A MOBILE APPLICATION DEVELOPMENT FOR RECOGNISING UNUSED MEDICAL EQUIPMENT USING DEEP LEARNING MODELS

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A project report submitted in partial fulfilment of the requirements for the award of Bachelor of Science (Honours) Software Engineering

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April 2021

DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

I certify that this project report entitled **"A MOBILE APPLICATION DEVELOPMENT FOR RECOGNISING UNUSED MEDICAL EQUIPMENT USING DEEP LEARNING MODELS"** was prepared by **WONG SHI TING** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Science (Honours) Software Engineering at Universiti Tunku Abdul Rahman.

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ABSTRACT

Poor waste management in medical equipment has impacted the environment. It needs a proper management system to reuse and recycle the medical equipment. Hence, a mobile application to recognise images of medical equipment for three entities: NGO/medical centre, member and admin is developed. The public can donate their unused medical equipment to NGOs/medical centres. NGOs/medical centres that need medical equipment can request medical equipment from the public through this platform. The admin is responsible for ensuring that the donation process is safe and legal. Three deep learning models, i.e., Inception-v3, ResNet-50, and VGG-16 are trained using transfer learning technique to recognise the medical equipment. These models are also used to overcome limitations faced by traditional machine learning models. The limitations include difficulties in training a new model from scratch, complexity of the image's features, low recognition accuracy when the size of a data set becomes bigger, and limited cost and time resources. Image data sets for 10 medical equipment, including commodes, wheelchairs, walking frames, blood pressure monitors, breast pumps, thermometers, rippled mattresses, oximeters, crutches, and therapeutic ultrasound machines, are collected for training and testing of the deep learning models. Besides, a grid search method is used to find the best combination of hyperparameters such as optimizer, batch size, epoch number, dropout rate, and learning rate. The deep learning models have successfully addressed and solved the limitations faced by traditional machine learning models. Inception-v3 outperformed the other two models with the highest accuracy of 0.9372 when testing with photos uploaded by the users.

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NGOs	Non-Government Organizations
WHO	World Health Organization
KKM	Kementerian Kesihatan Malaysia
SUS	System Usability Scale
API	Application Programming Interfaces

CHAPTER 1

INTRODUCTION

1.1 Introduction

Health care waste resulted from health care activities that may leave adverse health impact. An organized and safe waste management system is essential to manage health care waste. According to the World Health Organization (WHO) (2020), medical waste is the outcome of health care products such as sharps, non-sharp blood-contaminated items, body parts and tissue, chemicals, blood, radioactive materials, and pharmaceuticals. To safely handle medical waste, education and guidelines must be provided to the public to increase the awareness of medical waste issues. According to the survey and studies carried out in this project, there is very low awareness of recycling and reusing medical items, including medicine, wheelchairs, patient bed, walking aids, etc. Excessive medical wastes which are non-hazardous can be recycled and reused.

Malaysians need a channel to donate the medical items to give a second purpose to the leftover medical items for further utilization. Recognition of medical equipment can ease the donation process for adult citizens. However, the traditional machine learning approaches for object recognition face difficulty recognising medical equipment accurately and effectively. Limitations such as increased size of a data set, complexity of images features, and limited cost and time resources have impacted the performance of the traditional machine learning approaches. Thus, three deep learning models trained using transfer learning approach, i.e., Inception-v3, ResNet-50 and VGG-16, are implemented in this project to address the problems.

The main goal of the project is to design and implement a mobile application that provides a platform for the public to donate their unused medical equipment to NGOs and medical centres. In addition, it disseminates the knowledge of reusable medical equipment that can be donated to NGOs/medical centres. Furthermore, it eases the donation of unused medical equipment from the public to NGOs/medical centres. Moreover, the medical equipment recognition feature in this project solves the limitations faced by the traditional machine learning models.

1.2 Background

Management and disposal of medical waste in Malaysia are regulated by Environmental Quality (Scheduled Waste) 2005 (Artika & Faiza, 2019). The public often throws their leftover medical items such as medical equipment into dustbins as it is the simplest way to get rid of them. Much medical waste has caused pollution to the environment. However, some medical equipment is still in good condition. They can be reused and recycled. People are not aware and educated about medical waste management. The culture of donation of medical items is not a new thing. There are various NGOs that receive unused medical supplies and equipment from the public overseas, for instance, Med-Eq and Project C.U.R.E in the USA, Hospice of Hope and Jacobs Well Appeal in the UK. NGOs in Malaysia are Persatuan Diabetes Malaysia, Yayasan Jantung Negara, Persatuan SLE, Nutrition Society, St. John's Ambulance, Red Crescent Society, Hospis Malaysia, Mercy Malaysia, etc. Donation procedures are studied in this project.

Medical centres enforce medical waste management. They collect medical items from the public. There are yellow bins in the hospital which allow patients to return their unused medicines. Leftover medications result from the completion of treatments, the discontinuation of medications due to ineffectiveness, the change of treatment, and the experience of side effects. Some medical equipment such as wheelchairs and walking aids are left unused after the patient passes away. In the interview with Ms Tan from True Pharmacy, medicines are not collected for reuse. It is dangerous as the condition of medicines cannot be examined easily. The medical centres will usually dispose of them. Medical equipment is better suited for reuse by donation. Besides, NGOs such as Hospis Malaysia only accept medical equipment for donation.

1.3 Problem Statement

This project looks into the problems that have arisen as a result of the topic. The problems existed in Malaysian NGOs and medical centres. The issues are gathered through literature reviews, direct observation, questionnaire, and interviews with the public, NGOs and medical centres. The problems are as following:

i. **Low awareness on recycling unused medical items**

Based on the study of Bashatah and Wajid (2020) in the College of Nursing and Pharmacy and King Saud University, Riyadh, Saudi Arabia, 47.2% of pharmacy students and 61.2% of nursing students disposed of unused medicine in household dustbins, while flushing leftover medicines down the sink or toilet made up of 6.8% and 5.3% respectively. Surprisingly, only a small percentage of both groups claimed that they returned leftover medicine to the pharmacy or medical centre.

From the study above, there is very low awareness of recycling of unused medical items. People do not have the habit of recycling unused items. Medical waste is a source of pollution of land and water sources if it is not handled properly before disposing them in water or on land (Babanyara et al., 2013). Babanyara et al. stated that medical waste will lead to air pollution when it is burned in open burning. Harmful gases are released. Poor health care waste management is risky and must be avoided.

Based on the questionnaire answered by 47 respondents, 66% of respondents were unaware they could donate medical supplies and equipment to NGOs and medical centres. Recycling of unused medical items is rarely practised among Malaysian.

ii. Excessive health care waste

Biomedical waste in Malaysia is estimated to be 33000 tonnes annually (Ambali et al., 2013). A study of health hazards of medical waste and its disposal in India (Padmanabhan & Barik, 2018) showed that infectious waste (15-25%), sharp waste (1%), chemical waste or pharmaceutical waste (3%), cytotoxic waste, radioactive waste and general waste made up of less than 1% out of total medical waste.

Non-hazardous waste generated by health care made up 85% of total waste (WHO, 2020). WHO (2020) claimed that high-income countries produce up to 0.5 kg of hazardous medical waste per day in each hospital bed. The majority of the hospitals in low-income countries do not categorize waste as hazardous and non-hazardous. It is dangerous as waste will cause pollution to the environment and infect hospital patients or the public.

iii. Difficulties in the donation process faced by the public, NGOs/Medical Centres

In the interview with Hospis Malaysia, Hospis Malaysia feedbacked that they do not have transportation to carry the donated items from the public. Donors will deliver medical items such as medical equipment to their centre. As covid-19 is very serious now, the process of enquiring information from donors is difficult. Hospis Malaysia also shared that they are having troubles arranging transportation and appointments with the donors. In addition, the assistant pharmacist in Klinik Kesihatan Bandar Botanic Klang revealed that the patient will return the medical items to the medical centre by themselves. Inconvenient in returning medical supplies and equipment discourages the public from donating the medical items to NGOs and medical centres.

iv. Difficulties in object recognition by traditional machine learning approaches

Traditional machine learning approaches cannot handle the problem as one. Breaking down the problem into subproblems are required. It is time-consuming and burdening the engineers. In a real-world situation, the problem can be very complex and big. Patterns and features of images are diverse. The traditional way of recognising objects is challenging in today world. Resource of images of medical equipment is very scarce. Training of a new model from scratch needs a huge number of data to achieve a highly accurate model. In the past, data collection is one of the biggest challenges to build the object recognition model.

1.4 Project Objectives

- To provide a medical equipment donation platform for NGOs/medical centres, members, and admin to ease the donation processes.
- To perform transfer learning for object recognition using three deep learning models, i.e., VGG-16, ResNet-50, and Inception-v3.
- To implement medical equipment recognition in the mobile application using data sets created by collecting online images and self-taking images.
- To develop a mobile application that recognises the medical equipment using the best performing deep learning model.

1.5 Project Solution

To solve the issues faced by NGOs, medical centres and the public in reducing medical items waste and promoting a zero-waste culture, a list of project solutions is proposed. The donation medical items only include medical equipment, which is more suitable and needed by the NGOs/medical centres. A proposed solution is listed as the following. The targeted users are NGOs/medical centres, the public and the admin.

a) **Allow donation of medical equipment from the public to NGOs/medical centres**

   Members can donate unused medical equipment which is in good condition to NGOs or medical centres. It will greatly reduce waste and prevent the disposal of medical equipment that can harm the environment. NGOs or medical centre can view the list of equipment member wishes to donate. Verification can be done by NGOs or medical centres before allowing the member to donate.

b) **Medical equipment recognition**

   Members can scan the medical equipment that he wants to donate to register the medical equipment. Transfer learning by deep learning models, i.e., Inception-v3, ResNet-50 and VGG-16, are implemented.

c) **Provide information on medical equipment that can be donated**

   As the public's awareness level is low in properly disposing medical equipment, education must be provided to members to differentiate equipment that can be donated and cannot be donated.

d) **Search of drop-off points for donation**

   Majority of people are not aware of medical equipment donation to NGOs/medical centres. Searching of NGOs/medical centres location for the donation encourages people to donate.

e) **Pickup service**

   Member can request pick up service. The people in charge will pick up the items from a member's location.

f) **Allow communication between public and NGOs/Medical Centres**

   A chat engine between members and NGOs/medical centres will be implemented. As the public's knowledge in medical items is low according to the questionnaire, the chat box function allows members to drop any question to NGOs/medical centres. Chat engine can ease the donation process from member to NGOs/medical centres.

1.6 Project Approach

The methodology used in this project is evolutionary prototyping. A requirement gathering will be performed to gather the initial specification of this project. In this project, questionnaires and interview are used to collect data from NGOs, medical centres and the public, which the users of this mobile app. Data collected are transformed into project specifications. The prototype is built by Axure RP 9. Users' evaluation based on the project specifications is carried out. The developer refines the prototype to a better version according to users' feedbacks. Iterations for design, build prototype, users' evaluation, and refinement of the prototype are carried out until the prototype developed satisfies users. Testing and maintenance will be executed once the final product is completed. An overview of the workflow of evolutionary prototyping is shown in Figure 1.1. Details of workflow execution for the methodology are explained in chapter 3.

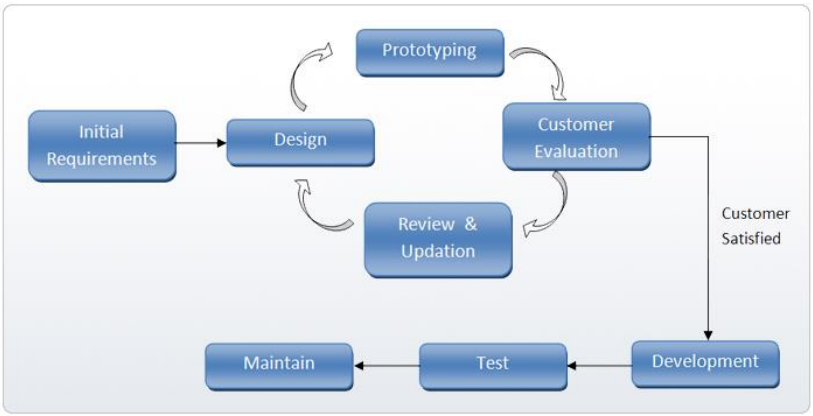

Figure 1.1: Development steps for evolutionary prototyping (Weebly, 2020)

1.7 Project Scope

This project builds a mobile application that uses the Flutter framework, Firebase, Android Studio and Visual Studio Code to build. TensorFlow Lite is used for medical equipment recognition. The medical equipment recognition will only focus on 10 medical equipment, including commode, wheelchairs, walking frame, blood pressure set, breast pump, thermometer, rippled mattress, oximeter, crutch and therapeutic ultrasound machine. Deep learning models implemented are Inception-v3, ResNet-50 and VGG-16.

1.7.1 Target Users

Targeted users of this mobile application will be NGOs/medical centres, members (public) and admin.

1.7.2 Medical Items for Donation

Medical items, including medical equipment in good condition, are eligible for donation. Medical equipment can be used or unused as long it is in good condition. For example, wheelchairs, hospital beds, rippled mattress, commode, adult diapers, and meal replacement nutrition drinks.

1.7.3 Project Modules

NGOs/Medical Centres

a) **Login**

NGO/medical centre can login to the mobile app after registration by using email and password. Details such as NGO's/medical centre's name, contact number, email, address and license are required for registration.

b) **Check the condition state of medical items**

NGOs/medical centres can check the medical items' condition by looking at the photos of medical items uploaded by users and information on the medical items. This feature is important to avoid spoilt items donated to NGOs/medical centres.

c) **Request for medical equipment in shortage**

When there is a shortage of certain items, NGOs/medical centres can request the medical equipment required. This feature allows a faster collection of medical equipment. Members will receive notification regarding medical equipment in shortage request.

d) **Arrange appointments with members**

NGOs/medical centres can arrange the schedule to pick up the medical equipment from members.

e) **Donation history**

NGOs/medical centres can view the history of all the donation received from members.

Member

a) **Login**

Member can log in using email and password. Member is required to sign up by email, name, username, contact number and password.

b) **Registration of medical equipment**

Member can register the medical equipment by scanning the medical equipment. This mobile app will recognise the medical equipment by the highest accuracy of the deep learning model trained. Information for medical equipment such as name, duration used, and photos are required. Members can view all the medical equipment registered before donating them.

c) **Search of drop-off points of NGOs/medical centres**

Member can search the nearest drop-off point to donate the medical equipment. Address and map will be shown to the member.

d) **Pick up service**

Member can request pickup service from the NGOs/medical centres. Member makes appointments with the NGOs/medical centres to pick up the donated items.

e) **View information on medical items that can be donated**

As there is very low awareness in reusing and reducing medical waste, information should be provided to assist members in donations.

f) **Chat engine to communicate with NGOs/medical centres**

Member can contact the NGOs/medical centres regarding donation matters. Enquiries can be asked in the chat box.

g) **Donation history**

Information such as the donation date, time, donated items, beneficial NGOs/medical centres is recorded.

h) **Notification**

Member will receive notification reminder for the appointment made. Notification of medical items in shortage will send to the member too.

i) **Share to Social Media**

Member can share their donation on social media. Donation details such as donated items and the beneficial party (NGO/medical centre) can be shared on Facebook, Instagram and WhatsApp.

