operations.

Mentioned environment is arranged at Lab7 to illustrate real market environment (Lab7 environment is given at Figure 5. 5). Lab7 environment is mapped as 24 equal grids to map each product to a location with an id. So, to complete environment setup Bluetooth Beacons are located at Lab7 as given Figure 5. 6. Positions of Bluetooth Beacons are given as (x,y,z) coordinate system and their values are as centimeters. Measurements of Lab7 environment are displayed as well.

Figure 5. 5 Lab7 / Computer Engineering Department / Dokuz Eylül University

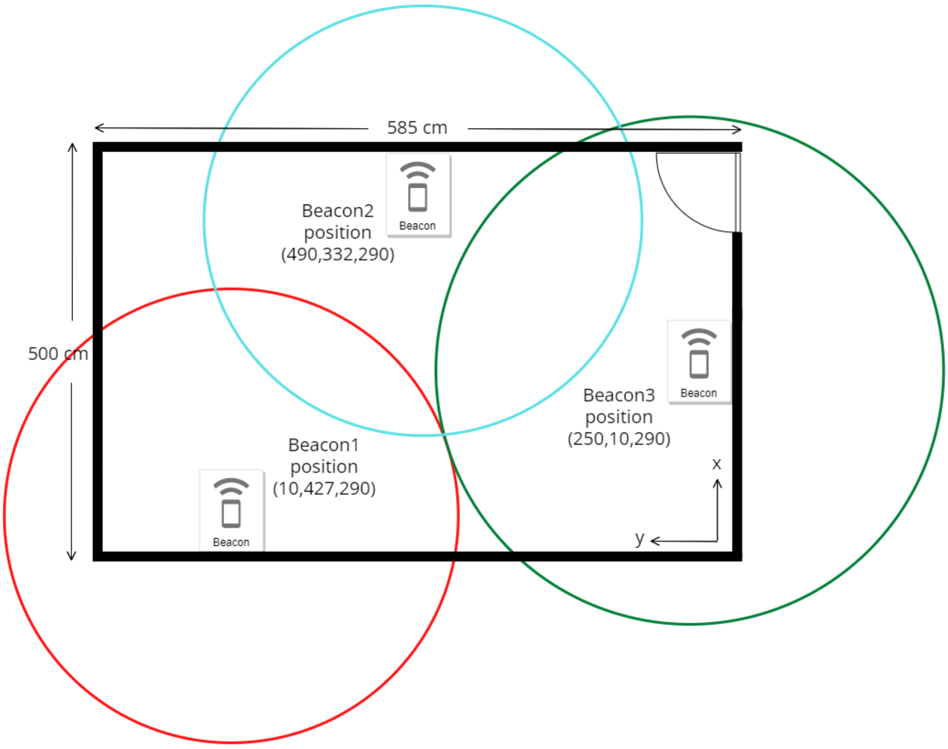

Figure 5. 6 Bluetooth beacons locations at lab7

To apply Trilateration algorithm, distance from each Bluetooth Beacon to mobile device had to be calculated. So, following formula is used to calculate distance.

$$d = 10^{\frac{Measured\ Power - RSSI}{10 \times N}} \quad \text{(Eq. 5.1)}$$

d is the distance between BLE and mobile device. Measured Power is RSSI value that measured from reference distance (1 m). RSSI is value of measured RSSI from device. N is a constant which is an environmental factor with a range 2-4.

Trilateration algorithm uses following mathematical approach to get (x,y) positions of customer. The circles that given Figure 5. 6 represent all the possible locations of a mobile phone at a given distance. The aim of a trilateration algorithm is to calculate the (x,y) coordinates of the intersection point of the three circles. Each circle is defined by the coordinates of its center like (x1,y1) and its radius like r1. These radius values are determined by the Eq. 5.1. Firstly, the equations of circles are calculated:

$$(x - x_1)^2 + (y - y_1)^2 = {r_1}^2 \quad \text{(Eq. 5.2)}$$
$$(x - x_2)^2 + (y - y_2)^2 = {r_2}^2 \quad \text{(Eq. 5.3)}$$
$$(x - x_3)^2 + (y - y_3)^2 = {r_3}^2 \quad \text{(Eq. 5.4)}$$

Then Eq. 5.2, Eq. 5.3, Eq. 5.4 are expanded as below:

$$x^2 - 2x_1x + {x_1}^2 + y^2 - 2y_1y + {y_1}^2 = {r_1}^2 \quad \text{(Eq. 5.5)}$$
$$x^2 - 2x_2x + {x_2}^2 + y^2 - 2y_2y + {y_2}^2 = {r_2}^2 \quad \text{(Eq. 5.6)}$$
$$x^2 - 2x_3x + {x_3}^2 + y^2 - 2y_3y + {y_3}^2 = {r_3}^2 \quad \text{(Eq. 5.7)}$$

Then, subtract Eq. 5.6 from Eq. 5.5:

$$(-2x_1 + 2x_2)x + (-2y_1 + 2y_2)y = {r_1}^2 - {r_2}^2 - {x_1}^2 + {x_2}^2 - {y_1}^2 + {y_2}^2 \quad \text{(Eq. 5.8)}$$

Then, subtract Eq. 5.7 from Eq. 5.6:

$$(-2x_2 + 2x_3)x + (-2y_2 + 2y_3)y = {r_2}^2 - {r_3}^2 - {x_2}^2 + {x_3}^2 - {y_2}^2 + {y_3}^2 \quad \text{(Eq.5.9)}$$

Rewrite Eq. 5.8 and Eq. 5.9 equations using A, B, C, D, E, F values:

$$Ax + By = C \quad \text{(Eq. 5.10)}$$

$$Dx + Ey = F \quad \text{(Eq. 5.11)}$$

Then, solution of the system is calculated as following:

$$x = \frac{CE-FB}{EA-BD} \quad \text{(Eq. 5.12)}$$

$$y = \frac{CD-AF}{BD-AE} \quad \text{(Eq. 5.13)}$$

Trilateration algorithm implemented with the distances that mentioned at Eq. 5.1 and located beacons' positions. x and y values of user location are determined with using mentioned equations. These location values are used to display user location in shopping path screen in application with blue dot. The position of user is recalculated depending on changes of user's distance from any beacon.

5.5. Path Finding

In this project, as mentioned in the previous sections, it is aimed to develop a market environment assistant. The Lab7 environment, which was mentioned for the routing and location detection processes of the market environment, was transformed into an undirectional and weighted graph (Figure 5. 8). Lab7 environment is divided into 24 equal sections (Figure 5. 7) and each section is assigned as a graph's node. Based on the direct connection between the relevant nodes by walking, the relevant nodes are connected to each other with the edges. As in a market environment, shelves prevented direct access between nodes and a graph was created considering these situations.

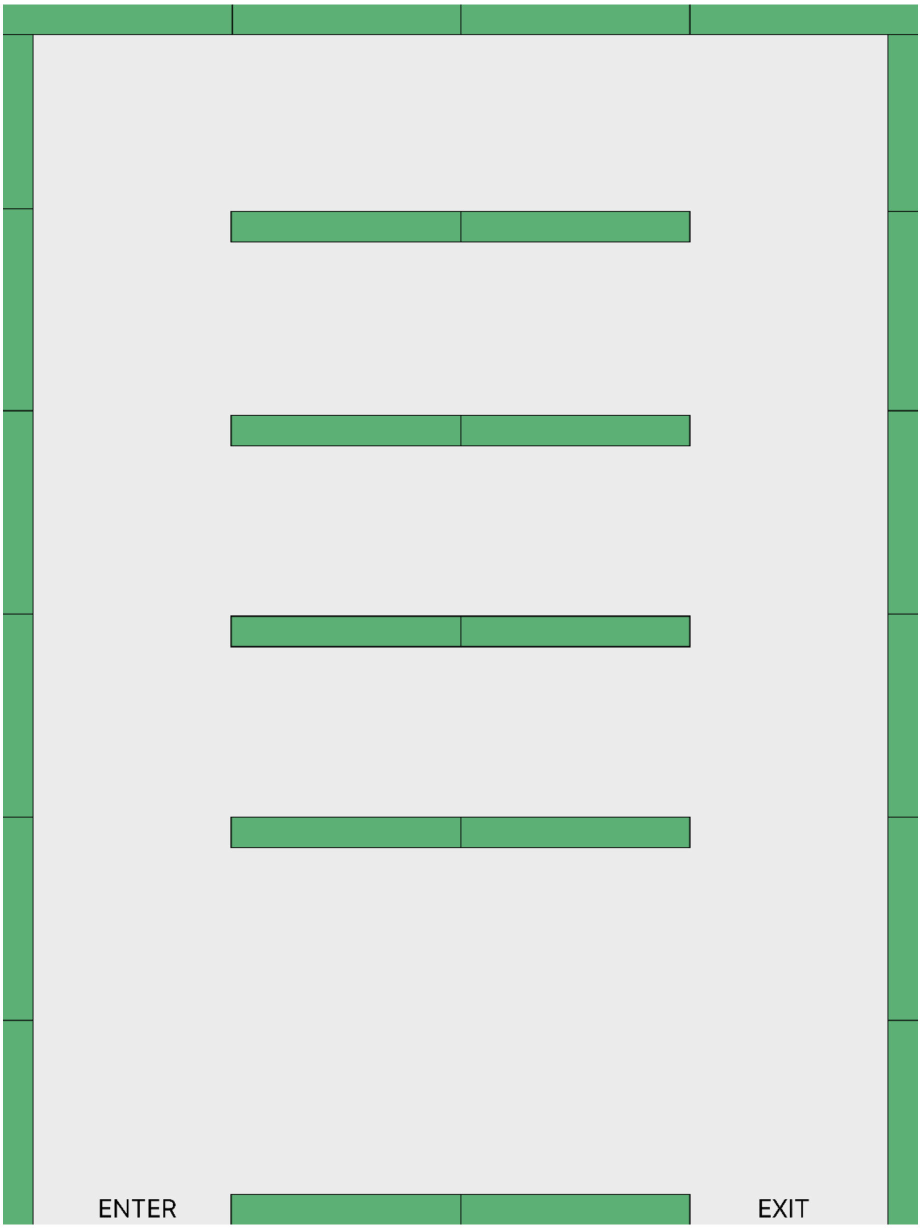

Figure 5. 7 Illustration of market environment

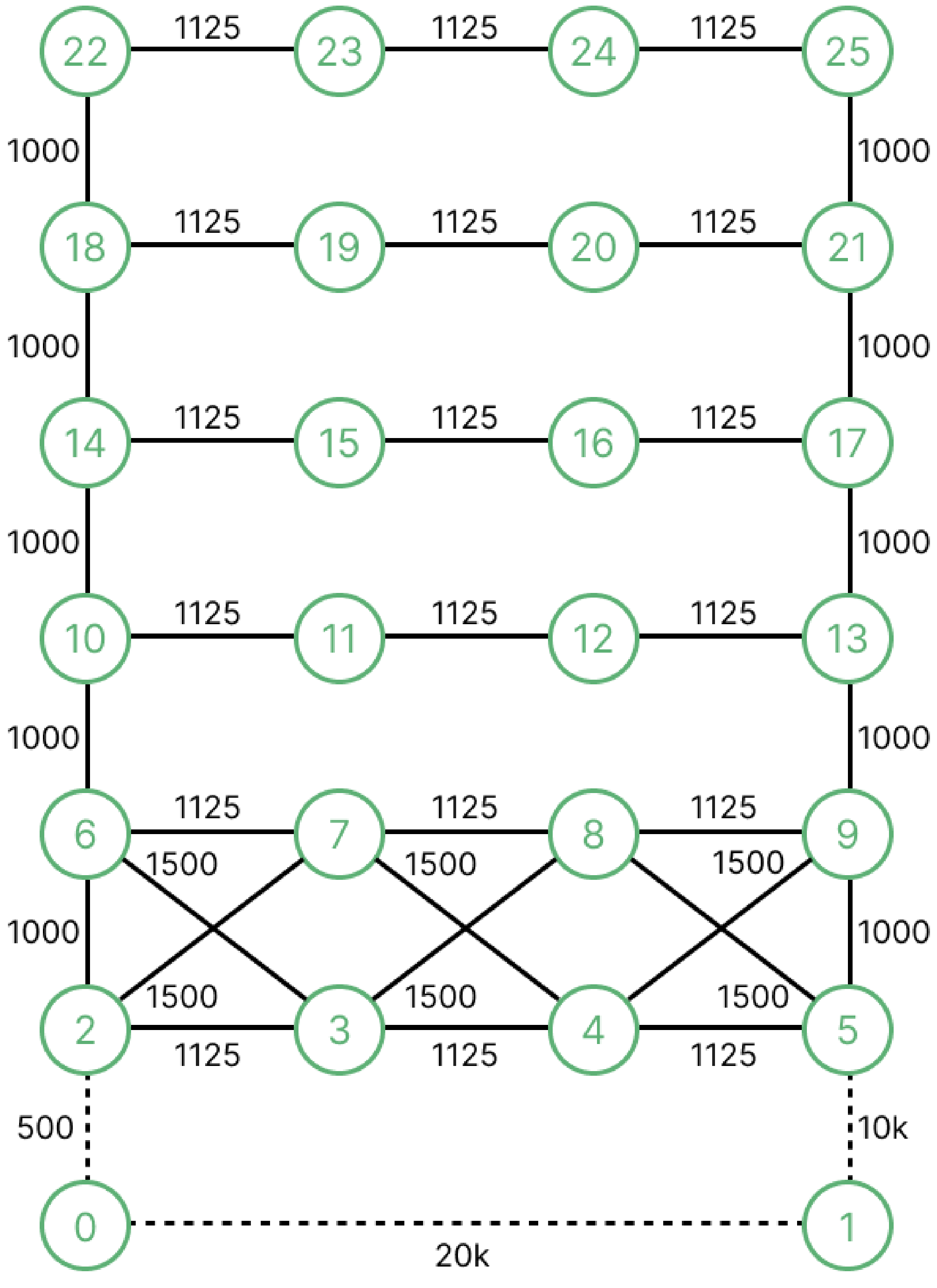

Figure 5. 8 Graph of market environment

In the market environment, it was necessary to develop a solution in which the customers would be directed to the exit by taking the products in the shopping list that they had previously created. In other words, the shortest way to reach the exit had to be found by passing through the points to be visited. With the conversion of the market environment to graph, it has become easier to determine this optimal route. Although the related problem is similar in nature to the Traveling Salesman Problem (TSP), it was necessary not to create a Hamiltonian Cycle. Because the person entering the market had to exit from a different point. For this reason, by adding a Dummy node, the exit point has been added to the places to be visited for sure. But this node should have been the last place to stop in the Hamiltonian cycle. In order to achieve this, an extreme weight assignment was made between the Dummy node and the market entry node. The weight of the edge between the other node (node with id 5) to which the dummy node is connected is assigned as an extreme value. Thus, the two edges to which the Dummy node is connected were forced to be the last node to be called due to extreme values. The magnitudes of these extreme values have been adjusted among themselves to return to the starting point finally (adding Dummy node (node with id 1) and updating weights (with dashed line) of this dummy node are illustrated in the Figure 5. 8).

In order to create the ideal shopping route, the location ids of the products added by the user while creating the shopping list are associated with the nodes of our graph. In other words, this is how we get the ids of the nodes that need to be called. It was necessary to generate a subgraph from the graph given in the Figure 5. 8 so that the customer, who would pass over these nodes and reach the output, would only visit the nodes they needed. This subgraph was created in a complete manner and the Floyd Warshall algorithm was applied to navigate the binary connections between all nodes with minimum weight. Thus, the minimum paths between the certain nodes were created by adding the visited nodes respectively. The fact that the Floyd Warshall algorithm gives us the path reached with the minimum weight of any two nodes in a graph was used when creating the ideal route. Floyd Warshall data (a sample of this data is given Table 5. 1), which was produced by using the distance matrix (Figure 5. 9) of the market environment converted to graph, was recorded statically and performance optimization was thus achieved at runtime. Thus, reduced graph obtained as given in Figure 5. 10, previously mentioned TSP approach applied over this graph to get shortest path while visiting certain nodes.

Fields	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
0	0	20k	500	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
1	20k	0	∞	∞	∞	10k	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
2	500	∞	0	1125	∞	∞	1000	1500	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
3	∞	∞	1125	0	1125	∞	1500	1000	1500	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
4	∞	∞	∞	1125	0	1125	∞	1500	1000	1500	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
5	∞	10k	∞	∞	1125	0	∞	∞	1500	1000	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
6	∞	∞	1000	1500	∞	∞	0	1125	∞	∞	1000	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
7	∞	∞	1500	1000	1500	∞	1125	0	1125	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
8	∞	∞	∞	1500	1000	1500	∞	1125	0	1125	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
9	∞	∞	∞	∞	1500	1000	∞	∞	1125	0	∞	∞	∞	1000	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
10	∞	∞	∞	∞	∞	∞	1000	∞	∞	∞	0	1125	∞	∞	1000	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
11	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	1125	0	1125	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
12	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	1125	0	1125	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
13	∞	∞	∞	∞	∞	∞	∞	∞	∞	1000	∞	∞	1125	0	∞	∞	∞	1000	∞	∞	∞	∞	∞	∞	∞	∞
14	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	1000	∞	∞	∞	0	1125	∞	∞	1000	∞	∞	∞	∞	∞	∞	∞
15	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	1125	0	1125	∞	∞	∞	∞	∞	∞	∞	∞	∞
16	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	1125	0	1125	∞	∞	∞	∞	∞	∞	∞	∞
17	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	1000	∞	∞	1125	0	∞	∞	∞	1000	∞	∞	∞	∞
18	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	1000	∞	∞	∞	0	1125	∞	∞	1000	∞	∞	∞
19	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	1125	0	1125	∞	∞	∞	∞	∞
20	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	1125	0	1125	∞	∞	∞	∞
21	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	1000	∞	∞	1125	0	∞	∞	∞	1000
22	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	1000	∞	∞	∞	0	1125	∞	∞
23	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	1125	0	1125	∞
24	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	1125	0	1125
25	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	1000	∞	∞	1125	0

Figure 5. 9 Distance matrix

Table 5. 1 Shortest path between nodes

Begin Node	Target Node	Path	Weight
0	1	0,2,3,4,5,1	13875
0	2	0,2	50
0	3	0,2,3	1625
0	4	0,2,3,4	2750
0	5	0,2,3,4,5	3875
0	6	0,2,6	1500
0	7	0,2,7	2000
0	8	0,2,3,8	3125
0	9	0,2,3,4,9	4250
0	10	0,2,6,10	2500
0	11	0,2,6,10,11	3625
0	12	0,2,6,10,11,12	4750
...			

The table given above was obtained by applying the Floyd Warshall algorithm. Begin Node shows starting node, Target Node shows the target location, Path shows the nodes that need to be visited in the shortest path between these two nodes respectively, and Weight shows the total weight of the path.

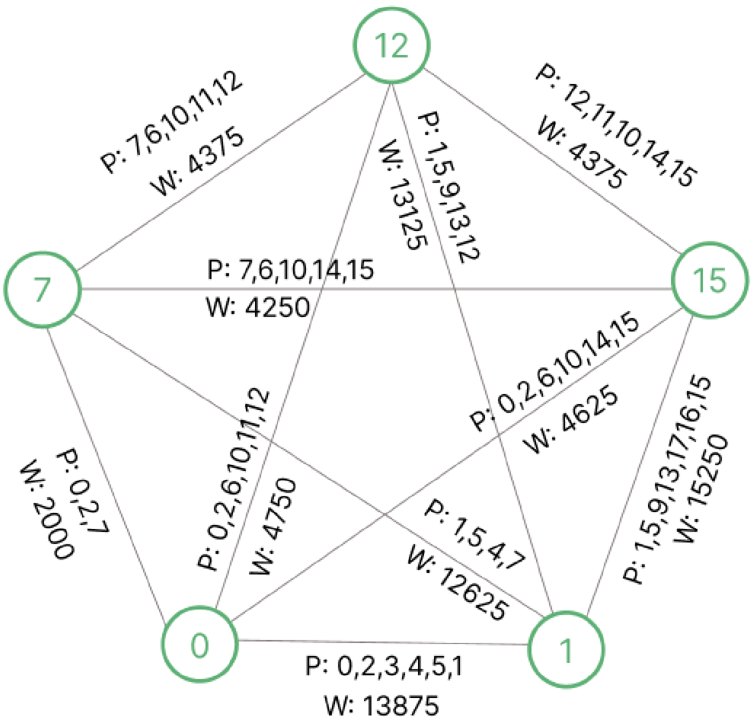

Figure 5. 10 A sample subgraph

The graph given above is the subgraph formed by the nodes to be visited. While creating the Hamiltonian Cycle, the shortest paths between all pairs and the weights of these paths are given on a complete graph. Thus, the TSP approach is ready to be run on this graph.

As a result, an ideal route has been tried to be created for the nodes that need to be visited by using the shortest path data obtained with Floyd Warshall. In this way, the ideal route calculation for the shopping list created by the user in the application is provided. The person was directed to the exit by being visited by the nodes containing all the products he added to the shopping list.

In addition, when the user searches for only one product while in the market, the current position is taken by the Beacons, and a node on the graph (Figure 5. 8) is assigned and the product they are looking for is determined as the target point. The shortest path was calculated using Floyd Warshall data from its current node to this node and presented to the user.

5.6. QR Code Scanning

The QR code scanning process was basically developed to provide two main services. The first of these is based on scanning the QR code of the relevant product to enable customers to get detailed information about the products when they come to the product. In other words, detailed information about the product whose QR code is scanned is shown to the users by being directed to the relevant information screen. This information shown to the user includes the name of the product, its price, ingredients and extra information about the product (such as nutritional value for food).

The second basic service is designed to provide users with simultaneous scanning of multiple products. Our application, which accesses the camera permissions of the phone, offers users multiple products with two basic approaches. The first of these is to display the prices of the scanned products in ascending order, with the sequence numbers above the QR codes on the user's screen. The other is to transfer the QR codes of the products to the users by wrapping them with red and green frames according to the consumption filters that the user has determined in his profile. In addition, the pressability feature has been added to the QR code areas detected in this service. Thus, it is possible for the user to go directly to the detail of the product by touching the relevant area. These two basic sequencing and marking services mentioned above have been achieved on a single screen, but also adapt to situations where the user changes the camera angle and distance. An example of the relevant service is given in the image below (in Figure 5. 11).

Figure 5. 11 Advanced QR scanning

A sample user login was made in the QR scan given above. For this user, vegetarian and halal nutrition type, egg and peanut options from allergies and cruelty free option from special selection were selected in filters screen. According to these filters, those that contain meat and fish products from the above-given foods, as well as those that are not halal and cruelty free, are shown in red. Since the contents of other products are not adverse to both nutritional type and allergies, those products are also shown in green. As another process, the prices of the six scanned products are listed in ascending order and the order information is presented to the user at the top of QR codes.

5.7. Frontend

React Native is used for the frontend part. The application was emulated by using the Pixel 3a API 29 virtual device created with Android Studio together with Expo technology. Also real devices are preferred to test frontend sections. These real devices are Samsung Galaxy A71 and Huawei P20 Lite. Axios technology was preferred in the communication to be provided with the backend. Reducers and actions have been implemented for management in the data layer of React Native.

Main structure of frontend components are previously designed in Figma. Then these designs are implemented with React Native and associated frameworks at given Table 5. 2.

Table 5. 2 Frameworks and usage purposes

Framework	**Usage**
expo-google-fonts/inter	Font styling
react-native-community/checkbox	Displaying and applying user filters
react-navigation	Routing between screens
react-native-elements	Creating main components of screens
react-native-svg	Drawing map, route and user location
react-native-vector-icons	Icons on screens
expo-barcode-scanner	Multiple/single QR code scanning
react-native-ble-plx	Bluetooth beacon management
react-native-async-storage	Async storage
nikbelikov/tsp-solver	TSP algorithm implementation
node-trilateration	Trilateration algorithm implementation

5.8. User Screens

5.8.1. Common Screens

Screen at Figure 5. 12 provides main functionalities of a sign in operation while containing forgot password and sign-up links. Applications logo displayed at the top of the screen. Mail and password information are controlled in two level. First controls are made at fronted level which about e-mail and password format, and second controls made by backend to validate mail and password matching. Also, appropriate error messages are organized for the error cases.

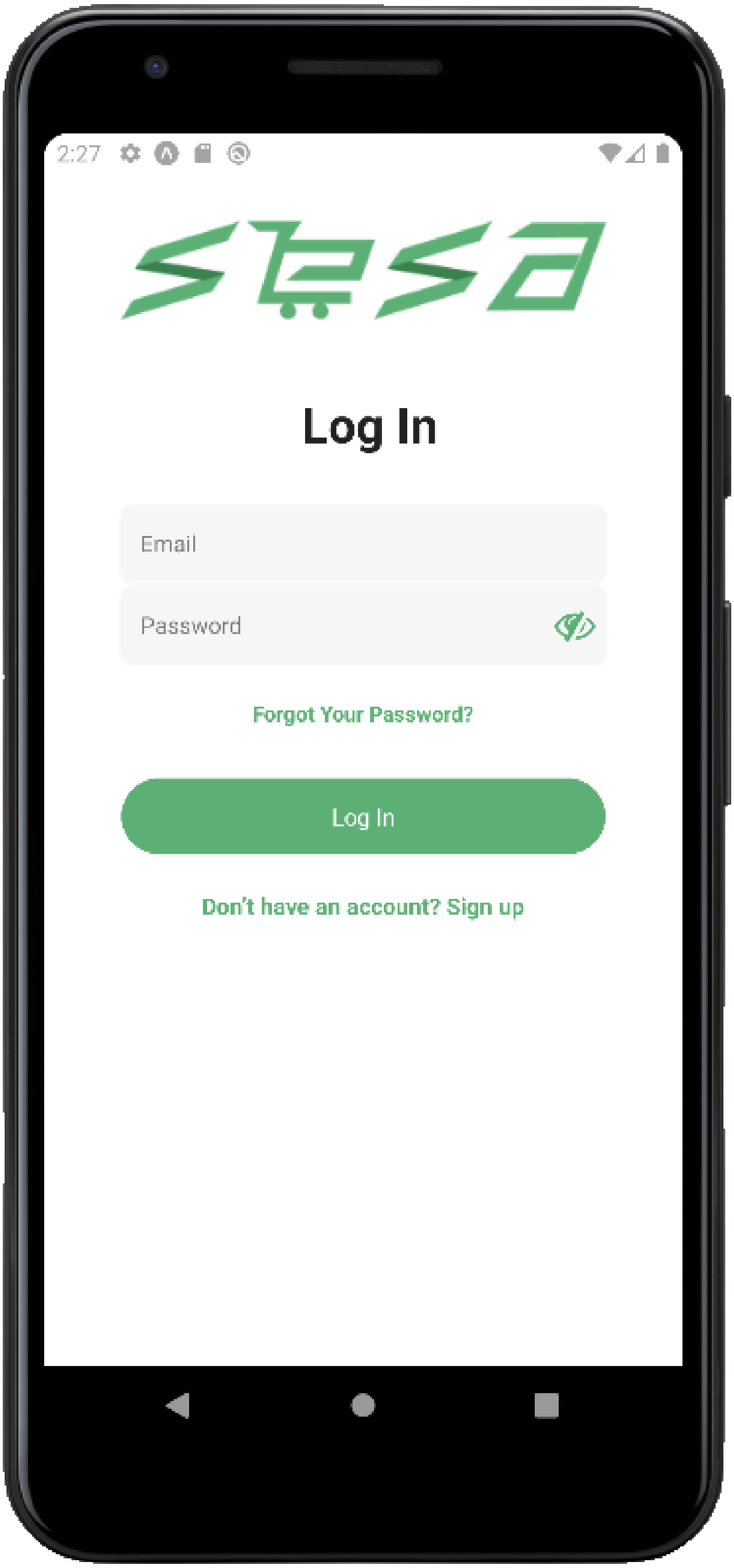

Figure 5. 12 Login screen

Screen at Figure 5. 13 provides resetting service for forgotten passwords as sending auto generated new passwords to user's mail.