Admin

a) **Login**

Admin can log in using email and password.

b) **Verification of registration of NGOs/medical centres**

Admin will verify whether the NGOs/medical centres are valid or not according to details provided by NGOs/medical centres.

c) **View monthly reports of medical items donated**

A bar chart or pie graph can be generated based on the number of medical equipment and types of medical equipment donated.

Features for all users
Settings

a) **Able to switch on or off the notifications**

Member and NGO/medical centre can switch on or off the notifications from the mobile app.

b) **Able to edit profile**

Member and NGO/medical centre can update the profile details in the profile settings.

c) **Able to change passwords**

The users of this mobile app can change passwords in login screen if they forget password or change in the account settings.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, similar mobile applications are studied and discussed in terms of their features and UI interfaces. Applications are analysed in order to gather useful features that can be implemented in the unused medical equipment donation mobile application. The focus of this study is to find out how donations and appointments can be made. In addition, the design of three entities which are NGO's/medical centre's, member's and admin's interfaces are investigated by referring to the interfaces of Boost and Boost Business.

2.2 Research and Evaluation on Similar Application

Nine similar apps are studied in this chapter section. The similarity of the nine apps can be categorized into low, high and very high. GivMed falls under the very high category. DrugStar, Blood Donor, ShareTheMeal, Charity Miles and reGAIN are high in similarity. Forest, Food Panda and Boost are low in similarity.

2.2.1 GivMed

GivMed Mobile App is built for the public to donate leftover medicine in just a few taps to organizations. Users can schedule the delivery of unused medicine by themselves or be contacted by organizations. They can view a list of medicines shortages, and regions that require it. Check out this link to learn more about GivMed.

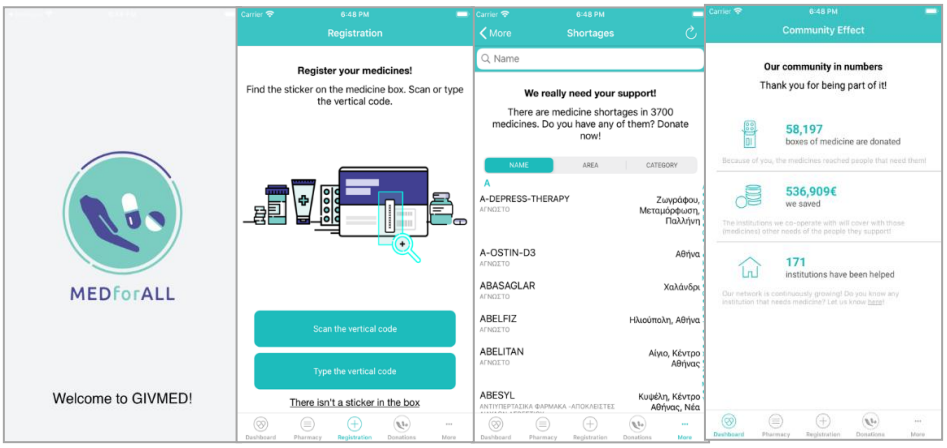

Figure 2.1: Interfaces of GivMed

Main features of GivMed

- Register the unused medicine

  User can either choose to scan or type in the barcode printed on the medicine package. The details such as name, descriptions, expiry date, barcode and notes will be displayed. User can change the medicine status (opened/ closed) for donation. If the medicine packages do not contain the barcode, users are prohibited from registering medicine.

- Schedule donation date

  User can choose when to donate medicine registered either now or before the expiration date. This feature only provided if users decided to deliver the unused medicine by themselves.

- History of the donations

  User can view the scheduled donations and the completed donations' details such as medicine name, NGOs, and donation date.

- Delivery by user or pickup service

  User can select between deliver the medicine by themselves or request pickup service from organizations. If a user wishes to deliver on their own, they need to schedule a date before the deadline set by organizations. The details such as medicine name, organization name, address, phone number and open hours will be shown on the screen.

- View NGOs for medicine shortages

  This feature allows user to view the medicine's name that the organizations require. The region that requires the medicine will be listed. User can sort the shortages according to region name or medicine name in alphabetical order.

- Community Impact

  This feature will show the positive effects of the donations. The number of medicines donated to the needy or poor, the amount of money saved by reducing the waste of medicine and the number of organizations the application helped are highlighted in this feature.

Analysis of GivMed

i. User Interfaces

The layout is neat and tidy by categorizing the features into the sidebar for Android and bottom navigation bar for IOS. The font size is considered appropriate for the young or elderly. Only three colours are used in the app, which shows minimalism. There is no home screen in this app. Users will be direct to the register medicine screen every time they open the app.

ii. Features

Scanning or typing the vertical code is a good feature as it prevents improper or expired medications to be registered. This feature also disallows medicine without a barcode to be registered to ensure safety. Furthermore, upcoming and completed donations are listed for the user to keep track of the donations' journey. Besides, community impact is another great feature that will motivate the user to donate more unused medicine as it shows the positive impacts of the donations.

GivMed also provides options to users whether to deliver the leftover medicine or request pick up service. However, there is no chat function that allows user and NGOs to communicate in the app. Users need to contact the NGOs through the phone number given. Another limitation of this app is no rewards given to users if they donate the medicine to NGOs. User will feel bored and discouraged if no rewards are given. Rewards such as points should be implemented to encourage users to keep on using the app for donations.

Conclusion of GivMed

GivMed is an app that is the same as this project. Good features that can be considered to implement in this project are verification of medicine by scanning and typing the barcode of medicine, donation date scheduling, medicine shortages of NGOs and community impact. Limitations, which are rewards system and chat function between NGOs and users, can be included in this project. A reward system is important to sustain the app by engaging users. Chat function can smoothen the communication between NGOs and users.

2.2.2 DrugStar

DrugStar is an app that reminds you to take your medications. Rewards will be given if users take their prescriptions successfully. User can donate to NGOs using the rewards. In addition, user can join campaign such as donate waste medicines to a pharmacy to earn points. Check out this link to learn more about DrugStar.

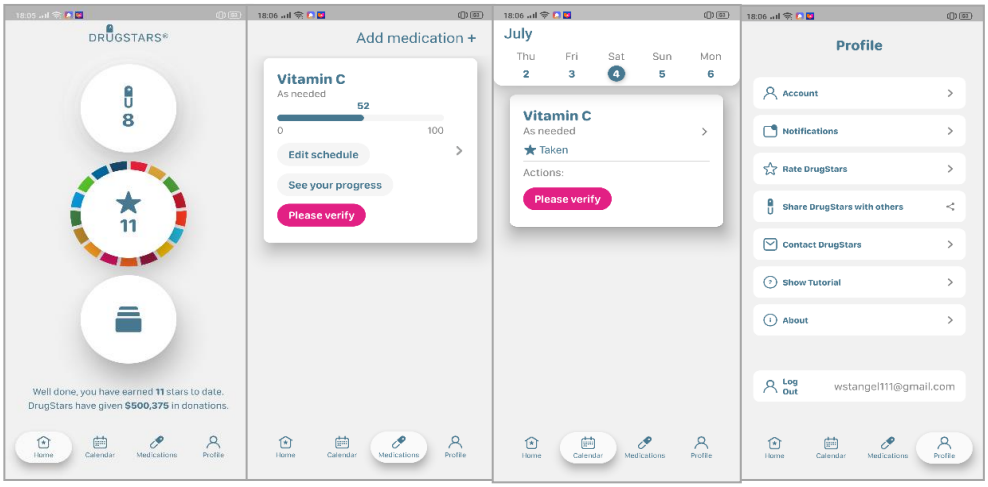

Figure 2.2: Interfaces of DrugStar

Main features of DrugStar

- Add medication

  User can add medication by typing the medicine name, the frequency of taking it, start date and end date of medication. Then, users can review the medications by answering a set of questions. By answering the questions, users earn "DrugStars" that can be converted to money to be donated to charity. An edit schedule is available for the user to modify the details of medications.

- View progress of medication

  User can view the progress of medications (overview). The overview is presented as a level bar format for benefit, difficulty, necessity, satisfaction, confidence, side effects, information and taking it. Besides, users can seek advice from authorities linked from the app to the webpage if medication is not working.

- Calendar of medications

  Medications that should be taken are grouped based on days. Users needs to tap "Taken" or "Skip" for each medication. The medications are sorted by the time in ascending order.

- Verification of medicine

This feature exists to avoid pills, week dispensers, prescriptions that are not valid to use. User can take a photo of the medication's name on the package. An error message is prompted if the medication's name is invalid.

- Medications' reminder

  Notification will be sent to users as a reminder to take the medicine by the time scheduled of the medication. This reminder can be turned on or off in settings. The sound of notification and show of medications name can be turned off in settings too.

- Donations

  This feature allows user to donate the "DrugStars" earned by taking medications on time or any related activities to charities. Moreover, users can view campaigns held by organizations, such as return waste medicine to pharmacy, share your medications experiences to others, etc. To verify the actions that you have done like returning the waste to pharmacy, a photo must be taken to claim the "DrugStars".

Analysis of DrugStar

i. User Interfaces

The layout is neat and tidy by categorizing the features into the bottom navigation bar for android. The colour of the interface of error message, such as an error in the image taken for medicine verification, is light red to warn the users, while the successful message of donations of "DrugStar" is shown in green.

The home screen interface (3 circles) is well designed as the medicine taken is on top of "DrugStar" earned, followed by campaigns held by organizations. After users tap on the medicine taken, it converts the medicine taken to "DrugStar". Users can see the immediate effect of "DrugStar" earned. The logical order of these two functions enhance user experiences.

ii. Features

Medication's reminder is a good feature that reminds the user about the medications. It provides preferences to users to turn on or off the notifications in settings. The history of medications is organized in calendar format. This feature helps users to organize medications with frequency, time, status of medication (taken/ skip). A proper arrangement of information is essential in making an awesome app.

For verification of medicine and return waste medicine to pharmacy, users must take a photo using the app on the spot. It is pretty inconvenient for the user who has the photo in the phone gallery. Upload photo option should be provided. Besides, no scanning of medical item feature is included in the app. Scanning of the medical item should be included to ease the registration of the medical item process.

Conclusion of DrugStar

DrugStar has many wonderful features and user interfaces that can be considered in this project. Features such as reminders and view progress of medications are great to be referred for features such as reminders for donation schedules and progress of donations in this project. The neat and organized layouts of DrugStar, such as error message, feedback message of successful donations of "DrugStar" and calendar of medications should be applied in this project.

2.2.3 Blood Donor

Blood Donor is a mobile application created by the American Red Cross. This application aims to save lives by easing the process of donation of blood. The public can schedule the blood donation and appointments, find local blood drivers and donation centres. A team can be formed to unite the people to donate blood whenever there is a shortage of blood. It is available on IOS and the Android platform. Check out this link to learn more about Blood Donor.

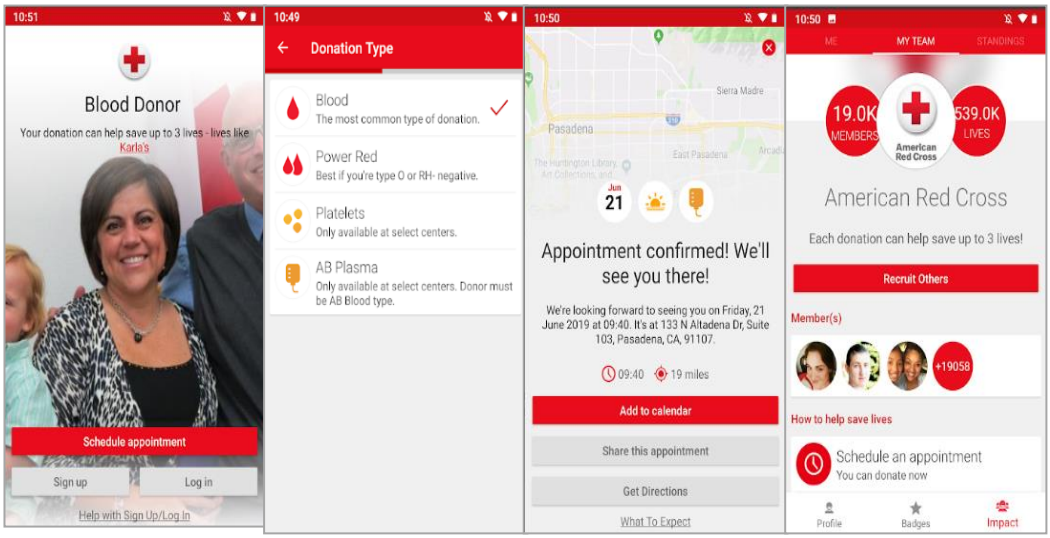

Figure 2.3: Interfaces of Blood Donor

Main features of Blood Donor

- Appointment scheduling

  Users need to select a date, time and donation type for scheduling the appointment. User can reschedule the appointment or cancel the appointment at any time.

- Locate blood drivers and donation centres

  User can locate blood drivers nearby or another location. The application will display the blood centres that are available for donations. Besides, it will send geo-targeted blood shortage alerts to users if their blood type is in need. User can tap on “Get Direction” to locate the actual location of the blood donation centre.

- Reminders for appointments

  Reminders for appointments will be sent to users. Users can add the scheduled appointment to a calendar and share the appointment on social media.

- Tracking of blood donations

  This feature allows users to keep track of his blood donations in blood, power red, platelets and AB Plasma. There are five stages for blood donations: the donation, processing, testing, storage and completion. Users can view the journey of the donations after they donated blood. Sharing of the journey to social media is available.

- Community

  User can join or create a lifesaving team. Recruitment of other blood donors to the team can expand the team, thus increase the ranking on a national leader board determined by the number of lives saved.

- Badges

  There is a various type of badges in blood donations’ journey. Once the requirements are reached, users can earn the badges. User can proudly share the achievement on social media.

Analysis of Blood Donor

i. User Interfaces

According to Schneiderman’s eight golden rules, design dialogs to yield closure is applied to the scheduling of appointment feature. User can select a date, time, donation

type and donation centre in sequencing orders. However, users might forget the previous selection made if the selections are done on few screens. The choice of colour for Blood Donor application is suitable.

For the main screen, the resolution of the picture shown is blurry. It might give a bad impression to users. Another shortcoming of the interface is bottom navigation of the app only available after users logs in. It creates confusion and inconsistency in the layout as the user can still schedule the appointment without log in.

ii. Features

Blood donation scheduling is easy and simple. Tracking of blood donations can organize the user's donation. User can view the history and decide when the next donation is. Blood donation is in high demand. Community feature can support one another, strengthen the relationship and gives the user a deeper sense of belonging. Besides, this feature can gather blood quick whenever there is a blood shortage.

Conclusion of Blood Donor

The features that can be included in this project are scheduling of appointment, tracking of donations, community and badges. These features are most relevant to this project. The procedures of scheduling appointment can be extracted to use in this project. Nevertheless, the weakness in the user interfaces of Blood Donor should be avoided in this project.