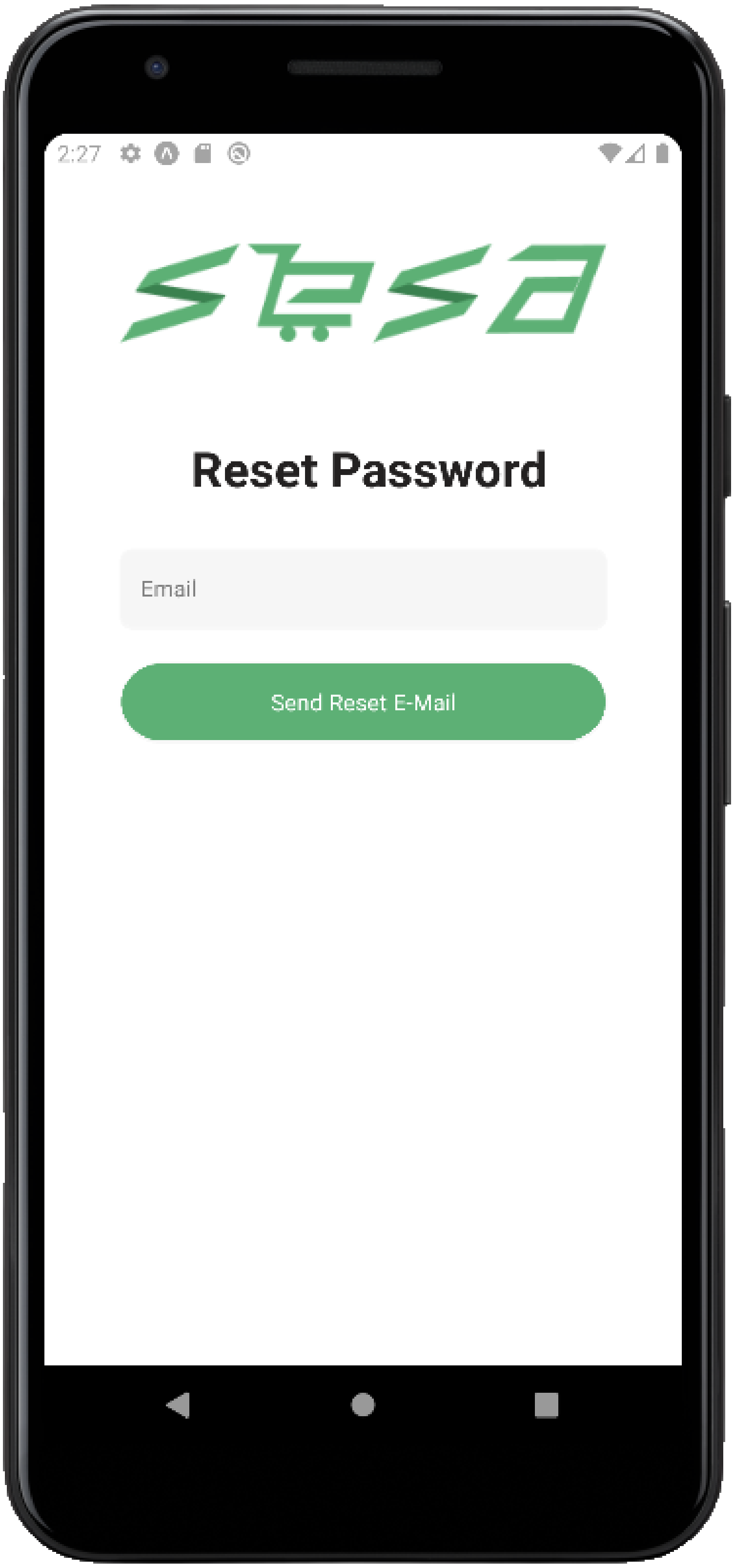

Figure 5. 13 Reset password screen

Screen at Figure 5. 14 provides navigation between two types of user for customer and employee.

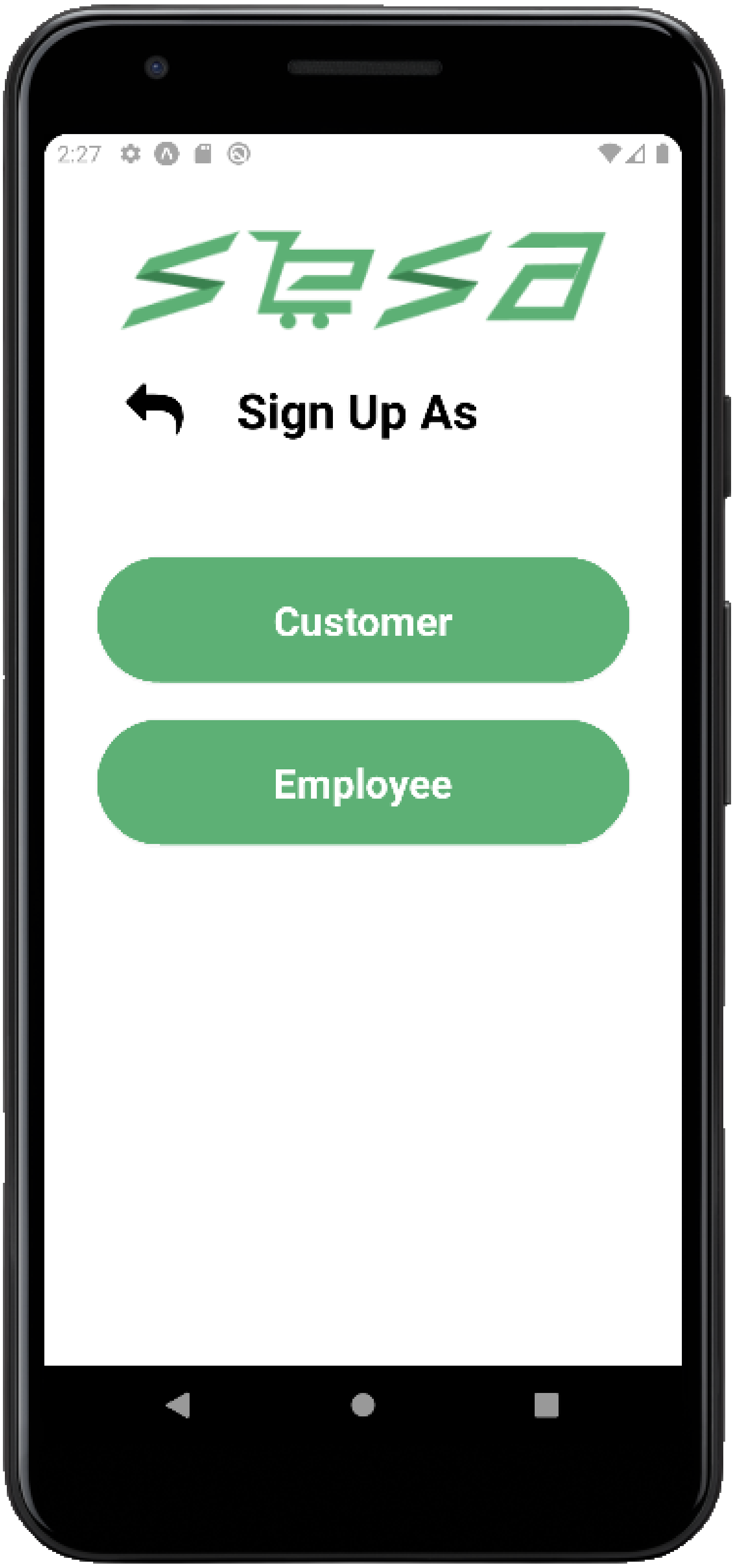

Figure 5. 14 Sign up navigator screen

Screen at Figure 5. 15 takes verification code from new user to validate mail address. Resend Code link send verification code again. When submit button pressed with true verification code, sign up operation completed.

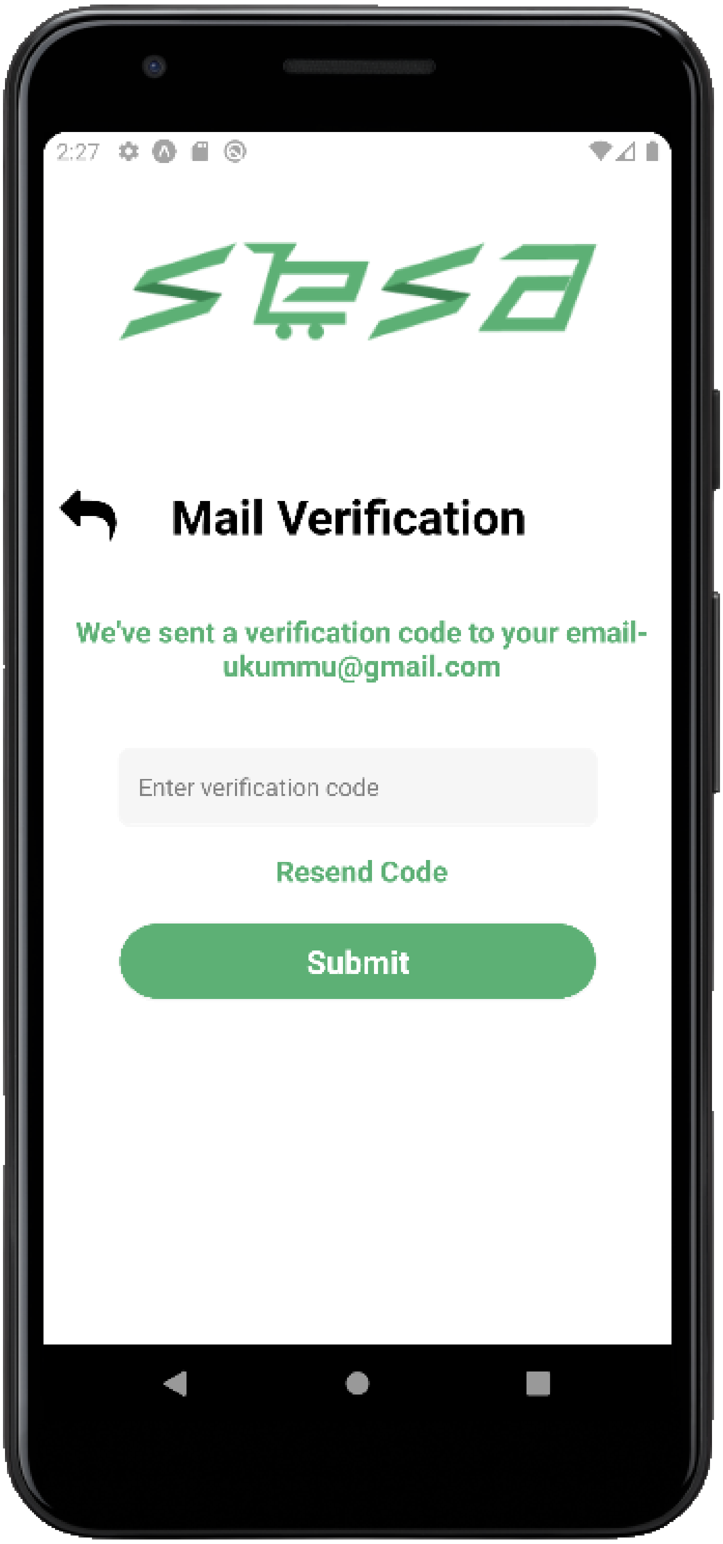

Figure 5. 15 Mail verification screen

At Figure 5. 16 displays a sample e-mail verification code mail.

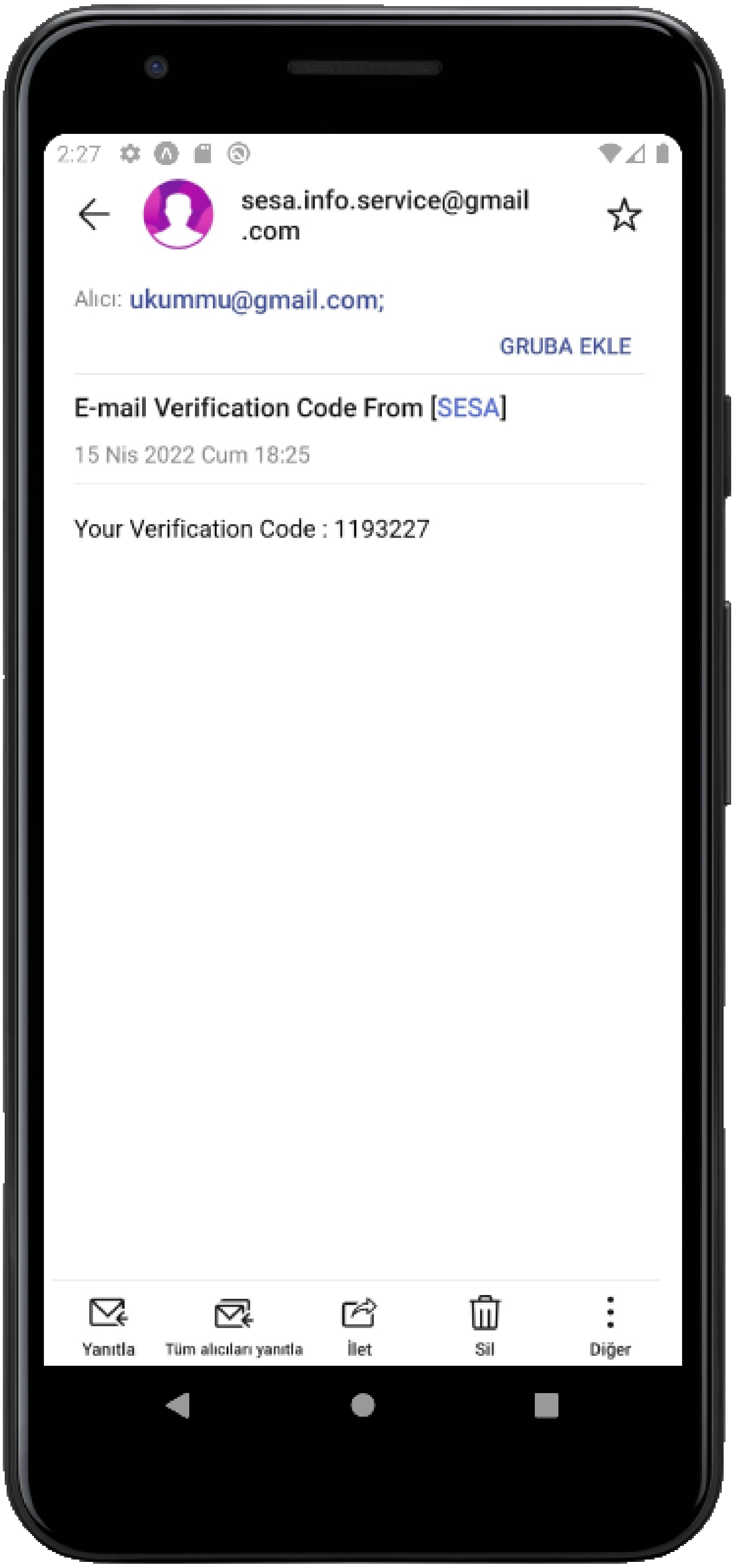

Figure 5. 16 Verification mail

5.8.2. Customer Screens

Screen at Figure 5. 17 takes new customer data as name, surname, mail and password. Required format and logic controls are also implemented to satisfy format with appropriate error messages (as existing mail address, wrong mail format etc.).