2.2.4 ShareTheMeal

ShareTheMeal is a charity app made by United Nation World Food Programme. It targets to solve the world hunger issue. The mobile app's user can feed a child by donating a minimum of 50 cents for a day. Distribution of food and progress of donations will be shown to users as well to ensure transparency. It is available on IOS and the Android platform. Check out this link to learn more about ShareTheMeal.

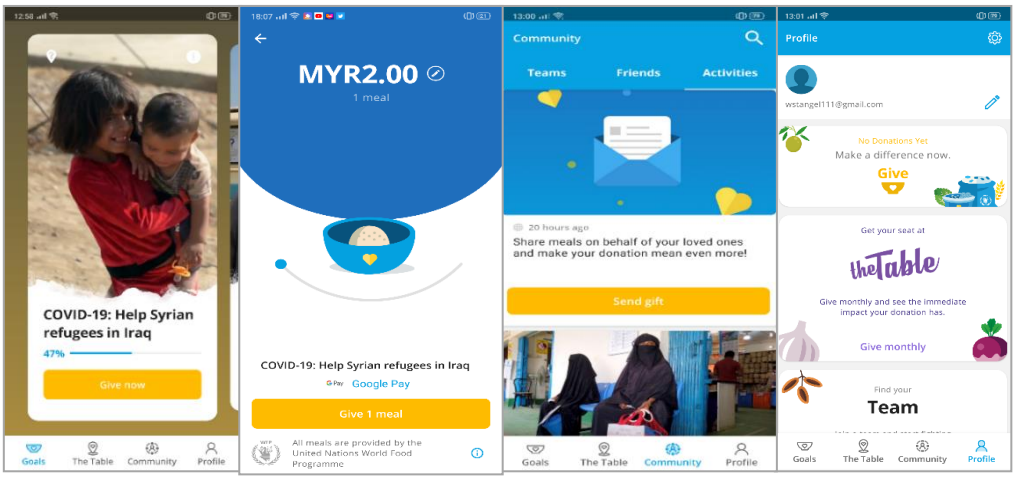

Figure 2.4: Interfaces of ShareTheMeal

Main features of ShareTheMeal

- Donate to funding events

  There will be a few current event goals like “COVID-19: Help Syrian refugees in Iraq” held by the United Nations World Food Programme. Users can donate a minimum of one meal or custom meal amount to any of the goals. The payment method is either credit or debit card.

- Donate monthly to children

  Users can give monthly to a minimum of one child. Users will receive updates about families that he aided.

- Friends

  Users can connect to Facebooks for friends to view the number of meals his friends has donated.

- History of donations

  Users can view the history of donations on the profile screen. The donations will be grouped by all, individual and subscriptions. Date, time and amount donated are shown.

- Community

  The xommunity feature allows user to join or create a team and connect with friends who have the same interest in helping the poor. User can search the team name or find the team in the list of popular teams to join the team. Details such as meals donated in total and the number of members will be shown for a team. Ranking of the team by the number of meals donated by members is available.

- Achievements

  In this feature, there are some badges that can be achieved by users. Once a user reached the target, the badge is earned and activated in the user profile. User can see other users who have the same badge. Each badge earned by a user can be shared on social media.

Analysis of ShareTheMeal

i. User Interfaces

The layout is neat and tidy by categorizing the features into the bottom navigation bar for android. The combination of colours in this app is well matched. For every action user does, there will be feedback such as button changes colour. Besides, there is a structured meals entry function when the user wants to donate the meals to prevent error entry.

ii. Features

ShareTheMeal provides a variety of donation methods to users. Users have much freedom when deciding whether to make donations for specific events or on a monthly basis. Besides, community and achievements are important features that support the donations. As “united we stand divided we fall”, the community gathers the power of people to contribute to addressing hunger issues. The ranking of the team in terms of meals donated by members is an appreciation for the members.

People often feel lonely and easily give up as they don’t think their little action can make any changes. Community feature will make them feel more motivated and strive for goals. Achievements can also encourage users to donate more to fight hunger. Without community and achievements features, the app will be boring and fasten the uninstalling by users.

Conclusion of ShareTheMeal

Almost all features in ShareTheMeal are designed in a very detailed way. For example, community and donation methods, which provide detailed information and a variety of preferences. User can either donate monthly or to an event. The project teams take much consideration to enhance each feature. Furthermore, the interfaces are one of the best designs which can be learnt. Community and achievement features are important

in delivering a donation mobile application which must be implemented in this project to sustain the mobile application.

2.2.5 Charity Miles

Charity Miles is a charity app designed for tracking fitness progress such as running, cycling and walking. Money will be contributed to charity which users picked out of more than 40 unique charities based on the distance they cover in miles. This app is creative and innovative to gather funds for charities at the same time encourage public to keep fit and stay healthy. Check out this link to learn more about Charity Miles.

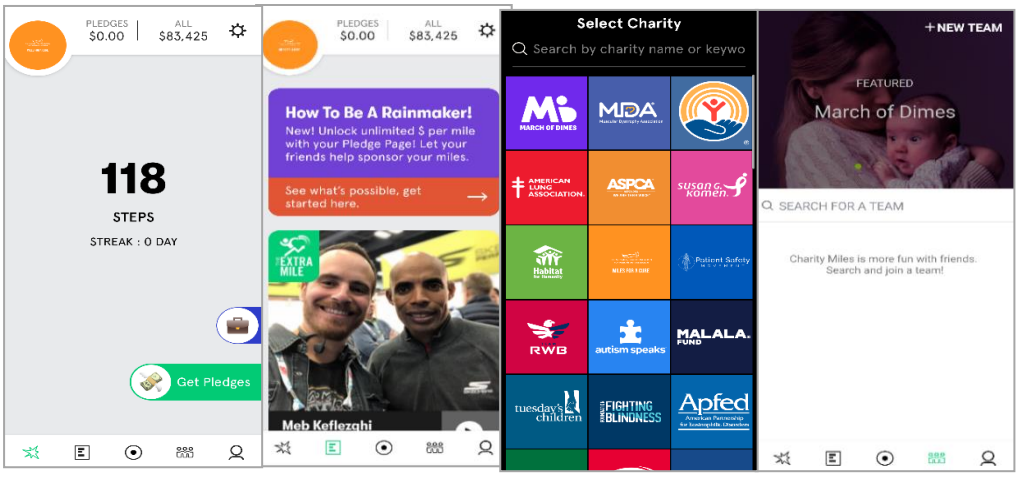

Figure 2.5: Interfaces of Charity Miles

Main features of Charity Miles

- Tracking of miles

  Charity Miles uses the phone's GPS and internal pedometer to track the distance covered. The majority of android phone sync the internal pedometer with the app to record down the miles. User can connect the app to Strava, Strava is an app that can be manually added into Charity Miles to have a more accurate calculation of the steps.

- Tracking of special activities

  This app can track special activities. By tapping the circular button in the middle of the bottom navigation of the screen, the user can select the activities, such as outdoor walk, outdoor bike, outdoor run, indoor walk and indoor run. This app will measure the activities using GPS for an outdoor walk or pedometer sensors for indoor activity. Accuracy can be increased and produce better results for users.

- Get sponsored by friends or family

  Users can generate a pledge page that allows the user's friends or family to pledge a sponsor based on the rate set by them. After the user completes the miles, his friends or family can donate directly to the charity chosen by him.

- Teams

  New teams can be created by users by filling up the team name, about and photo. User can also join the existing team. Team members and miles covered by the team are shown in each team profile.

- History of miles

  The history of miles covered by users will be displayed in bar chart format. It is sorted daily, monthly or yearly. Users can view the details of each activity such as the number of miles, date and charity donated.

Analysis of Charity Miles

i. User Interfaces

Bottom navigation is implemented in this app. The layout is clear and simple. However, more details should be provided for the screen showing the number of steps, for example, the bag icon button that allows the user to log in using his company email. Without any words for the icon, a new user will confuse. Another confusion the app is the get sponsor by friends and family feature. Users need to tap the "Get Pledges" that directs him to move the sliders for miles goal, the average pledge amount and the number of pledges. Then, the app will only direct the user to get sponsor by friends and family features. Inorganized features might be missed out by users.

ii. Features

Get sponsor by friends and family is actually a creative feature that exposes the app to more people. Users' friends or family might install the app to sponsor the donation by the user. Furthermore, the team is great as the community can support the users and attach them to continue his fitness activities. Moreover, the history of miles is an important feature that lets the user track his activities and form goals according to the progress. Improvement can be made if the user finds out the miles covered are insufficient.

Conclusion of Charity Miles

Confusion in organizing the features should be avoided. The simple and clean layout of Charity Miles can be adopted in this project. In addition, features such as team and history of the activities can be considered in this project. Interfaces of history can be referred. Bar chart and sorting can be included in this project for the feature of presenting the data.

2.2.6 reGAIN

reGAIN is a free mobile application that let users donate their old or unwanted clothes to charity. By donating recyclable clothes, shoes or accessories, user can get discount coupons in return. When the user sends the unwanted clothing to drop-off points, he can get the rewards immediately. reGAIN app not only allows the users to refresh and clear the wardrobe, the users can also use the coupons to purchase new items. Check out this link to learn more about reGAIN.

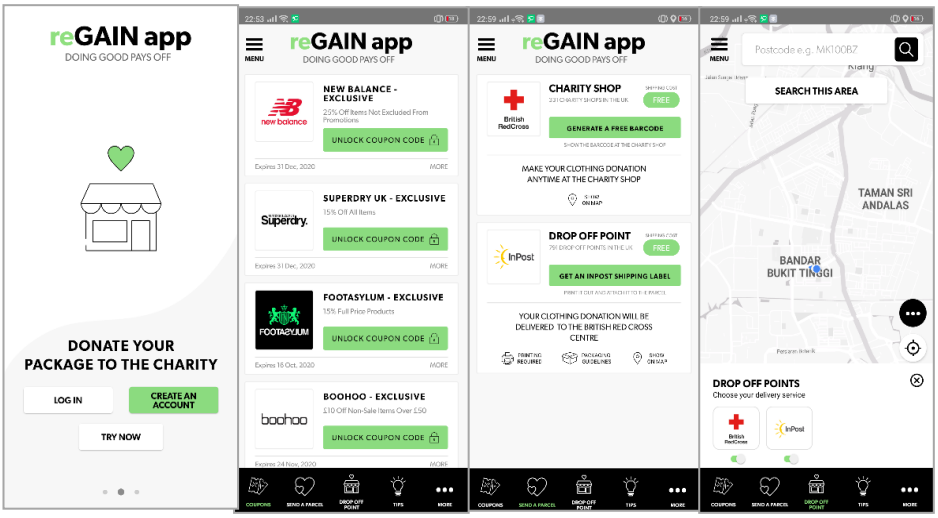

Figure 2.6: Interfaces of reGAIN

Main features of reGAIN

- Generate in-post shipping label

  Users needs to select the pack size for the package of unwanted clothes and type in a phone number to get an in-post shipping label. This in-post shipping label will be attached to the parcel before users ships it to the charity shop. Printing of the label, packaging guidelines and location of the charity shop are available to assist users.

- Generate barcode for drop-off

Users can choose to send their parcel to the drop-off point. A generate barcode function acts as a verification before users can get the coupons for donating unwanted clothes. The barcode must be shown to the person in charge of the charity shop.

- Search for drop-off points

  User can search for drop-off points using postcode. The map will be shown to help users locate the drop-off points.

- Coupons redemption

  After the user donates the unwanted clothes, the user will get 10 days access to the discount coupons within 1 hour. Users can browse the list of coupon codes. Users will get the coupons code once the admin unlocks the coupons.

Analysis of reGAIN

i. User Interfaces

The combination of colour used in reGAIN is soothing and youthful. Minimalism is also practised in this app. A lot of tips and guidelines are provided in this app. It is user-friendly to novice users. Feedback for each button, such as colour changed, is applied. Consistency in font, font size, colour and margin is high. Icons are utilized in the bottom navigation. Icons work better than words in delivering the information to users. Overall, user interfaces of reGAIN is consistent and responsive.

ii. Features

reGAIN did a great job in ensuring the donation is valid before users can get any rewards in return. The features of generating the barcode and in-post shipping label are important to verify unwanted clothes donations to the charity shop or drop-off point of the charity shop. Guidelines on the packaging, such as the size of the package, are provided to users. Instructions on shipping and drop-off are given clearly, too.

Conclusion of reGAIN

Generating of barcode and in-post shipping label can be considered to be implemented in this project. If rewards such as coupons or points are given, the donation must be valid and proven to avoid any cheating. In the long run, these features will assure the quality of a mobile application. The consistency and responsiveness of user interfaces can be referred to when designing the interfaces in this project.

2.2.7 Forest

Forest is a mobile application that aims to beat phone addiction. It transforms the user's focus into trees and eventually a forest. However, if users leaves the app when planting the tree, the tree will wither. The forest team collaborates with a real-tree planting organization (Trees for the Future) to let the user plants a real tree with coins earned. Check out this link to learn more about Forest.

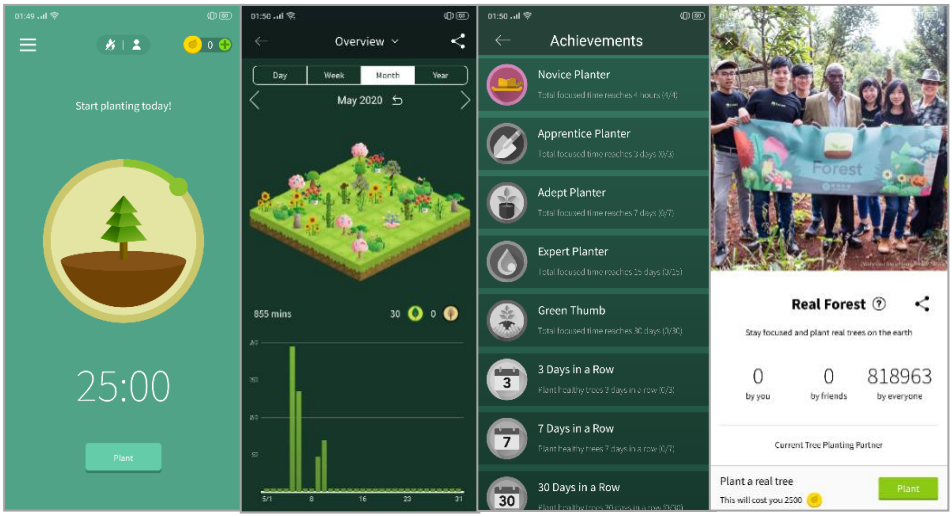

Figure 2.7: Interfaces of Forest

Main features of Forest

- Plant virtual tree

  A tree can be planted according to the focusing time. Users are restricted from leaving the app. If users leave the app, the tree will wither. A healthy tree will reward points to users. Planting mode, such as deep focus mode and plant together mode, give more preferences to users. The deep focus mode will strictly prohibit users from leaving the app, while the planting together mode allows user to plant with friends. Withering one's tree will cause others' tree to wither.

- Plant a real tree

  Users can use points earned to plant a real tree which will be planted by a real-tree planting organization (Trees for the Future). Users can view the number of trees planted by themselves, friends and everyone.