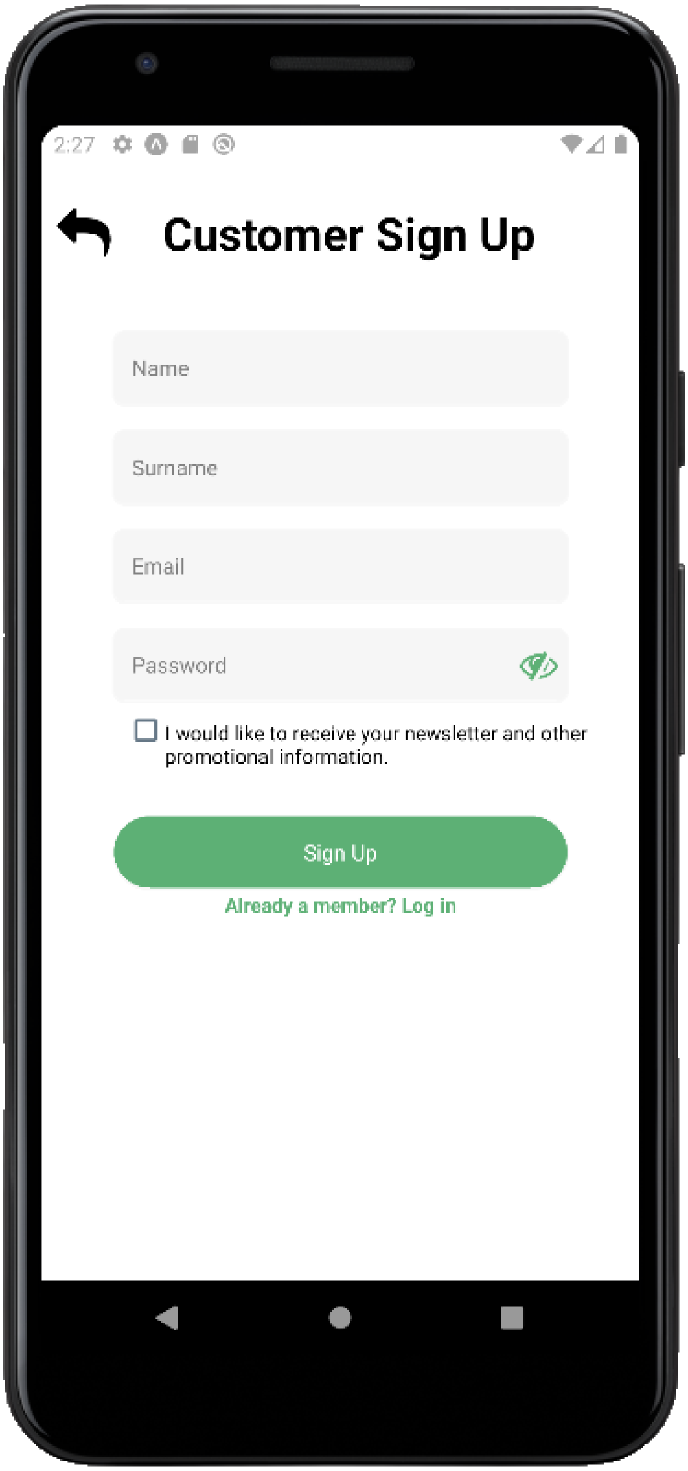

Figure 5. 17 Customer sign up screen

Screen at Figure 5. 18 provides product categories with suitable images to allow navigation for users much more easier depending on category of product.

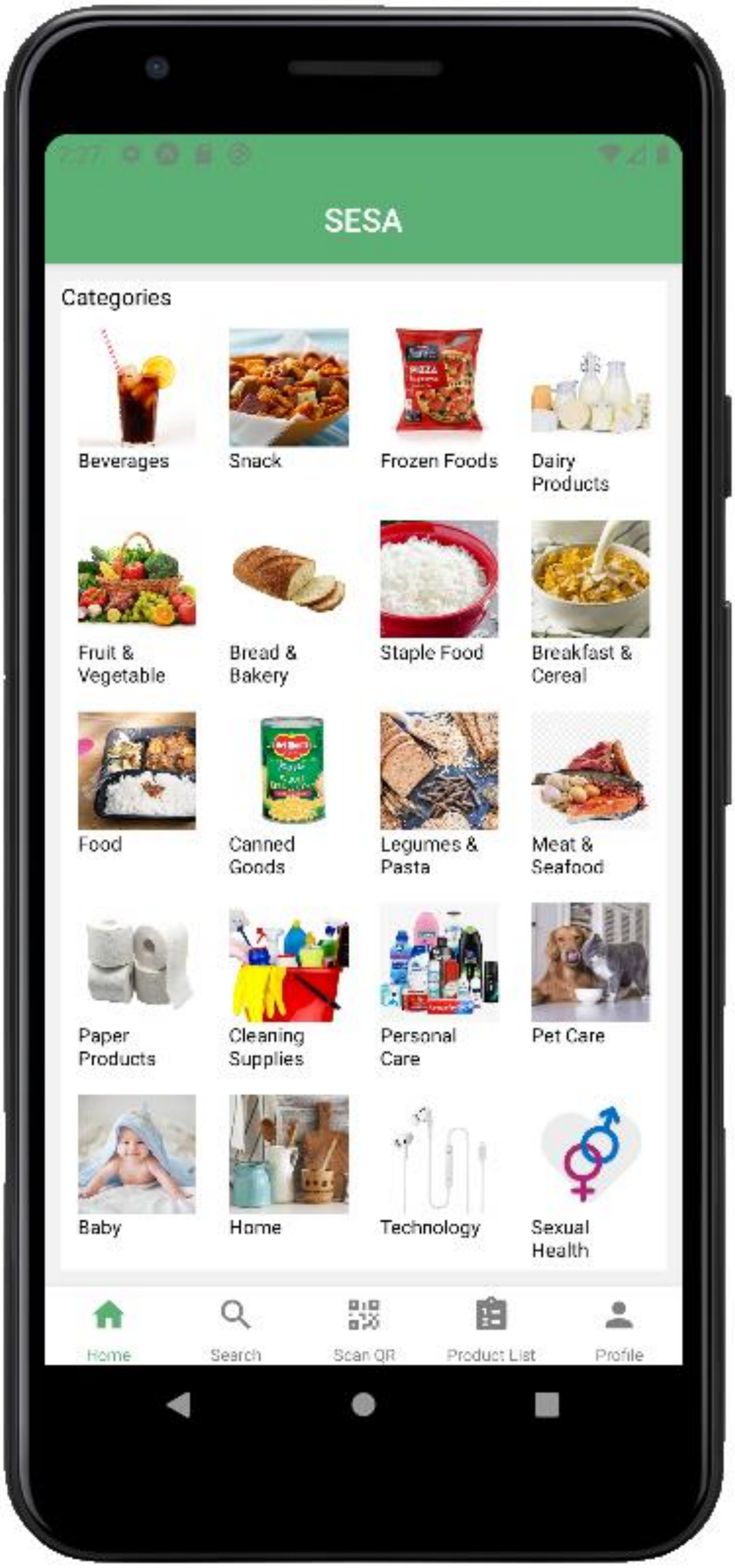

Figure 5. 18 Main screen

Screen at Figure 5. 19 contains only one kind of products that belongs to previously selected category (For example if user press Beverages from Main Screen, then this screen will contain only Beverages). Users can search for a specific product by name. Users can sort products in ascending or descending order. Users can also filter products with “Apply My Filters” option which determined in user profile. Filtering and ordering operations are made by drawers. User can press on the products which displayed on this screen to get detailed information. User can add the product to shopping list with pressing  icon. User can display the shortest path from current point to searched product point with pressing  .

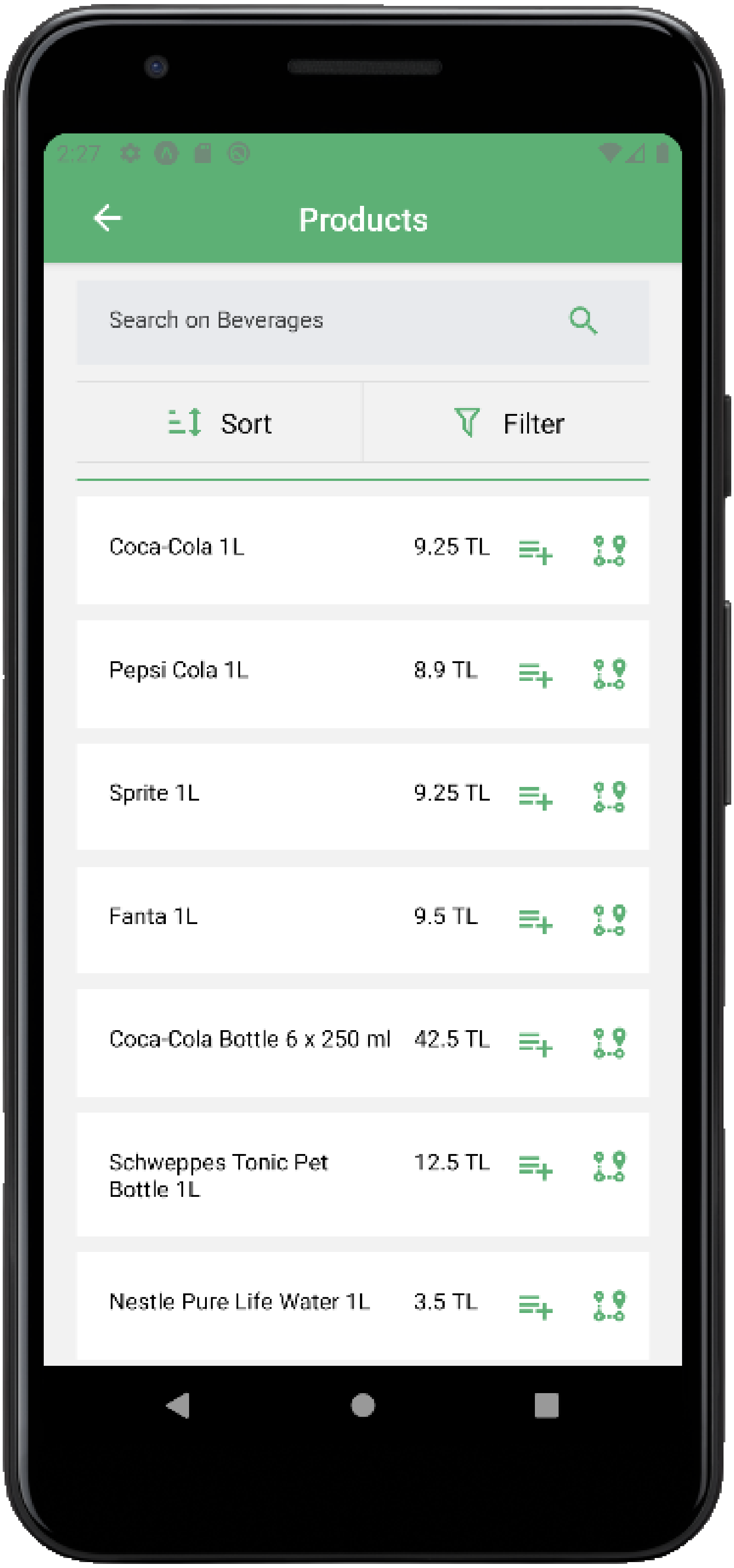

Figure 5. 19 Products by category screen

Screen at Figure 5. 20 displays market as an image. And user's current location (which determined by BLE algorithms) displayed as node with letter "B" (which stands for Begin) and searched products location is displayed with name of "T" (Which stands for Target). Then shortest path for searched product visualized by red line.