- Timeline

This feature records all the activities done by users such, as time, date, and the description of the activities. Users can edit the tag of the activities and share the activities on social media.

- Friend

  Users can add their friends via email address, getting friend request from others and view a list of friends. There are global users, which sorted according to deep focus mode ranking. Users can send friend requests to other users in the global ranking. Besides, users can know their ranking in the period.

- Achievements

  There is a various type of targets that user can accomplish. Users can claim the rewards in points for each achievement. Sharing to social media is included for achievements.

- News

  Updates of features and fixing of bugs of forest app will be posted in the news section. Users can gain the latest news for the app.

Analysis of Forest

i. User Interfaces

The layout of the Forest is neat and clean. Sidebar is used in this app for navigation. Green is applied in this app as the fundamental colour. Additionally, the entry of focus time for planting trees is designed in a circle that can control the input of users. It can prevent error in setting the time for planting a tree and let the user complete the task easily.

ii. Features

The developer team explores all the possibilities in making the app interesting. There are a variety of tree species for users to choose for planting the virtual tree. Different modes in planting the virtual tree such as deep focus mode and plant together mode are provided to users. The strength of this app is the formation of sense of responsibility for users to take care of the plant before the plant withers for the sake of not concentrating.

Planting of a real tree is another attraction that encourages the users to earn more points to convert the points to a real tree. Friends feature allows more interactions between users to the real world. Users can view the ranking of users by the number of

trees planted and the number of trees withered. Friend request can be sent to those with high ranking. Users can make new friends using this app.

Conclusion of Forest

The friend feature is one of the best features in Forest. Users can manage their friend list efficiently and engage with the community. The limitation of this feature is that user cannot leave messages or chat with friends. Modifications and improvements of this feature, such as the chat engine, can be made and adopted in this project.

2.2.8 Food Panda

Food Panda is a food ordering app. Users can order food from the restaurant selected for either delivery or pick up. Check out this link to learn more about Food Panda.

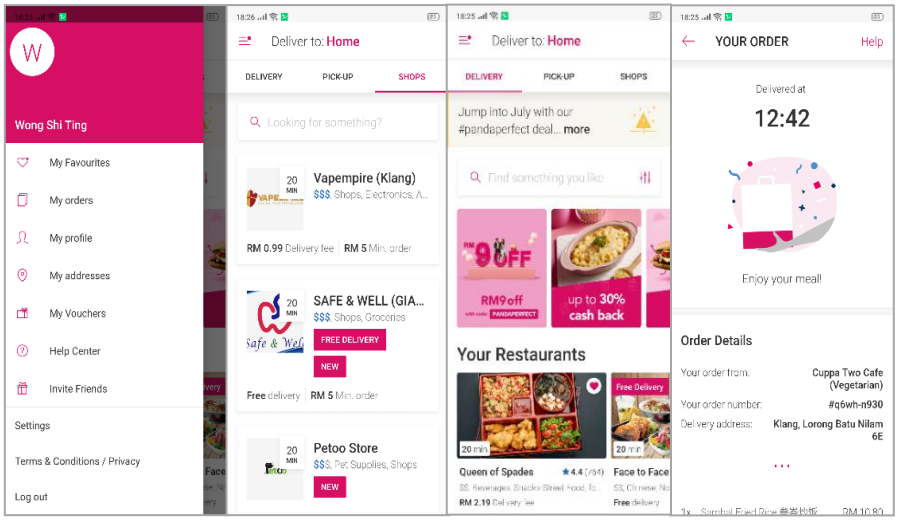

Figure 2.8: Interfaces of Food Panda

Main features of Food Panda

- Pick up or delivery service

  A list of restaurants available for pick up will be displayed. Users can make an order by selecting the restaurant, then followed by the dishes wanted. User can pay by online banking or credit or debit card. The steps are the same if users wish to request delivery. After the order is done, users can view the order made with the details.

- Favourite the restaurants

  This function allows users to find the restaurants in the favourite list. It is convenient and reduces the time for users to find the restaurants.

- Invite friends

  If a user invites his friends to use the app, he will get a voucher as a reward. Users can share the link provided in the app to their social media.

Analysis of Food Panda

i. User Interfaces

The interfaces for pickup and delivery look alike. Users might make a mistake, such as order food through delivery when he wants to order food for pick up. Other than that, the interfaces are great and simple to use. The combination of colours used in this app is pleasant. Pictures and details of food are given to guide users in using the app.

ii. Features

All the necessary features are included for a food ordering app. However, there is a bug in the app. When users cancel the payment process before successfully paying online, the app shows the order is successful. Besides, users cannot cancel their order if they order wrongly, even in five seconds.

Conclusion of Food Panda

Delivery and pick-up features can be referred to and implemented in this project. Although Food Panda is a food ordering app, its features can be studied as well when designing the medical equipment donations app for delivering and pick-up donated items function.

2.2.9 Boost

Boost is a mobile e-wallet app that promotes a cashless lifestyle. It ensures transactions of money is secure and rewarding. Rewards such as cashback, vouchers and promotion can be enjoyed by users. Boost partners with many banks, such as CIMB bank, Public bank, Hong Leong bank, etc. for the top up function. There are two mobile apps for Boost. The public uses boost for e-wallet function, while Boost business allows a businessman to process the transaction of money efficiently from the customers. Check out the links to learn more about Boost and Boost Business.

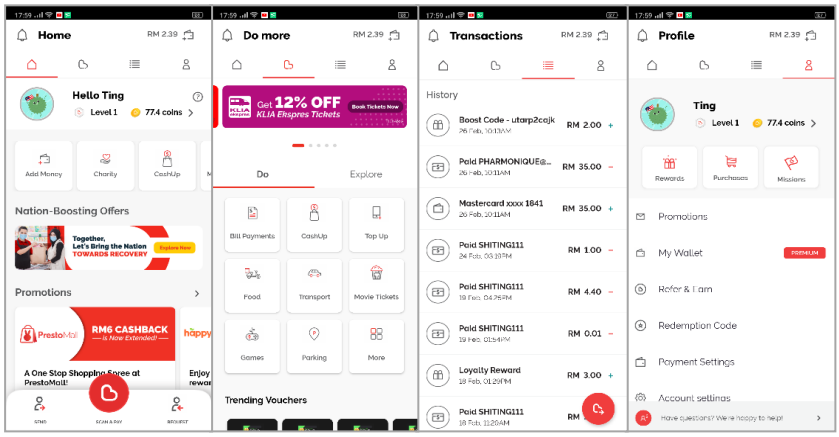

Figure 2.9: Interfaces of Boost

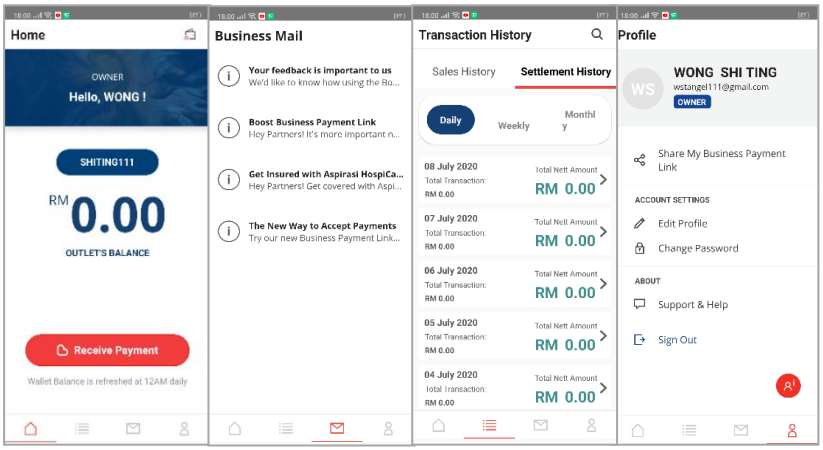

Figure 2.10: Interfaces of Boost Business

Analysis of the user interfaces

As unused medical equipment donations for NGOs/medical centres mobile app will be used by NGOs/medical centres, members, and admin, three different interfaces need to be developed. In comparison between Boost and Boost Business, the colour theme is the same, which are red and white as the base colour. However, the navigation is different. Boost navigation is at the top of the screen, while Boost Business is at the

bottom. Besides, the profile screen is unalike. Font and font size applied are not exactly the same. Font size in Boost business is slightly bigger than Boost. In general, both apps practised cleanliness and consistency in interface design. Icons are utilised to assist users. The history interface in both apps can be adopted in this project as it provides great content in an appropriate organizing way.

2.2.10 Conclusion of Similar Application Review

Each mobile application has its unique interface design. User interfaces design is subjective and depending on the users. However, it can be studied to extract the good layout and organizing of each screen to present the information and features to the users. Table 2.1 shows the comparison of features on the eight mobile application studied. Boost is excluded as it is studied based on the user interfaces only.

Table 2.1: Similar mobile application comparison matrix

	GivMed	DrugStar	Blood Donor	ShareTheMeal	Charity Miles	reGAIN	Forest	Food Panda
Register the unused medicine by scanning the medicine name	√							
Verification on donation items	√	√				√		
View NGOs for shortage on donations	√		√					
Shipping label for delivery						√		
Donations to funding events				√				
Delivery/ Pick up service	√		√			√		√
Team for users to join	√		√	√	√		√	
Achievements for donations			√	√	√		√	
Friends list				√			√	
Chat engine between users and NGOs								√
Donation's history	√	√	√	√	√		√	√
Scheduled donations reminder	√	√	√	√		√	√	√
Rewards such as coupons, points and vouchers for donation		√				√	√	

After comparing the features for each donation and related apps, this project will include the features below.

- Register of unused medicine by scanning the medicine name
- Verification on donation items
- View NGOs for medical items shortage
- Delivery or pickup service for donation items
- Team for users to join
- Donations' history
- Chat Engine for NGOs and members
- Scheduled donations reminders
- Rewards such as coupons, points and vouchers for donation

Most of the similar apps investigated do not include scanning of medical item feature. Registration of unused medical equipment by scanning the medical equipment photo should be included in this project before users can donate it. Scanning can definitely provide another useful alternative other than typing the medical equipment name. Verification on the donated items must be carried out to prevent improper medical equipment. Medical equipment shortage for NGOs/medical centres can be implemented in this project. This feature fastens the donation from the public to NGOs/medical centres. Delivery or pick-up service is essential to deliver the unused medical equipment to NGOs/medical centre as it might be inconvenient for users to travel to the NGOs/medical centres site. Community or team acts as a support for users to continue their good deed to donate the unused medical equipment. Competition among the team can be formed as the ranking of the team will be carried out. The history of donations will be the proof of users' donation to NGOs and help users record down the journey of donation. Besides, the chat engine is important for NGOs and members to communicate for scheduling the donation. Reminders will be sent to users to remind users about the donation's appointment. Another feature, which is the rewards system, can be implemented each time users donate the medical equipment. However, the team or community for users to join and rewards feature will not be included in this project. They will be considered in future enhancements.

2.3 Software Development Methodologies Review

Dennis, Wixom and Tegarden (2015) explained that the systems development life cycle (SDLC) is the process of designing, building and delivering an information system (IS) to users that can support business requirements. It consists of four main processes, which are planning, designing, analysis and implementation. The software development methodology is a list of steps and deliverables implemented in the software development life cycle. It acts as a guideline to lead a software team in executing the works in an organised manner. There are many unique and different software development methodology. Each of them has its pros and cons. In this section, the review of various software development methodologies will be carried out before deciding the final methodology.

2.3.1 Waterfall

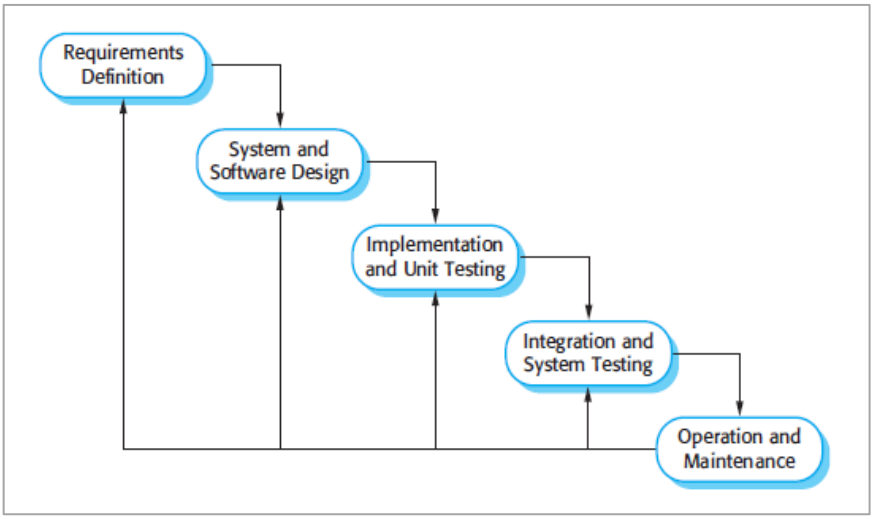

Figure 2.11: Waterfall Methodology (Sommerville, 2011)

Adel Alshamrani and Abdullah Bahattab (2015) stated that the waterfall model is the most traditional and famous SDLC model. It is easy to understand compared to other methodology. Linear sequential practised in each phase in the waterfall model. One phase must be completed before the next phase begins. Based on Figure 2.11, there are five phases in the waterfall model. Dennis, Wixom and Tegarden (2015) affirmed that key deliverables are basically very lengthy in each phase to be provided to the project sponsors for approval. After approval, the project team can continue the works and start a new phase.

Table 2.2: Pros and cons of the waterfall model (Cadle, et al., 2014)

Pros	**Cons**
• Simple and easy to understand. • Easy monitoring progress for managers as high visibility in each phase. • The project manager finds it easier to manage with obvious and clear project milestones.	• Customers might not satisfy with the final product. • Higher cost in reimplementation of new requirements when they are identified during testing. • Poor assumptions can critically impact the project schedule and cost.

The majority of time, consumers do not understand their requirements and do not express them explicitly on the system they want. According to Pressman and Maxim (2015), the structure of real projects seldom follows a sequential flow. Many iterations can happen to review previous phases. As per Sommerville (2013), the waterfall model is only appropriate for projects with well-defined problems and specifications. Nowadays, software projects that are fast-paced and tight schedule are inappropriate for the waterfall model (Pressman and Maxim, 2015). As each phase will take a very long time to document and get approval from top management and project sponsors, a presentable and functional system will only be produced in the later phase.

2.3.2 Agile Development

Agile development follows the agile manifesto and twelve principles (Dennis et al., 2015). It aims to achieve customer satisfaction and the early incremental delivery of software. Software developers will develop fast and test early instead of waiting for the whole system to be completed. What is agility? Ivar Jacobson who contributed to UML claimed that agility is what the modern software process all about. Changes occur all the time. Requirements changes, technology evolutions, software development team member changes will strongly affect software production. In other words, the capability of a software team to cope with change determines a software product's success.

According to Dennis, Wixom and Tegarden (2015), customers are highly involved in software development. Changing user requirements is normal and

permitted in agile development. Customers need to review the deliverables by the software team. Modification can be made once customers find out any issues. Besides, the development teams tend to practise face-to-face communication to increase efficiency and effectiveness. Developers and customers work together on a daily basis.