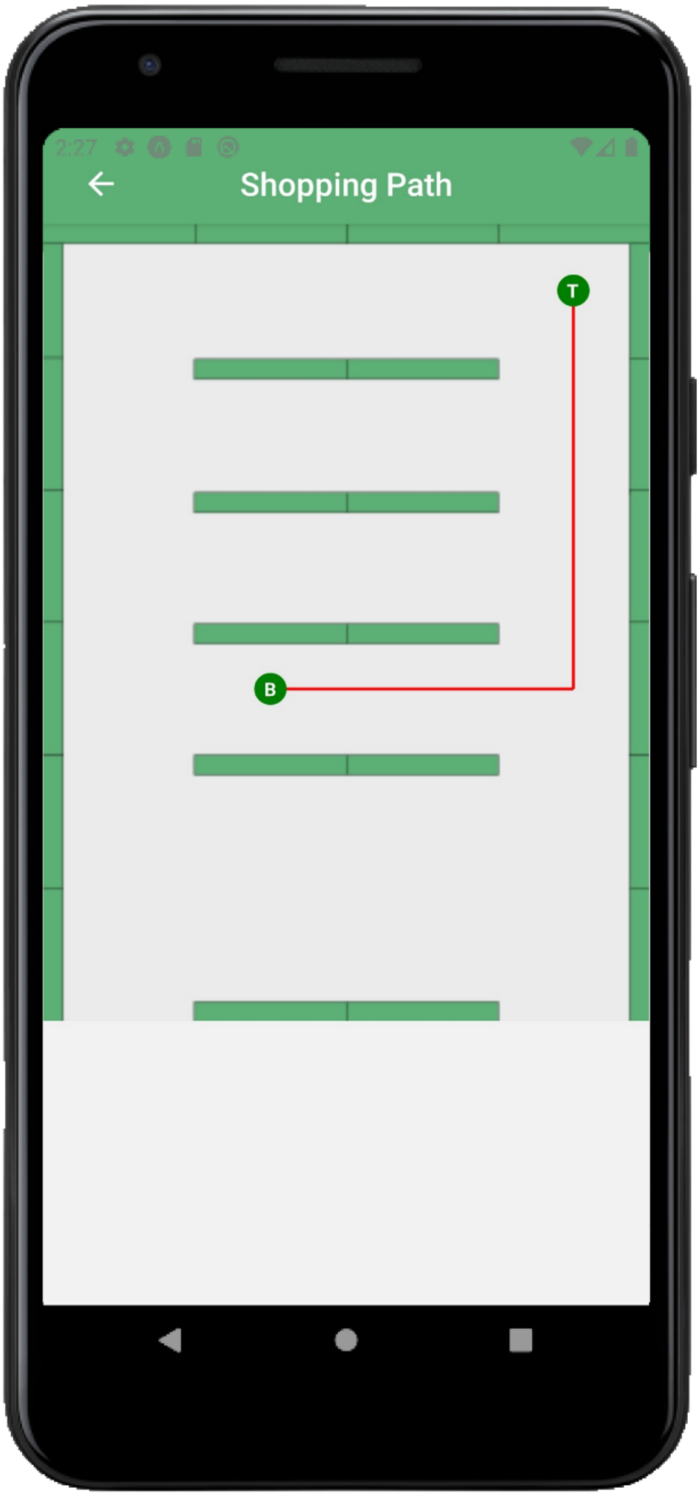

Figure 5. 20 Shopping path for a product screen

Screen at Figure 5. 21 includes name, price, ingredients and extra information about a product.

Figure 5. 21 Product detail screen

Screen at Figure 5. 22 contains all products that located in market. Users can search for a specific product by name. Users can sort products in ascending or descending order. Users can also filter products with “Apply My Filters” option which determined in user profile. Filtering and ordering operations are made by drawers. User can press on the products which displayed on this screen to get detailed information. User can add the product to shopping list with pressing icon. User can display the shortest path from current point to searched product point with pressing .

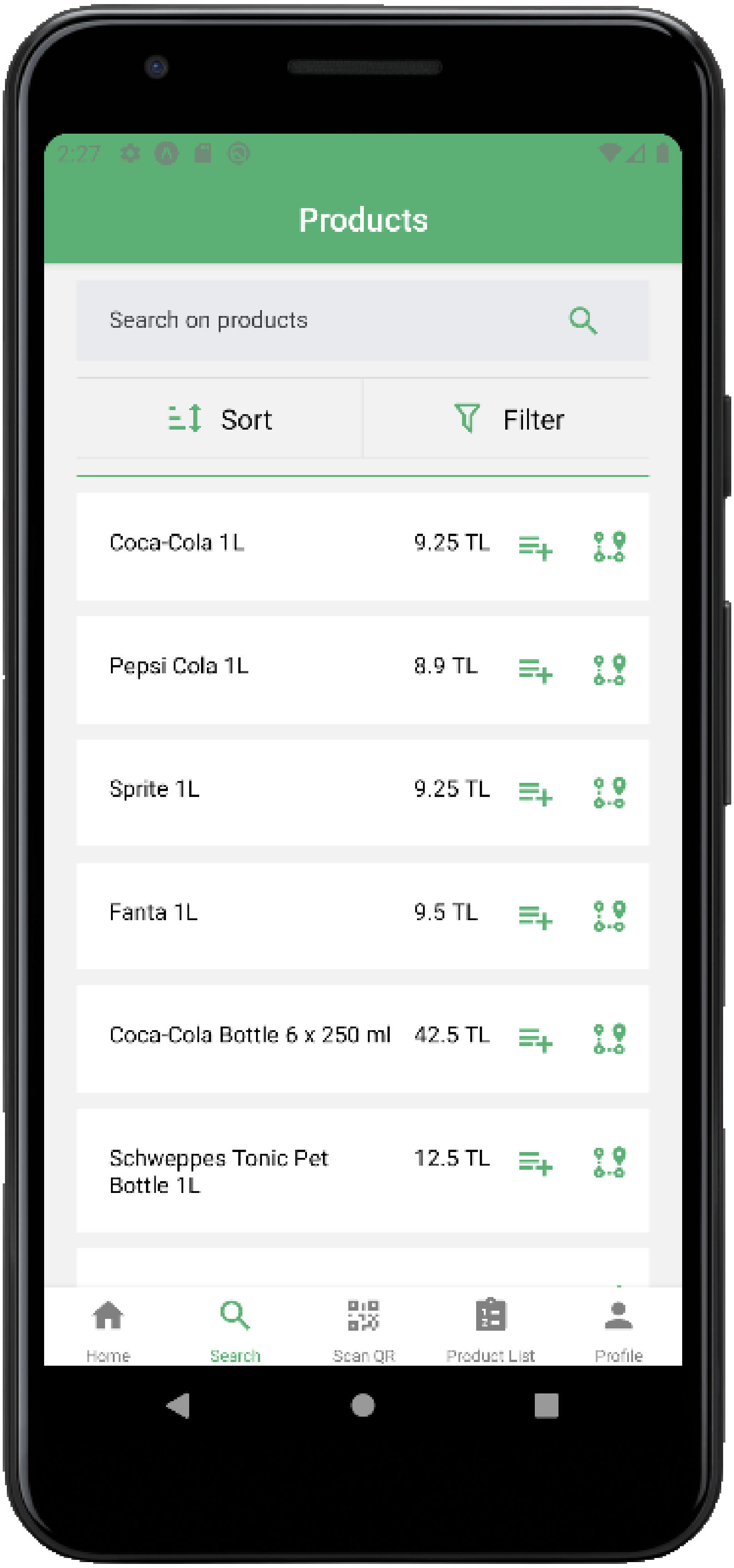

Figure 5. 22 Search screen

Screen at Figure 5. 23 provides options for QR Code scanning operations as two options “Product Detail” and “Advanced Scanner”. Product Detail screen scans for single QR Code with the user’s mobile devices camera to retrieve detailed information of detected product. Thus, user navigated to detailed information screen (screen at Figure 5. 21) of related product thanks to scanned QR Code.

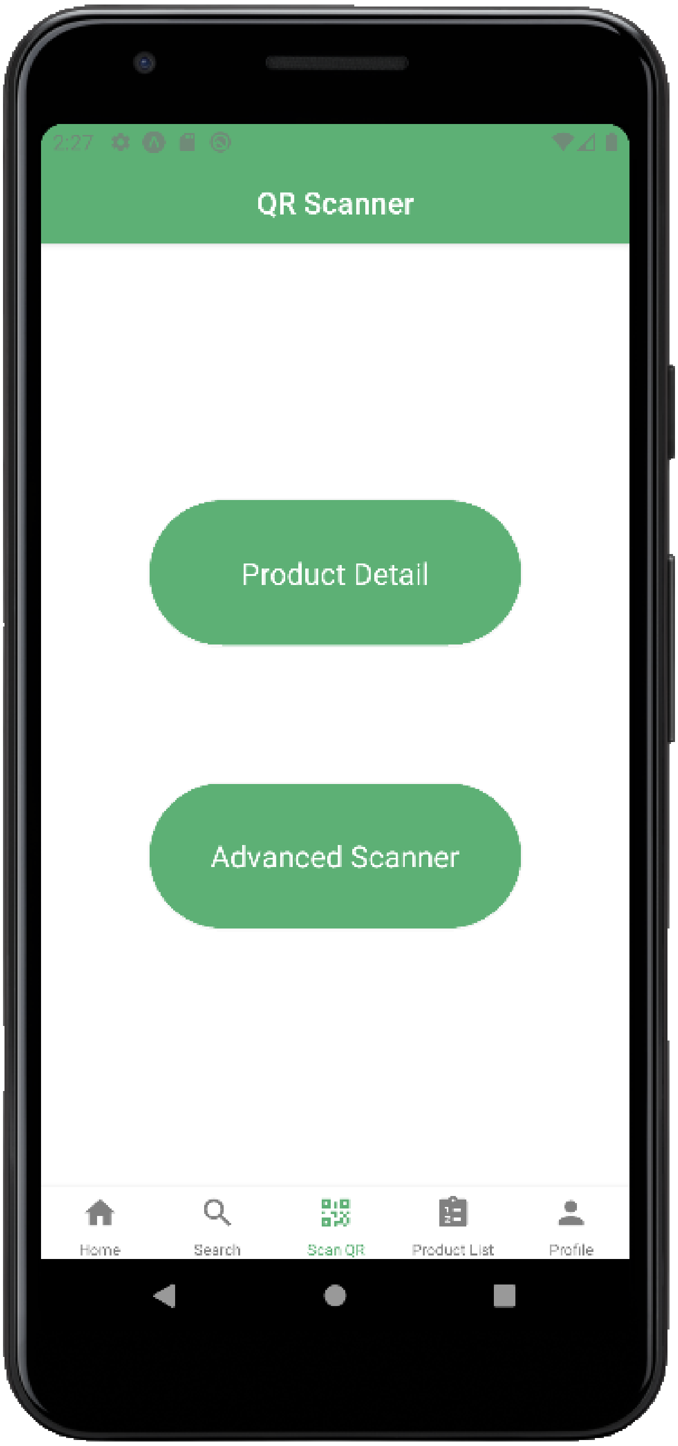

Figure 5. 23 QR code scanning navigator screen

Screen at Figure 5. 24 scans for multiple QR Code that observed by camera. Simultaneously multiple QR Code scanning operation provides three main service as following. Firstly, simultaneously detected QR Codes sorted by the price in ascending order with the order number (that colored with turquoise). Thanks to this sorting service user can prefer cost effective product easily. Secondly, detected QR Code fields of products are colored with two main color as red and green. These colors describe that related product is suitable with users filter whether not (red means not fitting, green means it is okey). Thus, user can easily understand whether related product contains allergic content for him/her, kosher, halal or cruelty free etc. Thirdly, colored QR Code scanned fields are pressable. Which navigates the user to detailed information screen of product when pressed this fields.

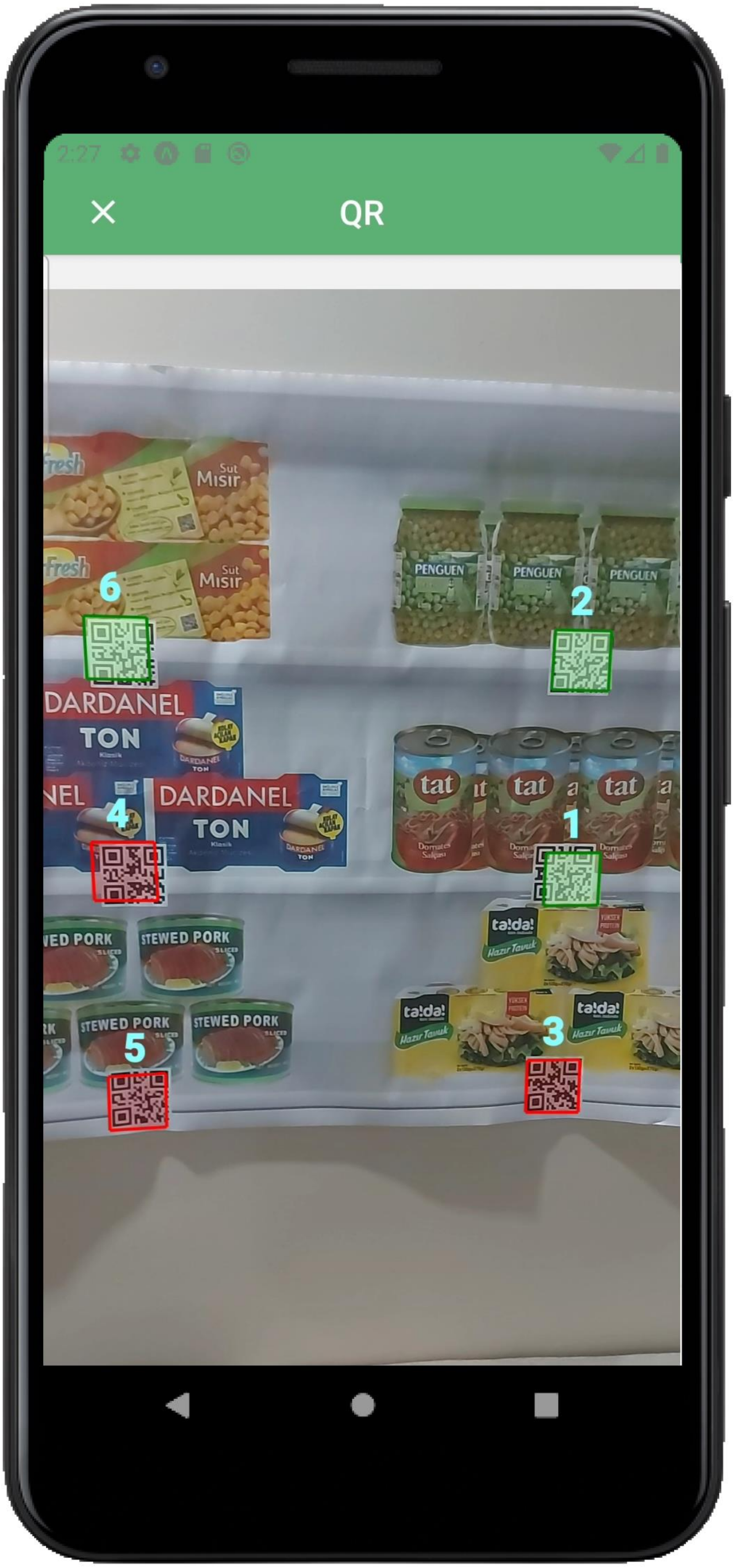

Figure 5. 24 Advanced QR code scanner screen

Screen at Figure 5. 25 displays products which added to shopping list. User can display total amount of products that added shopping list. User can Delete whole list with pressing “Delete List” button. Also, user can display shortest path to buy all products (that added in shopping list) and exit.