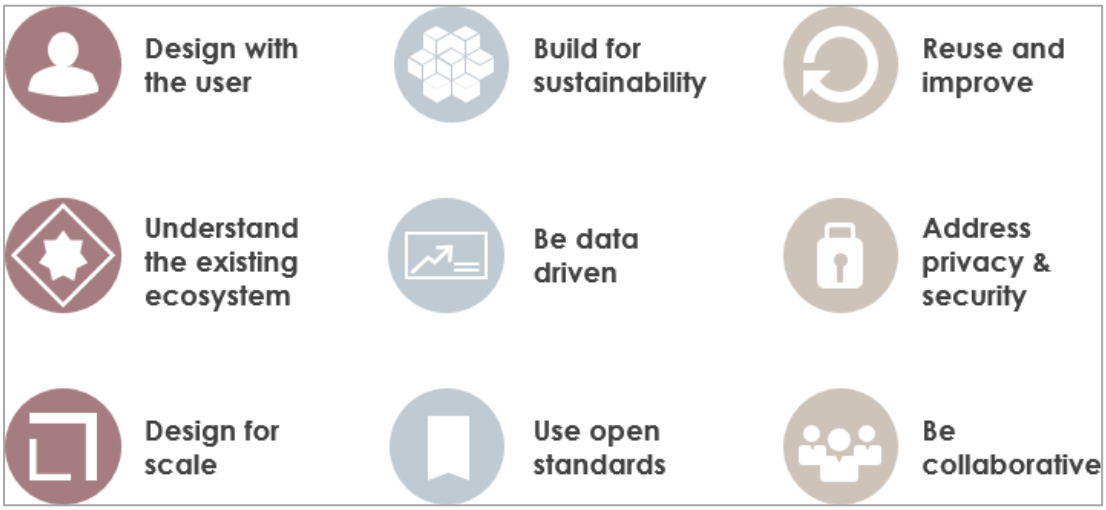

Figure 2.12: Agile manifesto (Visual Paradigm, 2020)

Knowledgeable customers or users that ensure the requirements are well-defined for the software that is being developed in the small application project will be perfect-fit for agile development (Mora et al., 2012). Mora also pointed out that the agile methodology less emphasis on the documentations compared to traditional methodology like the waterfall model. Construction and requirements gathering of software can be overlapped. Examples of agile methodologies are Extreme Programming (XP), Kanban, Scrum, Features Driven Development, Rapid Application Development and Crystal. Table 2.3 summarizes the strength and weakness of agile development.

Table 2.3: Pros and cons of Agile Development (Douglass, 2015)

Pros	**Cons**
• Increase project control by tracking progress in term of project objectives. • Early return on investment (ROI) as error feedback on the system can be given earlier. • Responsive to changes. • Project risk can be reduced by using a risk list or risk management plan.	• Lack of documentation as software developers focus on the delivering the work. • Higher commitment from both development team and clients which is time consuming. • Difficult for large teams due to high collaboration among developers.

2.3.3 Prototyping

The prototyping development model is a methodology that builds, tests and rebuilds a prototype when needed until a successful, workable final product is achieved (Mora et al., 2012). A prototype is an early version of the system product that can showcase the main ideas, concepts and design pattern (Sommerville, 2013). Issues arise in the early stages, and solutions can be formulated. Users and project sponsor can review the prototypes and give feedback on them (Pressman, 2015). If they find out some requirements do not match with their initial plan, they can voice out or propose new ideas. Throughout the process, comments from end-users and project sponsors are useful in reanalysing, redesigning, and reimplementing the new prototypes with additional features and modifications (Dennis et al., 2015).

Non-functional requirements are often ignored in the prototype due to time constraints. The main purpose of the prototype is to ensure the functional requirements are well-defined by including the risky and ambiguous requirements in the prototype (McDermid, 1991). There are two types of prototyping model, which are rapid throwaway prototyping and evolutionary prototyping.

Table 2.4: Pros and cons of Prototyping Development

Pros	**Cons**
• Enable fast development of the system for users to interact with. • Refinement of requirements can be made early to avoid extra expenses.	• Poor documentation as requirements change rapidly. • Uncertainty in the number of iterations should be carried out before the final product.

a) Rapid Throwaway Prototyping

According to Dennis, Wixom and Tegarden (2015), rapid throwaway prototyping methodology focuses on the analysis phase that collects the details and develops main concepts for the application. A design prototype is developed and demonstrated to the end-users. This prototype is not workable. It only aims to provide clearer image and explanations of part of the system to be presented to users. Once the problems solved in each prototype, the prototype is thrown away. Each prototype functions as confirmation of requirements before moving to the next design and implementation.

b) Evolutionary Prototyping

Prototype built initially is incrementally refined with end users' comments until it is finally approved and accepted. As compared to rapid throwaway prototyping, the prototype in the evolutionary prototyping methodology can be reused. Developers will not have a hard time to rebuild everything from scratch. Development time can be saved as well as saving the cost.

2.3.4 Spiral Model

The spiral model is a model that functions by building steadily more complete versions of the software. The software processes begin at the center of spiral and working outwards (Mora et al., 2012). The customers evaluate and review the work. Modifications can be made based on suggestions given by them. Then, risk analysis is carried out. These processes are repeated for each loop of the spiral. The spiral methodology is the combination of prototype and linear processes.

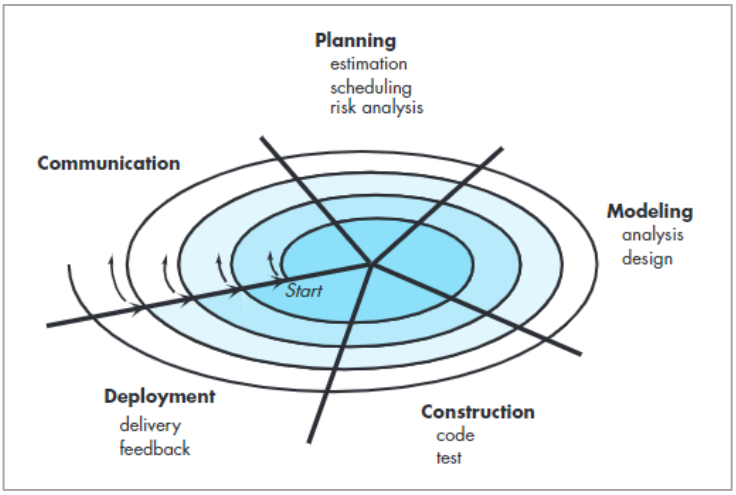

Figure 2.13: Spiral Model (Pressman and Maxim, 2015)

A spiral model is suitable for large-scale systems. As the software evolves, customers and developers develop better understanding of the requirements when the software development progresses (Pressman and Maxim, 2015). Prototypes act as a risk reduction method. By integrating both sequential model approach and prototyping approach, strengths in both methods can be obtained in software development.

Table 2.5: Pros and cons of Spiral Model

Pros	Cons
• Development is fast as prototypes can be developed for evaluation. • Risk can be properly handled. • Additional features can be added in a systematic way. • Adapt to changes well.	• Not suitable for a small project. • More documentations workload as more intermediate phases. • The loop of spiral might be infinite.

2.3.5 Comparison between Software Development Methodology

Table 2.6: Software Development Methodology Comparison Matrix

Methodology / Characteristics	Waterfall	Agile	Prototyping	Spiral
Requirements gathering	In the early stage	Continually changes	Often changes (unsure which is feasible)	In the early stage
Flexibility in changes of requirements	Low	High	High	High
Delivering of product	Slow	Fast	Fast	Fast
Risk handling	Bad	Good	Good	Good
User involvements	Low (In early stage)	High	High	High
Development team size	Big	Small	Small	Very Big
Project Size	Large	Small or medium	Small	Large

Prototyping technique will be used in this project based on the review of each methodology since the development team is limited and product delivery needs to be fast while requirements are always changing. Evolutionary prototyping is used as reusing the prototype created to save time compared to rapid throwaway prototyping. Customers are involved in evaluating and reviewing the prototype in each iteration.

2.4 Research on Object Recognition Approaches

Object recognition is a computer vision technique that can identify objects in digital photos or videos. It can act like a human who can recognise the targets using computer vision algorithms. There are many use cases for object recognition to ease human's activities. For example, face recognition in the attendance system, traffic check, automated CCTV surveillance, etc. The rapid evolvement of object recognition can be seen over the years. There are differences between traditional approaches by machine learning and deep learning approaches for object recognition. Several approaches for object recognition will be investigated in this section. The best solution will be selected to be implemented in this project.

2.4.1 Traditional Machine Learning Approaches

To recognise an object in an image, traditional machine learning approaches require feature descriptors such as Speeded-Up Robust Features, Binary Robust Independent Elementary Features, and Histogram of Oriented Gradients to detect the object. Then, a feature engineer is needed to perform manual extraction and selection for the important features in the images (Mahony et al., 2019). Edge detection, corner detection or threshold segmentation might be performed in feature extraction (Mahony et al., 2019. Traditional machine learning approaches work fine with small data sets and a small number of output classes. However, the efforts for feature extraction become bigger when more data and classes are involved. After feature extraction, a shallow structure classifier is used to categorize the images into classes.

2.4.2 Deep Learning Models

2.4.2.1 Transfer Learning with CNN

The traditional machine learning approaches often work well when training data and testing data come from the same distribution. If the data distribution appears differently, training the model from scratch is required to adapt to the new problem. In the real world, the cost of retraining the model is expensive and time consuming. Thus, transfer learning is introduced to address the issues (Pan & Yang, 2010). Transfer learning is a technique that transfers the knowledge learned from a model to another model (Pan & Yang, 2010). It is beneficial, especially when the data set available is small and computational power is a concern. Figure 2.14 illustrates how transfer learning works to deal a new problem compared to the traditional machine learning approach.

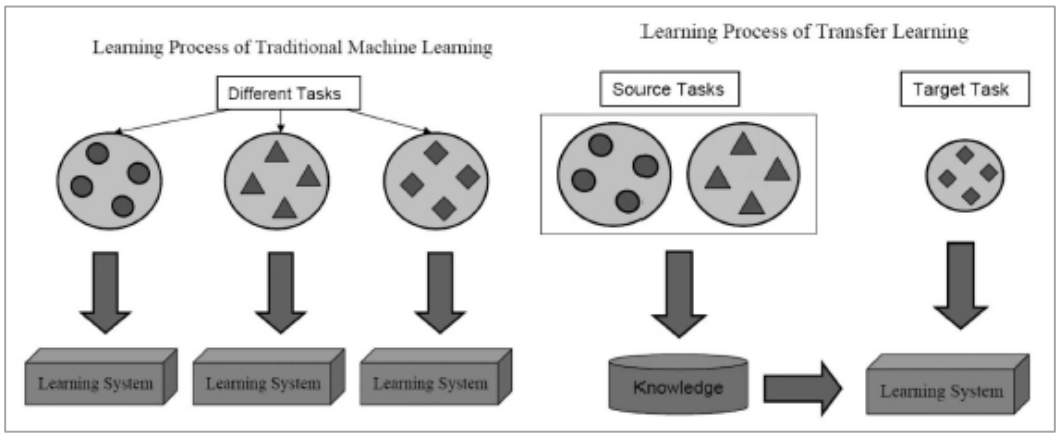

Figure 2.14: Differences between Traditional Machine Learning and Transfer Learning (Pan & Yang, 2010)

Convolutional Neural Network (CNN) is a deep learning model capable of processing data with a grid pattern like images. Convolution, pooling, and fully connected layers are the three types of layers used in CNN. Convolution and pooling layers are in charge of extracting the features while the fully connected layers act as a classifier to map the final output to the right classes (Yamashita et al., 2018). CNN can learn the features efficiently due to its parameter sharing and local connectivity characteristics. The feature detector in the CNN shares weights by parameter sharing (Pokharna, 2016). It allows weights that are useful in one part to be used in another part of the image. Local connectivity is where each neuron only connected to a subset of the input images but not fully connected like a neural network (Pokharna, 2016). Local connectivity helps to minimize the number of parameters in the architecture and increase the computation efficiency.

2.4.3 Comparisons between Traditional Machine Learning Approaches and Deep Learning Models

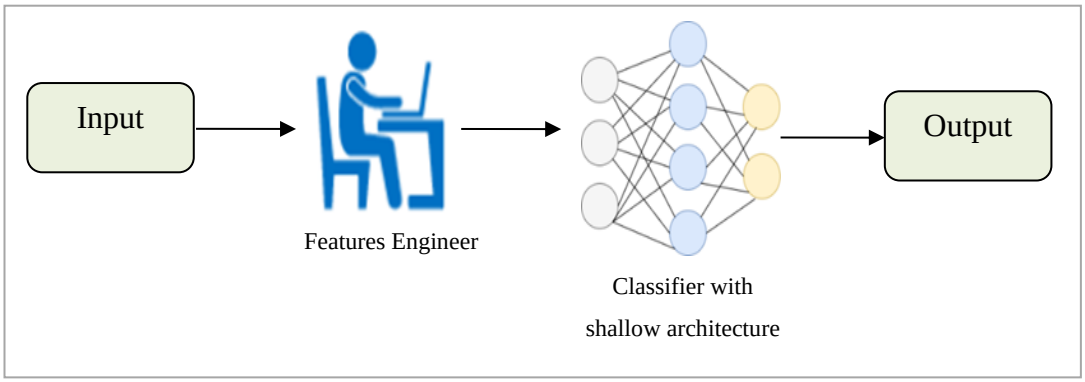

Figure 2.15: Machine Learning Object Recognition

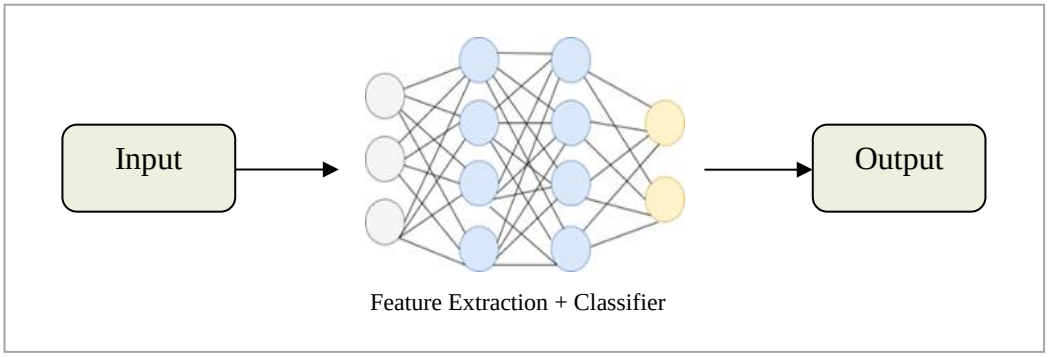

Figure 2.16: Deep Learning Object Recognition

The arrival of the big data era has led to evolution in artificial intelligence industry. The presence of deep learning has provided new opportunities in artificial intelligence areas. The key advantage of deep learning is where it can process massive amounts of data. As the data set increases, the performance of learning increases. However, the performance of traditional machine learning approaches cannot be improved as data increases. Machine learning methods require domain experts to figure out the features and recognise the patterns in images before feeding them into training algorithms. Deep learning methods remove the feature extraction by domain expertise. It consists of a "deep" number of layers to process a large number of data incrementally.

The deep learning technique comes out with an end-to-end model to train all the data by itself. Machine learning needs to reduce the problems into a simpler problem. The experts will analyse each of the components to get the final solutions. Moreover, deep learning requires a longer time to train as the model architecture is huge and complex. High computational power such as GPU is preferred to run the deep learning models. Despite the disadvantages in training time, deep learning models provide high accuracy results compared to the traditional machine learning models. In conclusion, deep learning really surpasses object recognition with its power in processing big data and high accuracy performances.

2.5 VGG-16

In the paper "Very Deep Convolutional Networks for Large-Scale Image Recognition", Simonyan and Zisserman presented VGG-16 in 2014. This pre-trained model is named VGG-16 as it has 16 layers, which contains trainable weights (Thakur, 2019). It has 138,357,544 trainable parameters. The Characteristic of VGG-16 is the fixed kernel size. Convolutional kernels are 3x3 with a stride of one, while maxpool kernels are 2x2 with a stride of two (Simonyan & Zisserman, 2015). VGG-16 accomplished a 92.7% in top-5 test accuracy for the ImageNet data set (Simonyan & Zisserman, 2015).

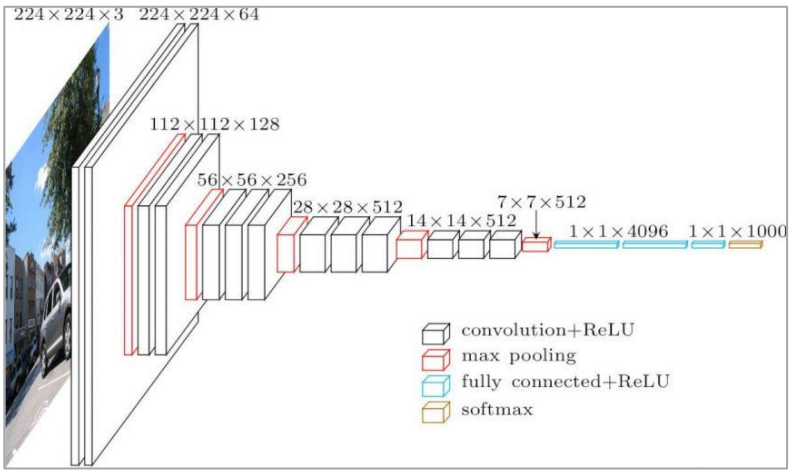

Figure 2.17: VGG-16 Architecture (Hassan, 2018)

The first layer of VGG-16 is a convolution layer with an input size of 224 x 224 RBG image. There are two or three layers of convolution followed by a max pooling layer. It follows this arrangement for the whole architecture. Then, there are three fully connected layers, including a prediction layer which is a softmax activation layer for 1000 classes. Rectification (ReLu) is used as the activation for the Conv layers and the fully connected layers.

2.6 ResNet-50

He et al. introduced ResNet-50 as a convolutional neural network in their paper "Deep Residual Learning for Image Recognition" in 2015. It can be named residual learning. ResNet achieved the top-5 error rate of 3.57 and won the 1st prize in the ILSVRC 2015 classification competition. ResNet-50 has 50 layers with trainable weights. When a convolutional neural network goes deeper and deeper to extract features and fits in more data, a vanishing gradient problem will happen. The vanishing gradient problem causes the gradient of loss function to approach zero. Thus, model training is difficult to continue. ResNet-50 can skip one or more layers in the connections of the model to solve the vanishing gradient problem (He et al., 2016). A residual block shown in Figure 2.18 illustrates how ResNet can skip the layers to feed the subsequent layer directly.

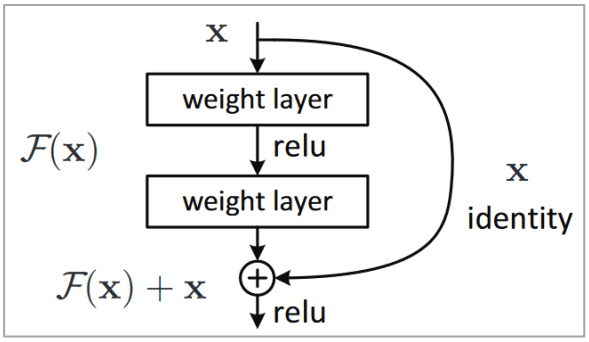

Figure 2.18: Residual Block (He et al., 2016)

A residual block contains identity mapping, which can skip the connections. Sometimes, input (x) and output (F(x)) will not have the same dimensions. Thus, He et al. proposed two related equations in their paper "Deep Residual Learning for Image Recognition" in 2015.

Table 2.7: Equations for Identity Mapping

Equation 1	Equation 2
y = F(x, {Wi}) + x.	y = F(x, {Wi}) + Wsx

Where

x = input

y = output

F(x, {Wi}) = residual mapping to be learned

Ws = linear projection

Equation 1 is implemented when the input and output dimensions are the same. When input and output dimensions are different, Equation 2 can be implemented. As stated in the "Deep Residual Learning for Image Recognition" paper, there are two ways to address different input and output dimensions issues: (1) Increase the dimensions with an extra zero padding on the skip connection; (2) Add a 1x1 convolutional layer as the projection shortcut (Ws) to match the dimensions. No additional parameters are added in the method (1).

With its skip connections characteristics, ResNet (Residual Network) allows for the training of highly deep neural networks. ResNet-152 is a version of ResNet that

can train up to 152 layers (He et al., 2016). In this project, ResNet-50, which is the smaller version of ResNet-152, are implemented and investigated on its performances.

2.7 Inception-v3

Inception-v3 is a convolutional neural network model that was introduced by Szegedy et al. in their paper "Rethinking the Inception Architecture for Computer Vision" and won 1st runner up in ILSVRC 2015. Inception-v3 consists of 48 layers. Each Inception-v3 module consists of four operation types in parallel, which are 1x1, 3x3 and 5x5 convolution layer, and max pooling layer. Common features can be captured by a 5x5 convolution layer, while area-specific features can be captured by a 3x3 convolution layer. Multiple kernel sizes are implemented to capture more complete features from the images. In the paper, a few optimization ideas are presented to scale up convolutional network efficiently. The optimizer ideas covered are factorization convolutions, auxiliary classifiers, efficient grid size reduction, and model regularization via label smoothing. The study on each optimizer is discussed below.

a) Factorizing Convolutions with Large Filter Size

Factorizing convolutions focus on reducing the number of parameters and the computational cost without affecting the network efficiency. Factorization techniques proposed by Szegedy et al. (2015) are factorization one 5 x 5 convolution into two 3 x 3 convolutions and factorization of one n x n convolution into two convolutions with 1 x n and n x 1 size respectively. Besides, another inception module is proposed where 1 x 1 convolution is expanded to promote high dimensional representations. The inception modules formed by the factorizations mentioned are illustrated in Figure 2.19.

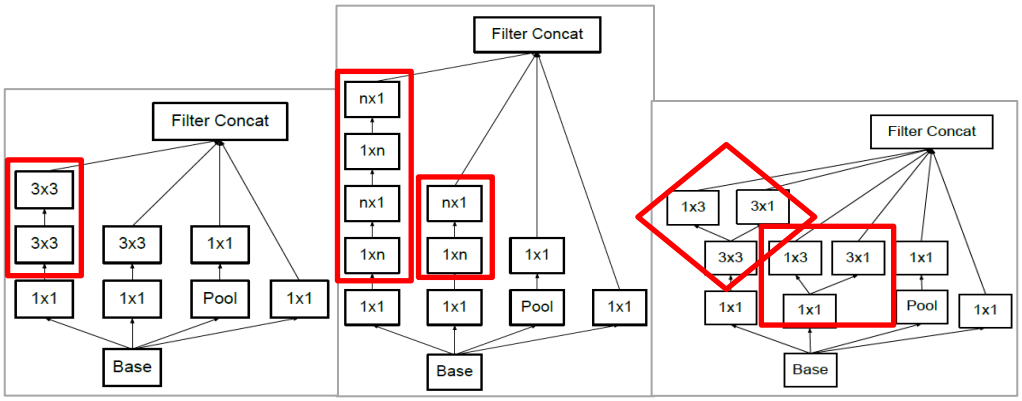

Figure 2.19: Inception Modules (Szegedy et al., 2016a)

b) Auxiliary classifiers

An auxiliary classifier is used in Inception-v1 to enhance the convergence of deep networks (Szegedy et al., 2015). However, an auxiliary classifier is recommended to act as regularization in Inception-v3 as it did not show significant improvements in the training of deep network (Szegedy et al., 2016b).

c) Efficient grid size reduction

Traditional convolutional networks used pooling operation to reduce grid size of feature maps. Due to the high cost of convolutions, Szegedy et al. (2015) proposed a grid size reduction approach that uses convolution with stride 2 and max pooling to create 320 feature maps. To proceed to the next inception module, the two 320 feature maps are combined to create 640 feature maps.

d) Model regularization via label smoothing

Label smoothing allows the model trained to be less confident as it supports small logit gaps. It is used when the loss function is cross entropy and softmax function is applied to the penultimate layer's logit vector z for computing probabilities p as output (Wanshun, 2019).

Inception-v3 aims to fasten the computation process to increase training efficiency by the optimizers proposed. It is used intensively in image classification and video processing. Thus, Inception-v3 is chosen to be investigated in this project for medical equipment recognition.

2.8 TensorFlow Lite

TensorFlow Lite is a set of tools to assist developers to execute TensorFlow models on mobile, embedded, and IoT devices (*TensorFlow Lite Guide*, 2020). The TensorFlow Lite translator and TensorFlow converter are the two key components of TensorFlow Lite. Before running the TensorFlow models on hardware, the TensorFlow Lite converter will convert TensorFlow models into an efficient and more suitable form by optimizing them to improve binary size and performance. Specially optimized models can be run by TensorFlow Lite interpreter on hardware including mobile phones, embedded Linux devices, and microcontrollers.

TensorFlow Lite is used to implement machine learning on devices. It is a pre-trained model for performing use cases like image classification, object detection, text

classification, face recognition, etc. (*TensorFlow Lite Examples | Machine Learning Mobile Apps*, 2020). Pre-trained models can be further customized based on the project specifications. TensorFlow Lite consists of APIs for various languages such as Java, Swift, C++, Python and Objective-C. Besides, there is TensorFlow.js which is a library to be used in JavaScript. For example, it can integrate with mobile app implementing a react-native framework.

According to the TensorFlow Lite guide (2020), an official documentation for TensorFlow Lite, workflows for using TensorFlow Lite are listed below.

1. Picks a model from pre-trained models.
2. Convert the custom model into TensorFlow Lite format.
3. Deploy to the mobile application using the TensorFlow Lite interpreter with APIs in the language used.
4. Optimize the model to reduce the model's size.
5. Improve the efficiency using the model optimization toolkit.

2.9 Frontend Frameworks

Flutter and React Native are discussed in this section. Both frameworks are free and open source. They are a cross-platform mobile application development framework that can be implemented using Android Studio. However, Flutter and React Native are different in some ways. Differences between them will be explained in this section too.

2.9.1 Flutter

Flutter is an open-source mobile UI framework for free. Google launched Flutter in May 2017. It allows the development of a native mobile app with only one codebase in the android and IOS platform. Flutter is made up of two components: a software development kit (SDK) and a framework for UI library based on widgets. The programming language for Flutter is Dart. Flutter focuses on front-end development.

2.9.2 React Native

React Native is a free and open-source cross-platform mobile application development framework. It is older and has a larger community compared to Flutter. Facebook created React Native in 2015. JavaScript is used as the base language for React Native. React Native is heavily dependent on third-party libraries and modules. Only UI rendering and device access modules are provided to the developer.

2.9.3 Comparison between Frameworks

Table 2.8: Flutter and React Native Comparison (Jagtap, 2019)

	Flutter	**React-Native**
Created by	Google	Facebook
Year launched	May 2017	2015
Programming Language	Dart	JavaScript
Installation	Installation requires extra steps (E.g., setting of paths)	Installed easily via NPM
User Interface	Rich in components	Less components
Documentation	Organized and detailed Flutter Documentation	Lacking React-Native Documentation
Community	Smaller	Bigger
Testing	More unit, widget, and integration level testing features.	Few unit testing frameworks

According to Jagtap (2019), although Dart is a new language introduced by Google, it is considered easy to learn if the developer experienced in object-oriented programming. With official documentation by Flutter, it can be learned easily. Flutter is using JavaScript as the fundamental language. If the developer is very familiar with web development in HTML, CSS, and JavaScript, React Native is easy for them to learn in a short period of time. Installation of Flutter can be done by following the official documentation with an extra setting up of path variable, while React Native can be installed through NPM in command prompt.

Flutter is better in detailed and well-structured documentation that is friendly to beginner. It guides the user through a command line-based tool called Flutter Doctor. Flutter Doctor shows the installation progress to the user in terms of what has installed and what has not. However, React Native lacks in the documentation. Developers need to figure out the information by themselves. Flutter has rich features and API components, including device API access, UI rendering components, stateful management, navigation, testing and other useful libraries (*Flutter - Beautiful Native*

Apps in Record Time, 2020). React Native is heavily dependent on third-party libraries and modules. Only UI rendering and device access modules are provided to the developer.

As React Native is older than Flutter, the community is larger for React Native (Lawton, 2020). More resources can be found for React Native. When it comes to fixing the bugs and errors, the developer's life is easier as helps can be obtained from the community. Testing is essential in delivering a quality software product. In this case, Flutter has more testing modules that can be used in the unit, widget, and integration testing. React Native only provides limited unit testing through JavaScript frameworks. React Native depends on third-party applications like Appium for in-depth testing of software.

In conclusion, Flutter and React Native have their pros and cons. Sometimes, it is just up to the developer's preferences and experiences. Flutter will be implemented in this project due to its high performance, amazing UI features and single codebase.

2.10 System Usability Scale (SUS)

System usability scale (SUS) is a measuring tool to evaluate the usability level of a variety of applications (*System Usability Scale (SUS) | Usability.Gov*, n.d.). It was designed by John Broke in 1986. There are 10 questions in the user satisfaction form. The respondents are given 5 options from strongly disagree to strongly agree. Each of the questions will be mapped to a category of evaluation. Usability, complexity, ease of use, learnability, navigability, consistency and satisfaction are the key components for evaluation. To calculate scores, scores from strongly disagree to strongly agree are converted from 1 to 5. Then, the score will be subtracted by 1. All the scores will be added together. To convert the scores from 0-40 to 0-100, scores are multiplied by 2.5. A system that gets above 68 SUS scores will be considered above average (*System Usability Scale (SUS) | Usability.Gov*, n.d.).

CHAPTER 3

SYSTEM METHODOLOGY

3.1 Introduction

The methodology implemented in this project is evolutionary prototyping. Activities in each phase are outlined and discussed in this chapter. The phases in the methodology are project initiation, iteration, including design, prototyping, customer evaluation and review, and updating, development, testing and maintaining. Besides, the workflows of the medical equipment recognition are discussed in this chapter.