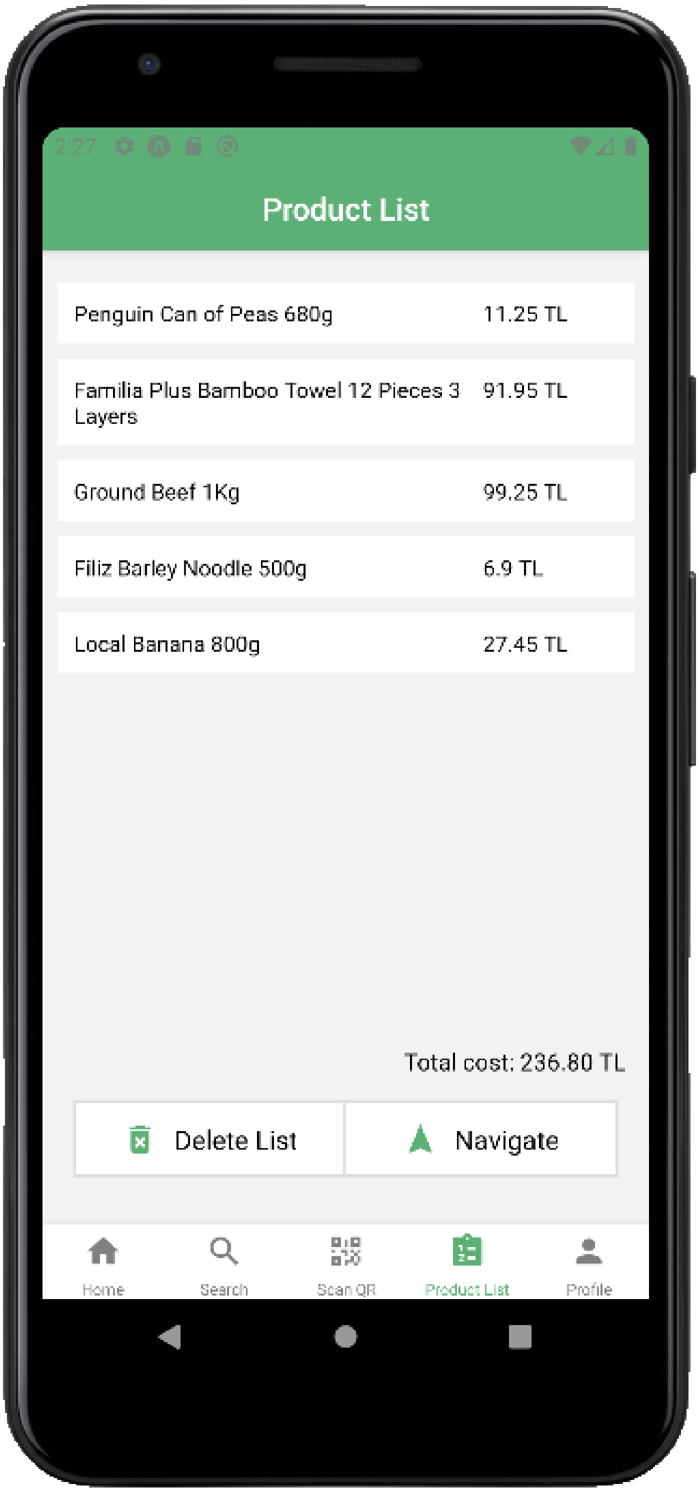

Figure 5. 25 Product list screen

Screen at Figure 5. 26 displays market environment as an image and shows the path that satisfies shortest path for products that added into shopping list. Thus, user can display shortest path for buying all products which he/her added into shopping list. This path contains stop points as green nodes within a number which means the order visit. And this product locations are connected with red lines as route. Secondly this screen displays customers current position in supermarket with blue dot. This dot updated in each position change of customer. Thanks to mentioned two services, customer can understand shortest path and current position of himself/herself.

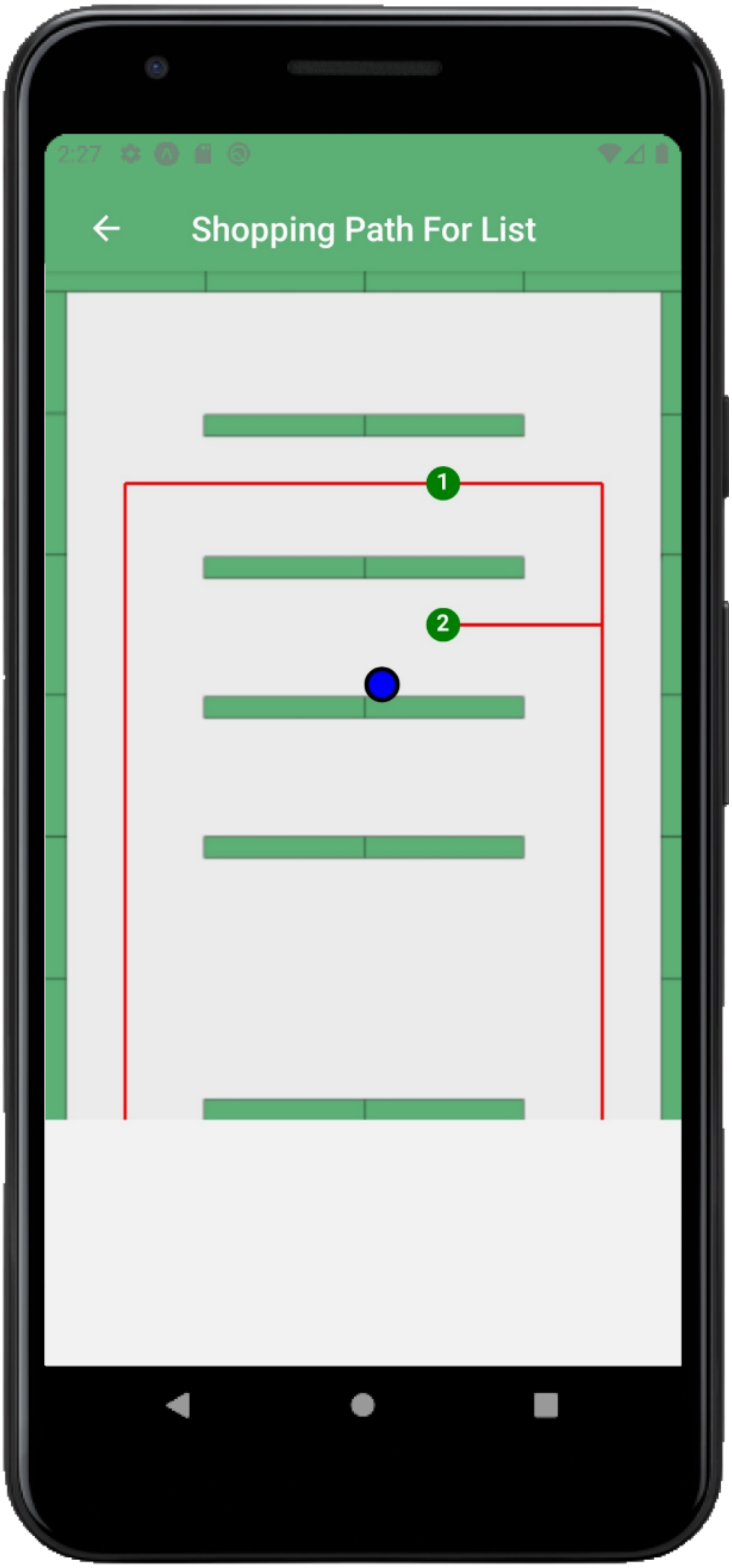

Figure 5. 26 Shopping path for list screen

Screen at Figure 5. 27 displays users basic account information as name, surname an mail. Provides three main navigations as “Change Password”, “My Filters” and “Help”.

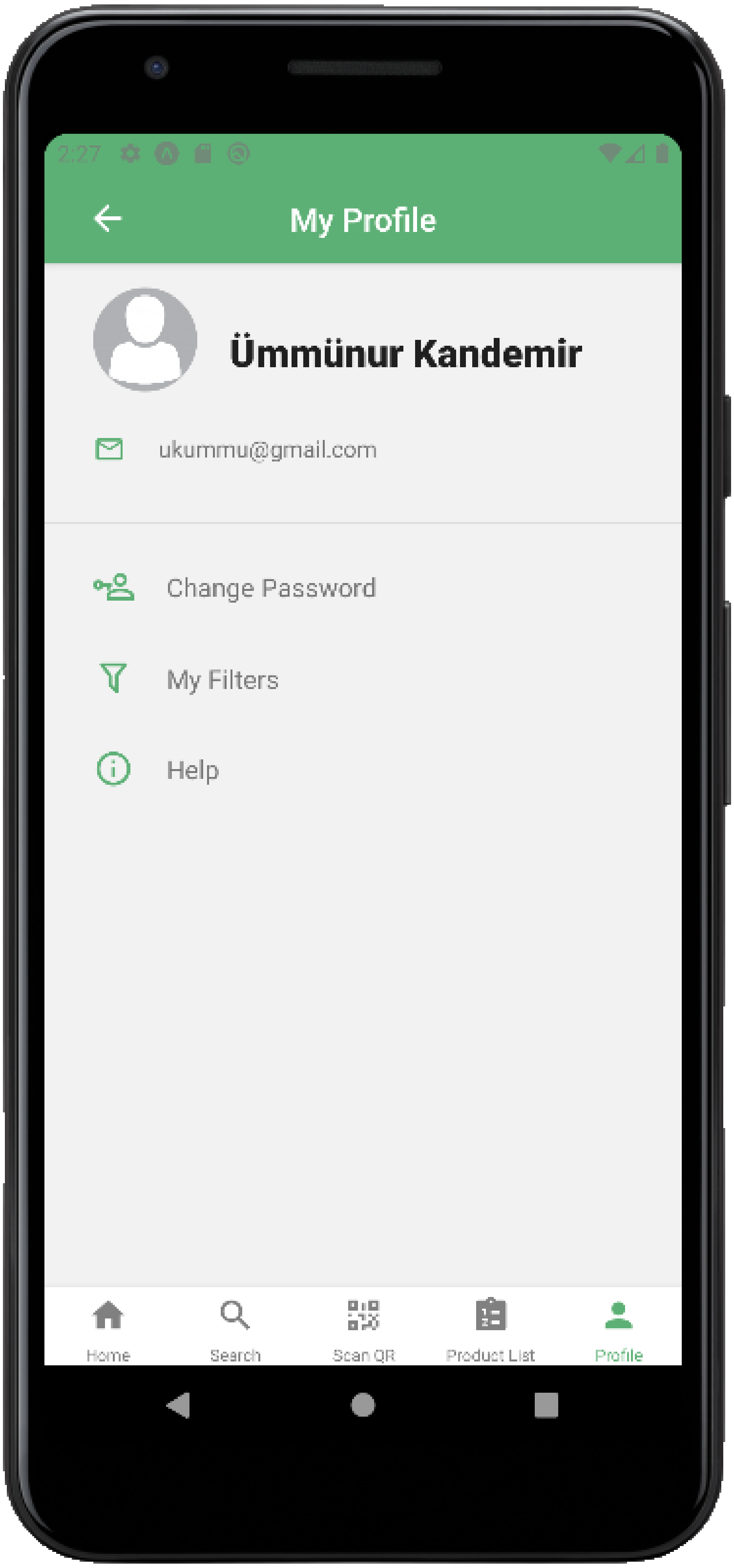

Figure 5. 27 Customer profile screen

Screen at Figure 5. 28 provides for reset password. Taking current password and updating with new one while controlling correctness for both format and value.

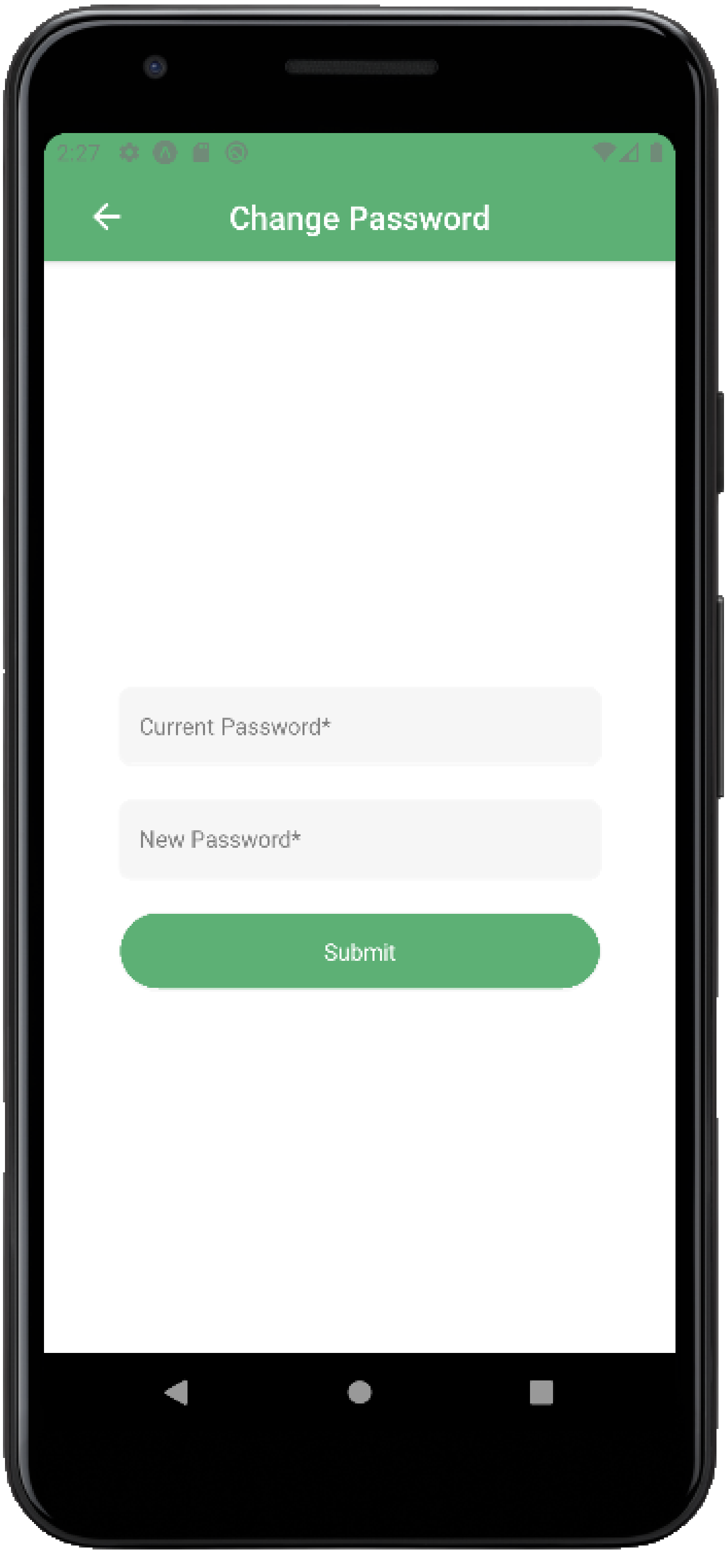

Figure 5. 28 Change password screen

Screen at Figure 5. 29 provides users to determine their sensitivities as filters. These filters are listed under four main categories as “Type Of Diet”, “Eating Pattern”, “Allergic” and “Special Option”. Thanks to his service customers becoming able to filter products depending on versatile allergic sensitivities, Diet types etc. (Also as mentioned at Advanced Scanner Screen, colors of scanned QR Codes are determined by this selections).

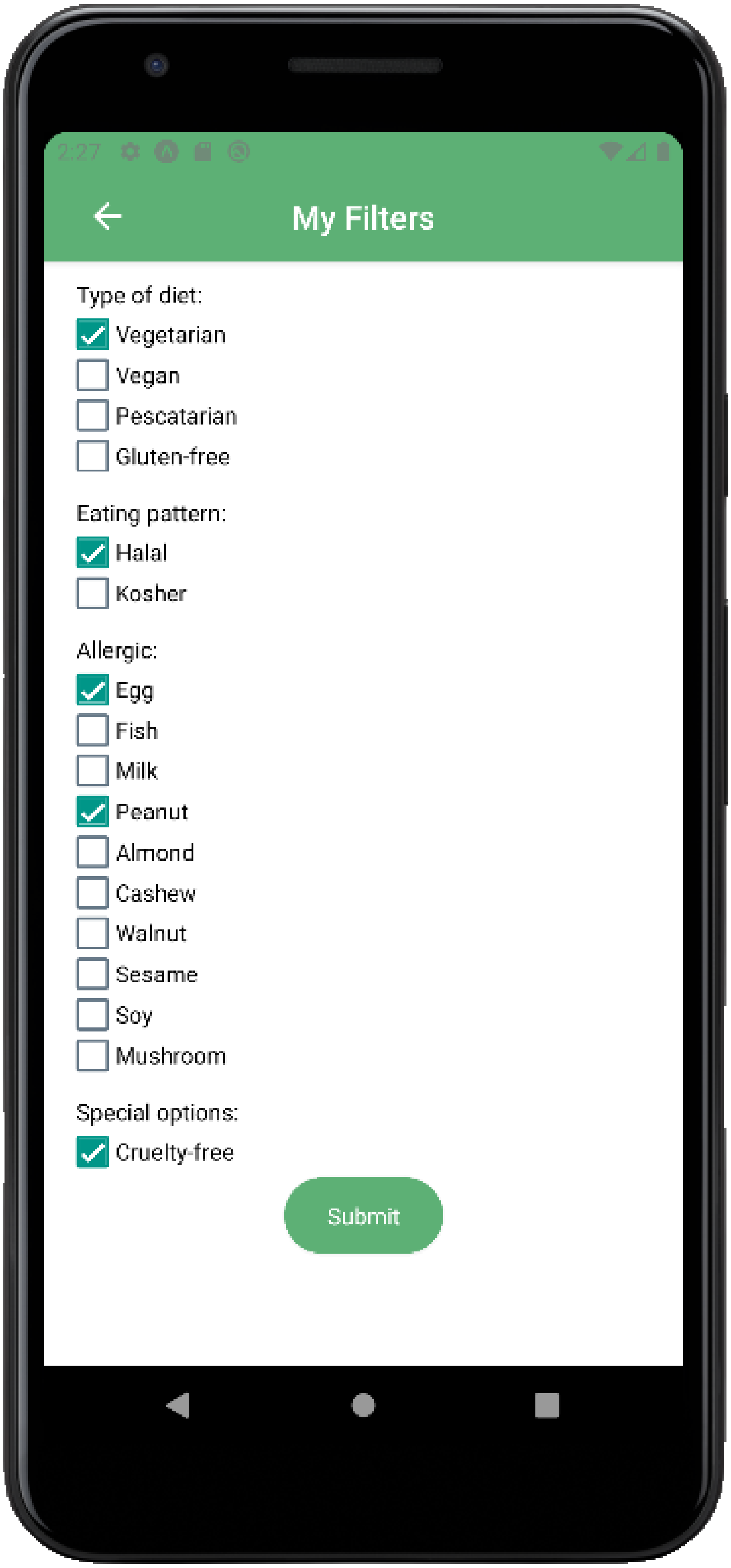

Figure 5. 29 Filters screen

Screen at Figure 5. 30 includes descriptions and usage information for SESA.

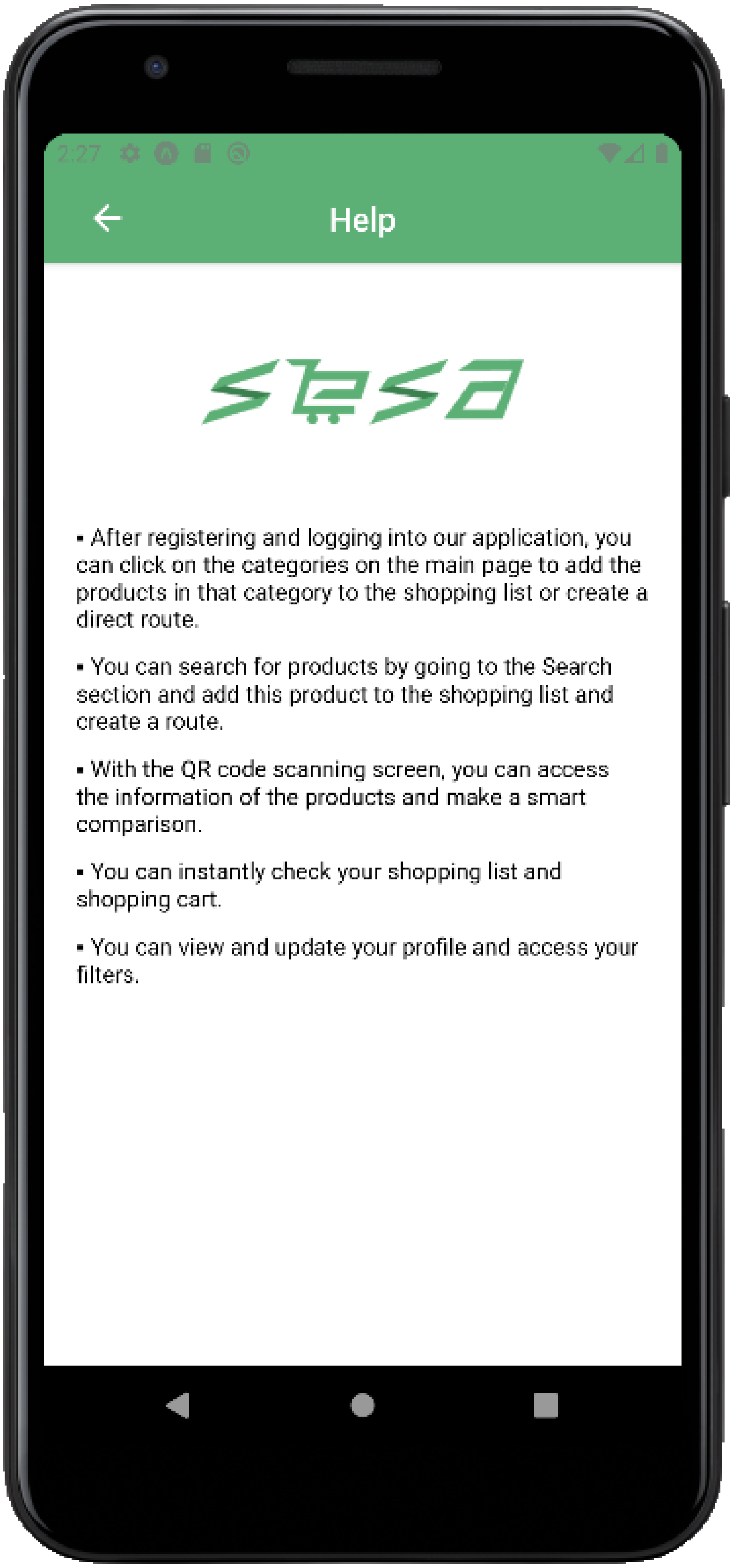

Figure 5. 30 Help screen

5.8.3. *Employee Screens*

Screen at Figure 5. 31 takes new employee data as name, surname, mail and password and market code (which is a label for detecting access scope of employee). Required format and logic controls are also implemented to satisfy format with appropriate error messages (as existing mail address, wrong mail format etc.).

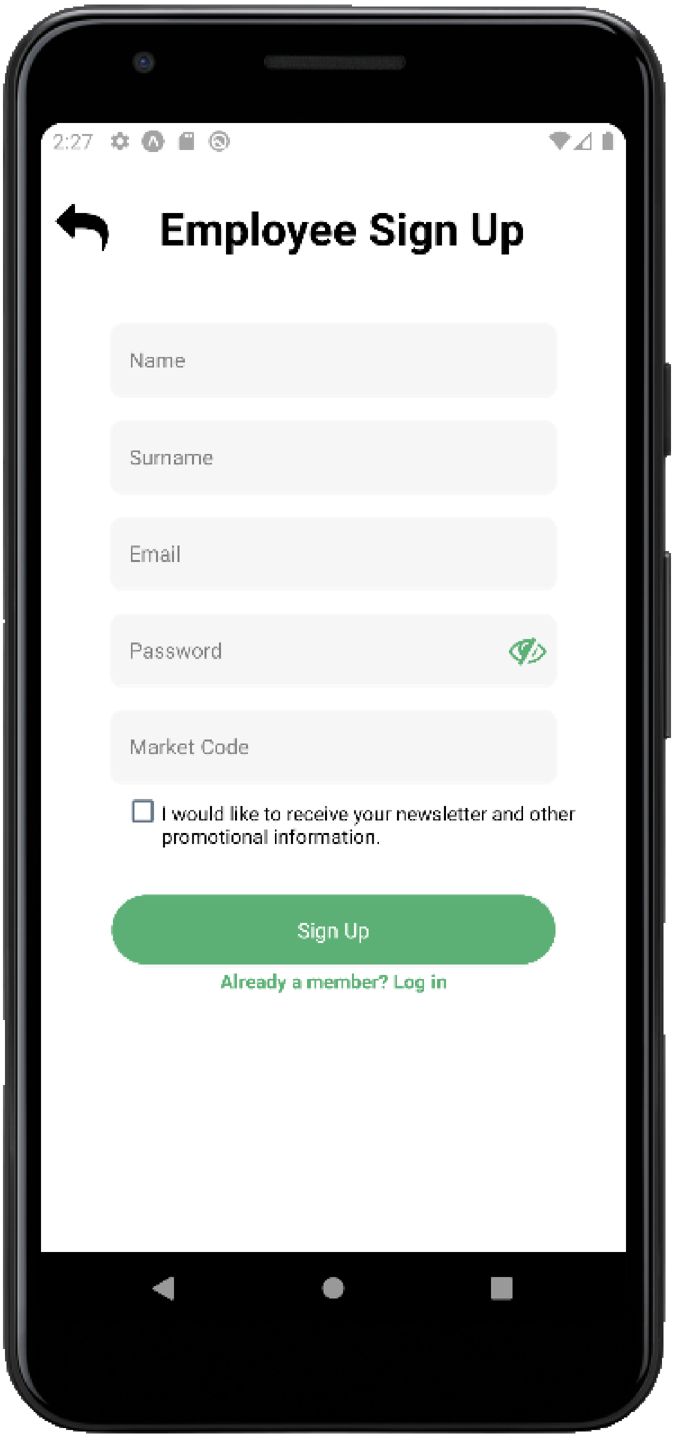

Figure 5. 31 Employee sign up screen

Screen at Figure 5. 32 allows to employees to update location of a product. It stands for updating location.