3.2 Project Initiation

To initiate this project, requirements gathering is the first step to gather information from targeted users. Methods used for requirement gathering are qualitative and quantitative. Background study on medical equipment that can be donated and reused is carried out. Literature review on similar application, software methodologies, frameworks and object recognition approaches are conducted. After understanding the background, requirements are gathered from NGOs, medical centres and the public. Use case modelling such as use case diagram and use case descriptions are designed to illustrate real life scenarios in stakeholders' view. Gantt chart and Work breakdown structure are used to control the project schedules completed within the timeframe and scope.

3.2.1 Requirements Gathering

Qualitative and quantitative methodologies are used to gather data from the targeted users. The literature review is used to gather information on medicine, medical supplies and equipment.

3.2.1.1 Qualitative Methodology

Qualitative methodology collects data that are non-numerical, including text, video or audio to analyse the requirements. The approach used in this project is interview.

Interview

Person in charge of the related department for medical items donation in NGOs and medical centres are interviewed. As the NGOs and medical centres have different approaches and procedures in collecting medical items from the public, both entities are interviewed to get more accurate requirements.

3.2.1.2 Quantitative Methodology

The quantitative method is an approach to collect data in numerical form for analysing the needs of targeted users (Muijs, 2010). The quantitative method helps to evaluate the data collected statistically. The approaches used in quantitative methodology is a questionnaire.

Questionnaire

Questionnaires containing a combination of 16 open-ended and closed-ended questions are sent out to a minimum of 30 respondents. The questionnaire is divided into 3 sections, including demographic data, awareness level on medical waste and feature's ideas for the app. The division of questions into sections aims to capture the data in an organised way. The 16 questions are made up of 5 opened-ended questions, 11 closed-ended questions, which are 2 scale questions and 9 multiple choice questions.

3.2.1.3 Literature Review

The literature review is conducted to review and evaluate the similar mobile application. Features and user interfaces are studied to identify the important features to be included in this project. Furthermore, software development methodologies such as a waterfall model, agile methodology, prototyping and spiral model are analysed. A software development methodology comparison matrix table is generated for these 4 methodologies. The pros and cons of each software methodology are reviewed. Software development methodology for this project is selected based on this project nature and software development methodology comparison matrix table.

As object recognition to recognise medical equipment will be implemented in this project, approaches for object recognition and TensorFlow Lite (machine learning framework) are studied. Traditional machine learning approaches and deep learning approaches are compared and contrasted for object recognition. For example,

workflows on executing TensorFlow Lite for mobile app. In addition, frameworks such as Flutter and React-Native are compared in the literature review section in terms of programming language, installations, user interface components, community, documentation and testing.

3.2.1.4 Use Case Modelling

After identifying the functional and non-functional requirements from requirements gathered, use case modelling techniques are used to represent the interactions between the system and the stakeholders. Use case diagram provides an overview and illustration of the functionalities of the system. Use case description is produced to describe details of each use case.

3.2.2 Project Plan

In the project plan, project schedules and scope are specified using Gantt chart and Work breakdown structure to ensure the project is completed within duration given and scope determined.

3.2.3 Work Breakdown Structure

Work breakdown structure is used to demonstrate each phase deliverables into smaller tasks with details. It breaks the deliverables into levels. Refer to Appendix C.

3.2.4 Gantt Chart

Gantt chart is utilized to outline the tasks involved in each phase of evolutionary prototyping with duration. It is used to track the project progress. Gantt chart is updated if any changes in the progress of the tasks. Refer to Appendix D.

3.3 Quick Design

After gathering the initial requirements from the targeted users, a quick design is carried out. A prototype is built by Axure RP 9. This prototype will demonstrate the storyboards and flows of interaction between user and system. The user interfaces are designed to get an overview of how the mobile app's screens should look like. Dynamic panels are used to link the interfaces to produce a responsive prototype for

customers to interact with in Axure RP 9. The main design and concepts are shown in this prototype.

3.4 Iteration

There are four stages: design, prototyping, customer's evaluation and review and modification in each iteration. Each iteration is repeated until the satisfying final product is produced.

3.4.1 First Iteration

Based on data collected in the early stage and the prototype built by Axure RP 9 in quick design phase, important features for this project are included in the first iteration.

i. Design

A draft of user interface for features and screen flows of the app are designed before developing the prototype. The activity diagram, design class diagram and DFD diagram for the features will be illustrated.

ii. Prototyping

The Front-end and back-end of the mobile application are built for the features in the first iteration. User interfaces of the mobile application are developed by referring to the prototype in quick the design phase. The database is designed based on the Data Flow diagram created in the design phase.

iii. Customer evaluation

Five potential users with medical background will test the prototype.

iv. Review

After customer evaluations, feedbacks are gathered and analysed by the developer to refine and improve the prototype. Then, the Second iteration begins.

3.4.2 Second iteration and third iteration

After reviewing the prototype in the first iteration, changes are made, and features are added in the second iteration.

i. Design

The design of the user interfaces will be drafted out for features needed in the iteration. The activity diagram, design class diagram and DFD diagram for the features will be illustrated.

ii. Prototyping

The developer will program the mobile application using the development tools. User interfaces of the mobile application are developed by referring to the prototype in the previous iteration and design phase. More data are added to the database according to the DFD diagram.

iii. Customer evaluation

Five potential users with medical background will test the prototype.

iv. Review

After customer evaluations, feedbacks are gathered and analysed by the developer to refine and improve the prototype. The next iteration started until the final product is satisfied by customers.

3.5 Development

After a few iterations to produce the best prototype, the development phase is started. Tools used to develop the mobile application are Flutter, Android Studio, Visual Studio Code, Firebase, Axure RP 9 and git as the version control system.

3.5.1 Front-End

Flutter framework is used to build user interfaces for this project. Widgets provided by Flutter will be utilized to build an attractive and user-friendly interface. An emulator in the android studio is used to demonstrate the app. Visual Studio Code is used as a code editor.

3.5.2 Backend

Firebase is chosen for its firestore as the database of this mobile app, firebase functions for the API, firebase authentication for authentication of the users, and firebase messaging for the notification. Firebase is a powerful backend-as-a-Solution (BaaS). Firebase was introduced by Google in 2014. Firebase is a NoSQL database that provides a synchronization function. It can synchronize data with a real-time database. When there are any changes in data, the firestore will update the collections

immediately. Documentation for firebase is clear and organized, which guide the developer to implement the database in the mobile application quick.

3.6 Testing

The testing processes such as unit testing, usability testing and user acceptance testing are performed.

3.6.1 Unit Testing

Unit test tests a single component or function in each module in the application. The test cases are prepared before developing the unit test codes. In the test cases, data, a description, predicted results are included. The results of the unit test, either pass or fail, will be recorded in the test cases report.

3.6.2 User Acceptance Testing

User acceptance testing is performed by end-users and clients to verify the requirements. 5 users with medical background from the public are chosen to carry out the test.

3.6.3 Usability Testing

The aim of usability testing is to determine whether the system meets the user's goal and expectations. 5 users with medical background from the public are chosen to carry out the test. The duration to complete each task for a scenario will be recorded. System usability scale (SUS) technique is used to measure usability (*System Usability Scale (SUS) | Usability.Gov*, n.d.). It was created by John Brooke in 1986. An evaluation form will be distributed to the testers after the test completed to fill up their opinions and suggestions.

3.7 Deployment

After all the tests are completed, a final report is produced to record down all the details of workflow in this project. The codes are built and release for production in APK format.

3.8 Medical Equipment Recognition Workflows

In this project, three deep learning models, i.e., Inception-v3, ResNet-50, and VGG-16 are trained using transfer learning technique to recognise 10 medical equipment. They are commode, wheelchairs, walking frame, blood pressure set, breast pump, thermometer, rippled mattress, oximeter, crutch, and therapeutic ultrasound machine. Transfer learning is a time saving and cost saving machine learning technique. Transfer learning is also a great choice when the data set is small. Instead of starting everything by scratch, transfer learning provides an alternative that learns previous patterns using a pre-trained model. A large data set is used to train the model to overcome the similar problem. It helps to extract low level features. There are various pre-trained models for transfer learning, such as VGG-16, ResNet-50, and Inception V3. The pre-trained models are built based on convolutional neural networks (CNN). CNN is a form of neural network. It usually applies to image related problems. After extracting the low-level features, a classifier is built on top of the pre-trained model to create a final model. Lastly, predictions are made. The three models are fine-tuned by a grid search method to find the best combination of hyperparameters. Hyperparameters tuning uses testing images from the same distribution. After hyperparameters tuning, the models are tested with photos uploaded by users to get the testing accuracies. The workflows of the object recognition can be illustrated in Figure 3.1.

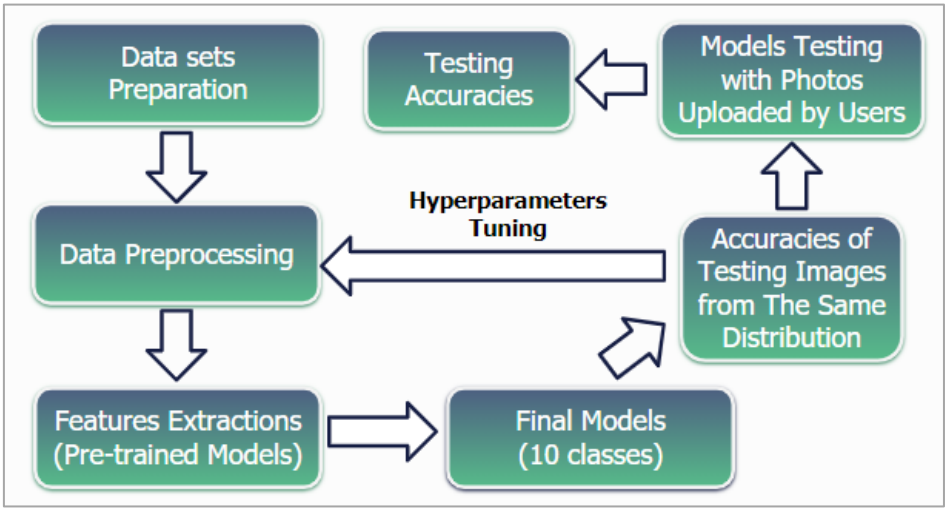

Figure 3.1: Object Recognition Workflow Summary

3.8.1 Cross Validation

A stratified K-fold cross validation method is used for splitting the data set into a train set and test set. It is suitable for a small data sample. First, shuffle the data set randomly. Then, split the data set into k folds. The K number used is 5. One of the folds is used as the test set. The remaining will be the train set. The process is repeated until all the folds have once become the test set.

3.8.2 Data set

Images data sets for training and testing are prepared by collecting 10 medical equipment images from various online resources. Data augmentation are carried out to increase the number of images for training purpose. New data set can be created to improve the performance of the deep learning model.

3.8.3 Data Pre-processing

The data sets are processed by converting from RGB to BGR. At first, the data pixel values are in the range of [0, 255]. To fit the data to the model with expected pixel values in the range of [-1, 1], a prepressing method is imported from Keras according to the pre-trained model to rescale the pixel values.

3.8.4 Low Level Features Extraction

After collecting the data set, a pre-trained model is chosen. Three pre-trained models VGG-16 (Simonyan & Zisserman, 2015), ResNet-50, and InceptionV3 (Szegedy et al., 2016b) are selected in this project. A comparison between the models is carried out. The models are available in Keras. The models can be imported from the Keras framework. To train the pre-trained model, there are several ways to train it, including train the whole model, train a few layers and freeze others, and freeze the entire pre-trained model. Figure 3.2 and Figure 3.3 show the relationship between data set size and the fine-tuning decision for the pre-trained model (Marcelino, 2018), the choices are affected by the size of data set. If the data set is small and the problem is similar to the data set trained in the pre-trained model, freezing the entire pre-trained model is allowed. Thus, before classifying the problem based on the data set size, data set trained on the pre-trained model needs to be identified. In other words, weights for the pre-trained model need to be selected.

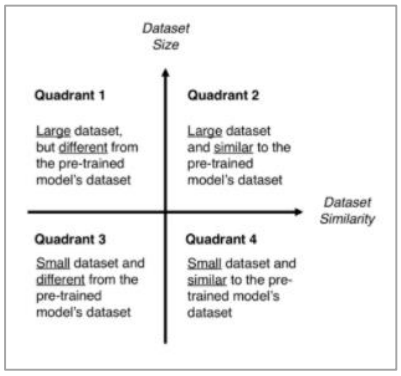

Figure 3.2: Data Set Size Similarity Matrix

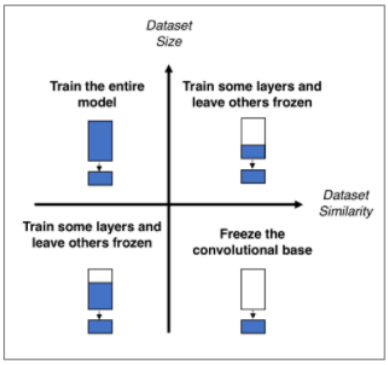

Figure 3.3: Pre-trained Model Fine-tuning

After researching the available data set, ImageNet is selected for the weights used in the pre-trained model. ImageNet is a huge data set made up of 14 million images from a variety of category (Devopedia, 2019). According to the ImageNet website, the ImageNet database contains images of wheelchairs, walking frames, thermometers, etc. (Stanford Vision Lab, 2010). It is suitable to be used as the weights in the pre-trained model to extract low-level features. Then, by referring to Figure 3.1 and Figure 3.2 diagrams, quadrant 4 is chosen as the size of the data set for medical equipment available is small and the data set's similarity with ImageNet is high.

3.8.5 Final Models

The last step is to create a classifying layer on top of the pre-trained model to create a final model for predictions. To flatten the neurons at the end of the pre-trained model to become the number of classes for predictions, global average pooling layer is added. Besides, a dense layer together with softmax activation is applied to convert the features into a single prediction. A softmax activation function is needed as classes for prediction are more than two classes. 10 classes will be predicted by the model. Accuracies of training and testing of images from the same distribution are recorded.

3.8.6 Optimizers

Optimizer is the commonly used algorithm in the neural network to reduce losses during training (Doshi, 2019). It changes the weights (parameters) of the model during training to optimize the model to increase the accuracy. In this project, various optimizers are applied, such as Adam and SGD in order to get better results. Learning rate for the optimizers will be fine-tuned using a grid search method. A Dropout

method is also used in the last layer of deep learning models to reduce the overfitting issue.

3.8.7 Grid Search

The data can be divided into several batches for few epochs. Batch size refers to the number of training data in an iteration. The batch size used in the model is 16 and 32. Besides, an epoch is the number of passes for the whole training process to complete. More than one epoch is required to optimize the training using optimizers to update the weights for the next epoch. The epoch size used in this model is 1 and 6. The combination of batch size, number of epochs, optimizers and learning rate are concluded from the grid search results.

3.8.8 GPUs

The codes are run on the Kaggle.com platform. An accelerator, which is Graphical Processing Unit-based (GPU), is selected to run the codes. GPU can run the tasks faster than Central Processing Unit (CPU). GPU is very useful, especially the execution of grid search to find the best combination of hyperparameters. For example, it took 3s to run an epoch compared to 180s for running on CPU.