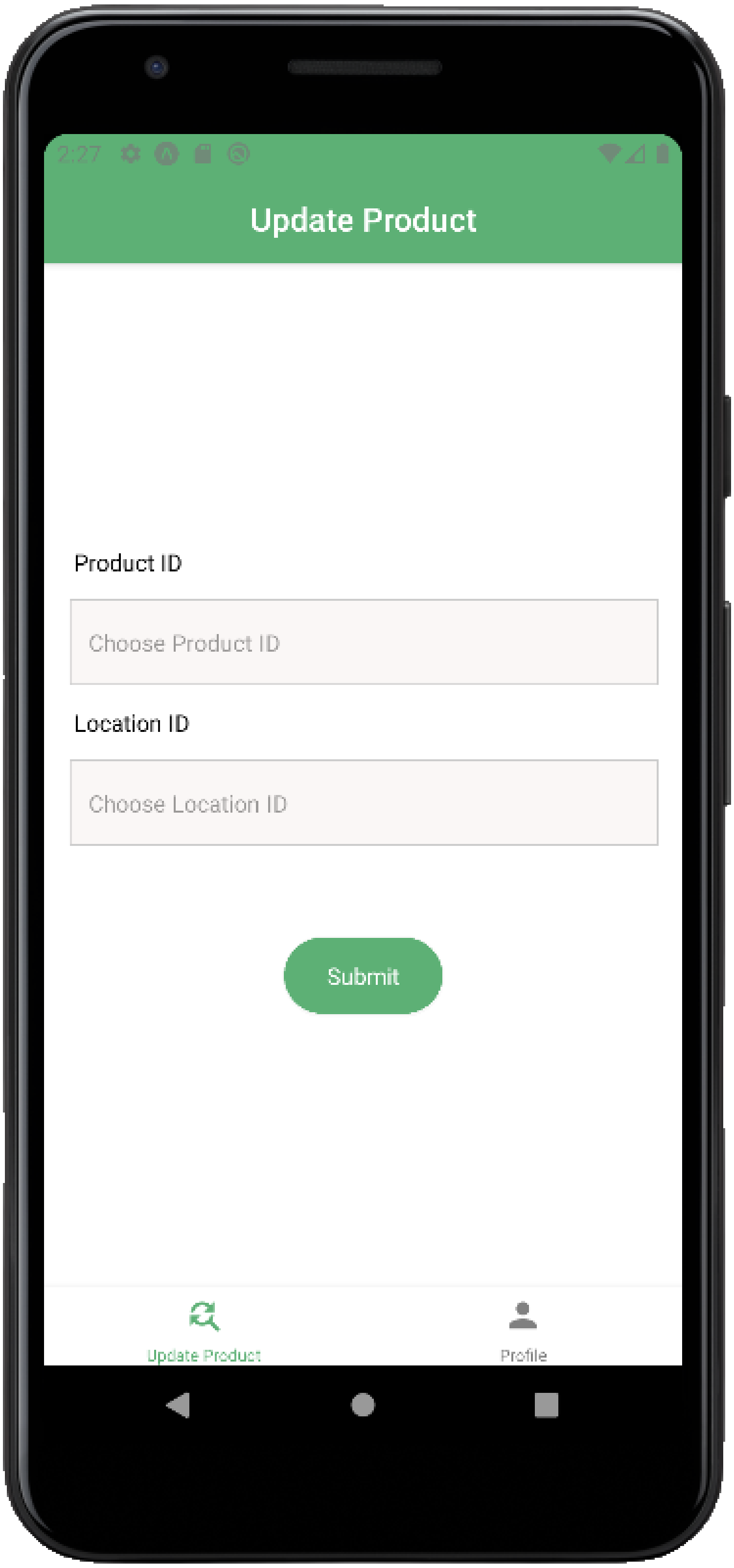

Figure 5. 32 Update product screen

Screen at Figure 5. 33 displays employees account information.

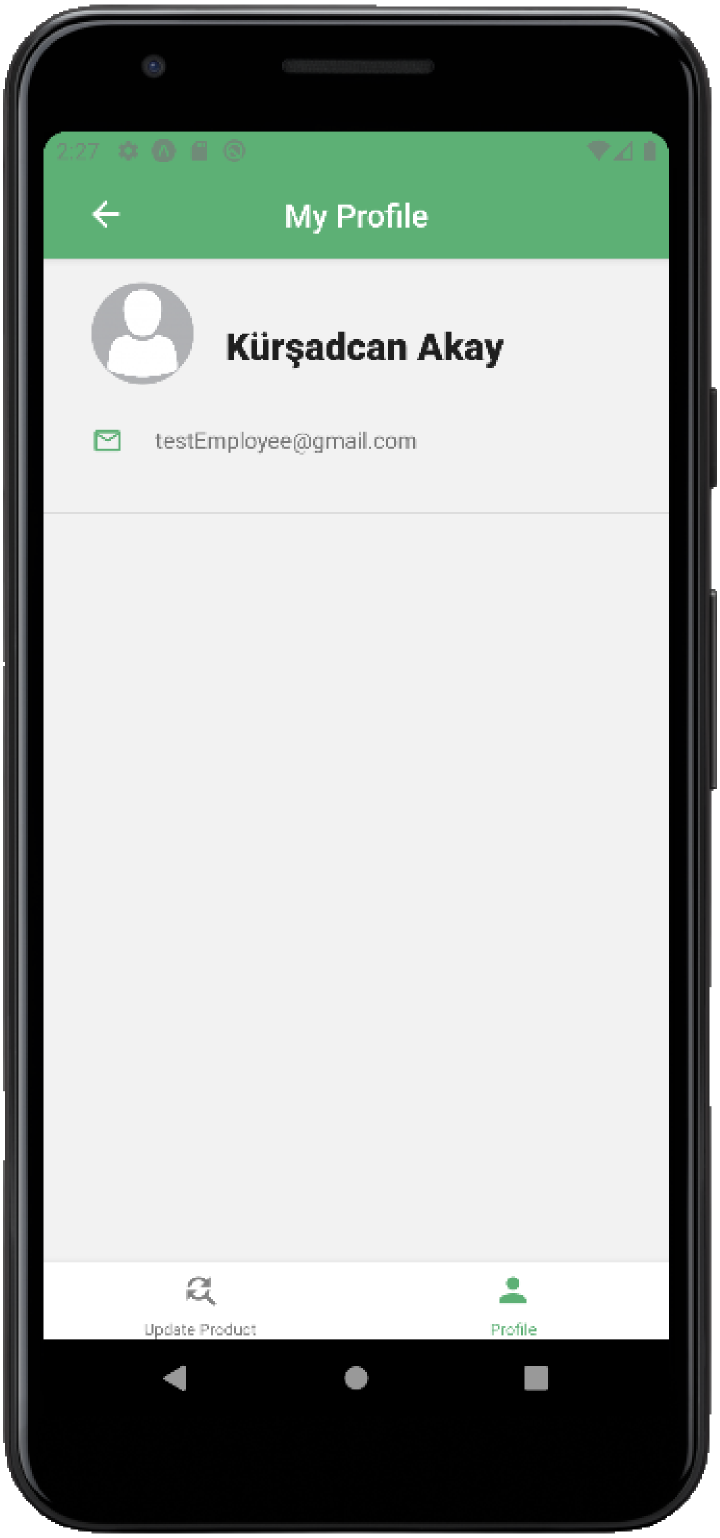

Figure 5. 33 Employee profile screen

CHAPTER SIX

TEST/EXPERIMENTS

6.1. End To End Test Scenarios

End to end test scenarios applied manually. Following table displays main end to end test scenarios with related information.

Table 6. 1 End to end tests

Test Scenario Name	**Test Environment**	**Test Story**	**Result**
Sign up customer	Android 11 Android 9	New customer opens application and sign ups to application	Success
Sign up employee	Android 11 Android 9	An employee opens application and sign ups to application	Success
Login customer	Android 11 Android 9	Customer sign ins with mail and password	Success
Login employee	Android 11 Android 9	Employee sign ins with mail and password	Success
Customer searches for product	Android 11 Android 9	Customer searches for Coca Cola and displays product	Success
Customer sorts of products	Android 11 Android 9	Customer sorted products in ascending order	Success

Customer adds product to shopping list	Android 11 Android 9	Customer adds several products to shopping list and displays them on the shopping list screen	Success
Customer deletes product from shopping list	Android 11 Android 9	Customer deletes shopping list	Success
Customer searches for shortest path of single product	Android 11 Android 9	Customer opens main screen and press beverages. Then press path icon for Sprite. From current position to target product, path expected to display.	Success
Customer searches for shortest path of shopping list products	Android 11 Android 9	Customer added several products to shopping list then displayed shopping list. Then pressed navigate button, expected to display path with visit orders and current position of customer by blue dot.	Success

Customer Scanned Single Product to Display Detailed Information	Android 11 Android 9	Customer opened QR Code screen and pressed “Product Detail” button. Camera opened and scanned a product, expected to display detailed information.	Success
Customer uses advanced scanner option	Android 11 Android 9	Customer scanned for 6 different products at the same time and expected display price order, red and green frames over QR codes (depending on filters), then pressed cheapest product which also labeled as green. Thus expected to display detailed information of related product.	Success

6.2. Bluetooth Beacon Location Detection Algorithms Test

SESA uses trilateration approach to detect location of customers. Uses RSSI values which is affected from environmental factors. To increase location detection accuracy, bottom-top approach applied. Following sub-sections describes order of tests.

6.3. Bluetooth Beacons Location Test

As mentioned above, Bluetooth signals are affected by obstacles because of that ideal height determined as 2.9 meter in the lab7 while concerning about room architecture. When we focus on Trilateration algorithms mathematical operations, each Bluetooth beacon had to be located as different as possible about their apses and ordinates. Optimal Bluetooth Beacon locations that determined is given at Table 6. 2. When very close axis or ordinate values determined, formulation was causing unexpected results. So distance calculation had to be optimized at the first step.

Table 6. 2 Bluetooth Beacons' positions

Bluetooth Beacon Name	**X Coordinate (m)**	**Y Coordinate (m)**	**Z Coordinate (m)**
Beacon1	0.1	4.27	2.9
Beacon2	4.9	3.32	2.9
Beacon3	2.5	0.1	2.9

For distance calculation formula (at Eq. 5.1) there was 2 independent variables as "N" value (Environment Factor) and "Measured RSSI" (Measured RSSI from 1m distance). The table given below (Table 6. 3) displays optimal N values and "Measured RSSI" values for each beacon. Also, values of N and Measured RSSI collected from different angles of related beacon.

Table 6. 3 Bluetooth Beacons' distance formulation parameters

Bluetooth Beacon Name	**N**	**Measured RSSI**	**Distance Error Margin**
Beacon1	3	-56	+- 0.2 m
Beacon2	3	-57	+-0.15m
Beacon3	3	-50	+-0.1m

Thanks to distance calculation optimization, trilateration algorithm had to be called under required circumstances such as location changing. Thanks to usage of useEffect structure of react framework, distances to related beacons are given as dependencies. Thanks to react-native-ble-plx library, application always scanned Bluetooth signals thus distance to each beacon always filtered. So, when a distance difference occurs from a beacon, trilateration triggered. Thanks to this structure position of customer always listened. Observations of deviations given below as a result (at given Table 6. 4).

Table 6. 4 Location detection test results

Observation ID	**Actual Position (x,y) (cm)**	**Displayed Position (x,y) (cm)**	**Deviation (m)**
1	(30,330)	(15,267)	0.64
2	(70,210)	(90,360)	1.51
3	(125,450)	(120,431)	0.19
4	(200,160)	(116, 98)	1.04
5	(380, 50)	(128,80)	2.5
6	(400,450)	(386, 427)	0.26

Sample observations are listed above, average deviation calculated as 1.02m in location detection.

Shortest path calculation for single product is successfully applied from detected location. Average deviation sometimes could cause begin node determination error. This situation caused by the node fields error tolerance because while determining the location of customer, application takes this location and assign the closest node in the graph. Then uses Floyd-Warshall algorithms output to find shortest path to searched products. Naturally, when begin node determined wrong, result also being wrong. Beside this situation, algorithm work fine.

When customer adds products to shopping list, there exists an exceptional situation for the solution of the shortest shopping path. Application generates a new complete graph with must-visited nodes with their shortest paths and weights between themselves. Then this new graph given as a input to TSP algorithm, but TSP doesn’t look for regenerated graph edges path information, it only looks for weights. While its creating Hamiltonian cycle, if there is a must-visited node as one of the path step between must-visited nodes it could visit same node more than once. There is no other exceptional situation, everything works fine.

6.4. QR Code

QR Code service tested with versatile product from different angles. Product detail service works fine and displays always scanned products. Multiple QR Code section tested by different products with the count range from 2 to 6. Distance from 1.5 meter is determined ideal distance for scanning, and filters are successfully applied, green and red frames to describe fitting with filters or not displayed successfully in several seconds.

6.5. Machine Learning Approach For Location Detection

As an experimental work, machine learning algorithms applied from the WEKA platform with the collected sensor data. Lab 7 environment sliced into 24 equal grids with the ropes (to ensure RSSI collection from correct grid) as given in figure lab ipi. 8 different Bluetooth Beacons located in lab7, then their RSSI Values collected from each grid. Each grid data labeled with the related grids location ID's. Totally, 1787 instance collected. Preprocessing operations completed and following results obtained (at Table 6. 5).

Figure 6. 1 Lab7 grids

Table 6. 5 Results of applied machine learning approaches

Applied ML Algorithm	**Accuracy (%)**
Random Forest	25
Naive Bayes Classifier	20
Logistic Regression	19
SVM	17
KNN	17
Multilayer Perceptron	16
Decision Tree	14

CHAPTER SEVEN

CONCLUSION AND FUTURE WORK

In this project, it is aimed to solve a daily problem by using various technologies. In this project, which was developed with React Native technology in a mobile environment in terms of access to the masses, the hardware and software were designed to work in harmony. In order to optimize the shopping processes of customers in a store environment, navigation to the products was successfully provided via Bluetooth Beacons. When users want to reach more than one product, they are informed with a route by creating a shopping list in a way that takes all products and exits in the shortest way. It is aimed to present a solution to this problem with the combination of Floyd Warshall and TSP algorithms. The contents of the products, which are another sensitive issue for the customers, were scanned simultaneously using QR code technology, thus saving time for the users. Thanks to this service offered, customers can learn the content of the products in seconds with the help of the filters they have determined through the application. This filter service was presented to the user with AR, and the prices of the scanned products were successfully displayed on the screen of the users in ascending order. The information obtained from the Beacons for location determination has been successfully manipulated and presented to the users with deviations in the tolerance range. It has been observed in various test scenarios that the application works as a whole.

A situation included in our solution with TSP and Floyd Warshall algorithms is open to optimization. After the real environment is converted to graph data, we create a new sub-graph from the points that will definitely be visited. All nodes of this sub-graph are produced by interpreting the original graph to form a complete graph. Then the TSP algorithm is run and the shortest path is calculated. However, optimization can be achieved with additional controls so that the acquired shortest path does not re-pass over a node that it has already visited during the navigation. In addition, since it is a real life problem, it is not only the location information of the products to be purchased from the store, but also their weight, resistance to ambient temperature, etc. Changing its prioritization can also be presented as an optimization. In order to increase the user experience, it is also possible as an optimization to show the route drawing with the help of navigational arrows using AR instead of just a bird's eye view. Finally, a route to discounted products can be offered to users in the store.

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