3.9 Algorithm

The algorithm below shows the steps of training the model.

1. Read the medical equipment data set, med_equip_data that consists of x classes
2. Define a set of hyperparameters optimizer, batch_size, num_epochs, dropout_rate, and learn_rate.
3. Define number of K-fold and shuffle mode
4. For each K-fold
    a. Split med_equip_data to train set and test set
    b. Assign a pre-trained model to base_model //pre-trained model can be VGG-16, ResNet-50, and Inception-v3
    c. Freeze base_model weights
    d. Add a new layer on top of base_model
    e. Perform data augmentation on med_equip_data and assign it as new_med_equip_data
    f. Preprocess new_med_equip_data
    g. Add a dropout rate to the new layer
    h. Compile the base_model with sparse_categorial_crossentropy (loss), optimizer, learn_rate, and sparse_categorical_accuracy (metrics)
    i. Create checkpoint to save the best model to .h5 file
    j. Fit the base_model with train set, batch_size, num_epochs
    k. Evaluate the model with test set

l. Print training and testing accuracies
m. Plot graphs for training and testing accuracies
5. End for

CHAPTER 4

PROJECT INITIAL SPECIFICATION

4.1 Introduction

In this chapter, the analysis of data collected is discussed. Functional and non-functional requirements in this project are illustrated and explained. Moreover, the use case diagram and use case description are included.

4.2 Facts Findings

Questionnaires are distributed to 47 public respondents. Three interviews are conducted with Hospis Malaysia, True Pharmacy and Klinik Kesihatan Bandar Botanic Klang. The analysis of results will be discussed in the following section. The questionnaire and interview questions are attached in Appendix A and B.

4.2.1 Questionnaire

Google form links are sent out to the public. A total of 47 respondents answered the google form. A total of 16 questions with the combination of open-ended and closed-ended questions are included in the google form. The respondents are mainly students with age between 19 to 30 years old. Summaries of the significant results are discussed below:

a) Awareness level on medical waste

1. Number of people aware of the donation of unused medical items

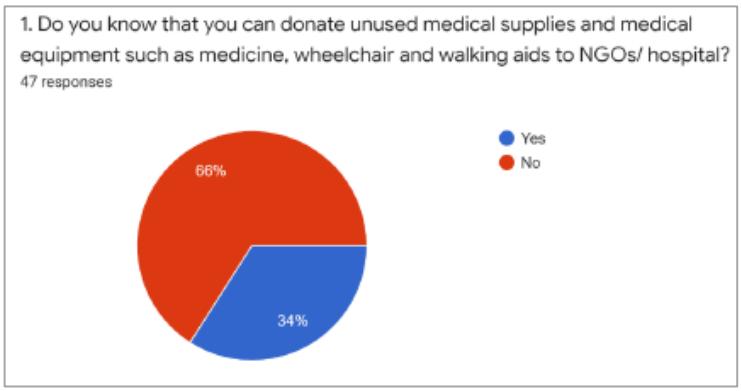

Figure 4.1: Number of people aware of the donation of unused medical items

More than half of the respondents (66%) do not realize the donation of unused medical items to NGOs/medical centres. It shows a very low awareness level among the public in recycling medical items.

2. **Knowledge of medical items that can be donated**

Extend from the previous question, people who knew the existence of donation of unused medical items had provided the medical items' name that can be donated which are mask, wheelchairs, gloves, medicine, pump, walking aids, crutches, aseptic dressing set and unused wound care supplies. This question aims to get more ideas on what medical items that can be included for donation in this project.

b) Features ideas for an unused medical equipment donation app

1. Features to be included in this app

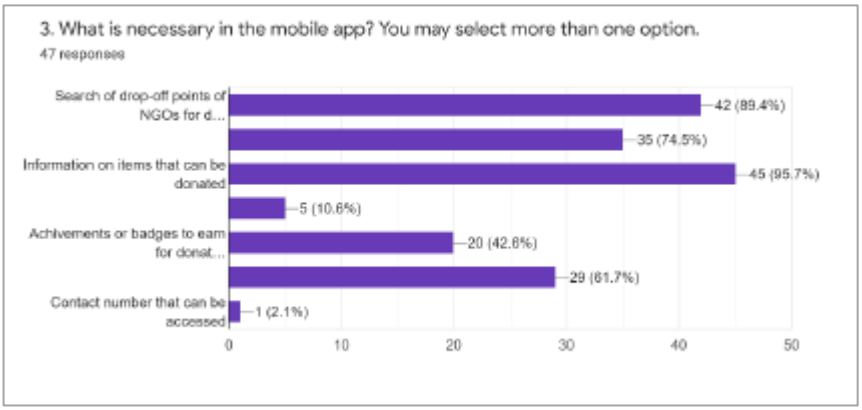

Figure 4.2: Features to be included in this app

Referring to Figure 4.6, the three highest percentage features are search of drop-off points of NGOs/medical centres, information on the items that can be donated and the chat engine for NGOs/medical centres and public users to communicate. These three features are important and should be implemented in this project.

2. Additional suggestions on the features

Summaries of the suggestions are listed below:

- Simple and informative
- Knowledge on how to differentiate the conditions of the medical items
- Customer service to guide the users on the app's operation
- User interfaces are user friendly to the older senior citizen
- Share to the social media
- Show a list of medical items that are in need by NGOs

As the targeted users might be old senior citizens who often consume medicines, the user interfaces must be attractive and easy to learn. The information on medical equipment feature will be included in this project. Share on social media is taken into consideration. Moreover, request of medical equipment in shortage will be implemented in this project as well as it is suggested feature concluded in the literature review on similar apps.

4.2.2 Interview

Three interviews are carried out with an NGO (Hospis Malaysia), one clinic (Klinik Bandar Botanic Klang) and one pharmacy (True Pharmacy).

a) Hospis Malaysia

Hospis Malaysia is a charitable organization that provides professional community palliative care service to those patients with life-limiting illnesses, including cancer, organ failure, AIDS, etc. In the interview with Hospis Malaysia, they will accept used medical equipment that are still in good and working condition. Examples of medical equipment they collect are wheelchairs, hospital beds, rippled mattress and commode. They also accept adult diapers and meal replacement nutrition drinks.

Hospis Malaysia faced issues when collecting items as they do not have a transport service. Donors must deliver the medical equipment to their centre. Hospis Malaysia shared about how a donor can donate the medical items and verification of medical items. The process starts with a donor calls their centre to enquire if they need the equipment that they intend to donate. Hospis Malaysia requires information pertaining to the condition of medical equipment to ensure it is still in safe and good working condition. If donated equipment meets the necessary standard of requirement, the donor will arrange for transportation and confirms the delivery date and time to their centre.

The medical equipment donated by the public will be lent to their patients. Equipment will be returned back to them by the patients' caregiver when the patient does not require it anymore or passes away. For adult diapers and other consumable items, they will give to patients who need them and cannot afford to buy them. Hospis Malaysia suggested features as follows:

i. List of items public want to donate
ii. Current condition state of medical items
iii. Feature for the public to upload photos of items
iv. Donors' details for NGO to follow up with official TQ letters
v. Provide a list of transporters by location for donors to arrange delivery

From the data collected from Hospis Malaysia, verification of medical items can be carried out in the app by photos and details of the condition state by the public. A list of medical items the public want to donate must be included for NGO to view and verify them. Official TQ letters can be considered to include in the chat engine feature to allow NGOs to show appreciation to the public. Delivery date and time from the public to NGO can be added in arrange appointment feature. Overall, the data Hospis Malaysia provided allows a better understanding of the flows of donation. Suggested features are taken into consideration to make the app better.

b) Klinik Bandar Botanic Klang

In the interview with Aina, assistant pharmacy in the clinic, the patient will return the leftover medical items to the clinic themselves. There are yellow bins in the clinic which used to collect unused medicine from the public. For the face mask or face shields, the public usually donates them to the representative of the clinic. All the medicine collected will be sent to a waste management company for disposal. The clinic accepts Mbi pump for the donation. Mbi pump will be reused or sold out.

From the interview, the medicine collected is disposed rather than reuse. Only non-medicine such as pump, face masks and face shield are reused or sold out to the public.

c) True Pharmacy

In the interview with Ms Tan, a pharmacist working in True Pharmacy, medicines are dangerous to be reused. Most of the time, the hospital will dispose them rather than reused them as they do not know how the donors keep the medicines. Medical items that are more suitable for donation are medical supplies and equipment that are not consumable. Moreover, the list of reusable medical items can be obtained from Kementerian Kesihatan Malaysia (KKM). The biggest problem now is most of people do not have a good awareness of waste medical items. They throw away the leftover medical items. The mentality of the people can cause this app very hard to be launched in the future. Some medicines' expiry date is blurry. Photos might not be able to capture the expiry date. Thus, she gave some suggestions to improve the app.

True Pharmacy suggested making the app as interactive as possible. For example, the public can request items they need as well. Not only NGOs and medical centres can raise the request. The app should be able to gather the people to use the app. Therefore, an interactive app is a must. Features that can be included are pick up service, request from the public on certain items such as healthy drinks, pampers and milk and verification of medical items. True Pharmacy stated that she thinks the pickup service feature is the best as compared to delivery or drop off as it is the most convenient. Some medical items, such as hospital bed and wheelchair, are very heavy. The donor might not be able to carry or transport it.

To commercialise the app, money concern in this project is highlighted by her. She gave me the Facebook account of Uncle Kentang and William Cheah. They are prominent figure who put a lot of efforts into helping the community, especially the poor. She highly encouraged me to contact them if I want to launch the app in the future to get different ideas and get funding from them.

In conclusion, besides medical items, other food supplies can be added to the donated items' scope. Chat engine is an important feature to allow interaction between NGOs/medical centre and the public. Pickup service will be included in this project. Problems such as the blurry expiry date need to be

taken note of. Creativity is very important to deliver the app to attract more users.

4.3 Requirements Specification

4.3.1 Functional Requirements

The functional requirements are listed based on the entities (NGO/medical centre, member, and admin).

A. NGO/ Medical Centre

1. A user shall be able to login to his account using email and password.
2. A user shall be able to sign up to his account using his organization's name, contact number, email, address, open hours, working days and organization's license.
3. A user shall be able to verify medical equipment members wish to donate by the details of medical equipment uploaded by members.
4. A user shall be able to publish medical equipment in shortage request.
5. A user shall be able to arrange an appointment with a member for pickup service.
6. A user shall be able to view donation history such as donated items' details, date and time received from members.
7. A user shall be able to communicate with members in the chat box by sending text messages.

B. Member

1. A member shall be able to log in using email and password.
2. A member shall be able to sign up using email, username, and password.
3. A member shall be able to register medical equipment he wishes to donate.
4. A member shall be able to view the registration of medical equipment.
5. A member shall be able to donate medical equipment registered after verification of medical equipment condition.
6. A member shall be able to select the NGO or medical centre to donate medical equipment.
7. A member shall be able to request a pickup service.

8. A member shall be able to make an appointment with NGOs or medical centres.
9. A member shall be able to view appointments made with NGOs or medical centre.
10. A member shall be able to search the nearest drop-off points of NGOs or medical centre.
11. A member shall be able to view information on medical equipment's knowledge.
12. A member shall be able to send message to NGOs and medical centre via chat box.
13. A member shall be able to view donation history with details such as donated items, date, time and NGO or medical centre.
14. A member shall be able to share the donation to social media such as Facebook, Instagram and WhatsApp.

C. Admin

1. An admin shall be able to log in using email and password.
2. An admin shall be able to verify NGOs or medical centre account.
3. An admin shall be able to view monthly reports of medical equipment donated from members to NGOs or medical centre.

4.3.2 Non-Functional Requirement

1. The system shall be operated for 24 hours per day without any crashing.
2. The system shall allow a user to use the system functions without training.
3. The system shall be able to backup user's data from time to time to prevent any data loss.
4. The system shall be able to send a reminder message to a user on time.
5. The system shall be able to validate user input to prevent incorrect input format by displaying error messages.
6. The system shall be able to respond quick when a user interacts with it.

4.4 Use Case Diagram

Requirements are analysed and presented in the use case diagram. Use case diagram helps to identify functionalities, actors and relationship between use cases and actors. Four actors included in the use case diagram are NGO, medical centre, member and admin. Total 19 use cases are included in the use case diagram.

Figure 4.3: Use case diagram

4.5 Use Case Descriptions

Table 4.1: Login Account Use Case

Use Case Name: Login account	ID: 1	Importance Level: High
Primary Actor: Organization, member, admin	Use Case Type: Details, Essential	
Stakeholders and Interests: Organization - He/she is either NGO or medical centre and wants to access the mobile app. Member – He/she is the end-user of the mobile app and wants to access the mobile app. Admin – wants to access the mobile app.		
Brief Description: Login account use case describes how an end-user log in to the application.		
Trigger: User wants to log in his/her account.		
Relationships: Association: Organization, Member, Admin Include: N/A Extend: Sign up account Generalization: N/A		
Normal Flow of Events: 1. User requests access to the application. 2. User types email and password to access the application. 3. System validates that the user exists in the user database and assigns user's access level. Perform sub flow 3.1 Verification of email and password. Perform exceptional flow 3.2 User is not found. 4. User is successfully authenticated, and access is allowed based on user's access level. Organization, admin and member will log in to their respective account. 5. System displays "Successfully login" message.		
Sub Flows: 3.1 Verification of email and password. 3.1.1 System receives the email and password of user. 3.1.2 System searches the email and password in the database. 3.1.3 System retrieves the user records.		
Alternate/Exceptional Flows: 3.2 User is not found. 3.2.1 System displays "Could not sign in with those credentials" message. 3.2.2 System executes the sign-up account use case.		

Table 4.2: Register Medical Equipment Use Case

Use Case Name: Register medical equipment	ID: 2	Importance Level: High
Primary Actor: Member	Use Case Type: Details, Essential	
Stakeholders and Interests: Member – wants to register medical equipment for donation. Organization – verifies the medical equipment registration.		

Brief Description: Register medical items use case describes how a member can register medical equipment for donation and get verified by organization.
Trigger: Member wants to register medical equipment for donation.
Relationships: Association: Member Include: Verify medical equipment registration Extend: N/A Generalization: N/A
Normal Flow of Events: 1. Member chooses to register medical equipment. 2. Member types in information of medical equipment such as name, duration used, and upload photos of medical equipment. Perform exceptional flow 2.1 Scanning of medical equipment 3. System displays "Medical equipment registered" message. 4. System sends medical equipment registration verification organization. Perform sub flow 4.1 Verification of medical equipment by organization. Perform exceptional flow 4.2 Verification of medical equipment is failed.
Sub Flows: 4.1 Verification of medical equipment by organization. 4.1.1 Organization checks the details of medical equipment. 4.1.2 Organization approves the registration. 4.1.3 System updates the status of registration (success) to member.
Alternate/Exceptional Flows: 2.1 Scanning of medical equipment 2.1.1 Member scans the medical equipment for registration. 2.1.2 System detects the medical equipment's details. 2.1.3 System saves the scanned photo as photo for the medical equipment in the database. 2.1.4 System displays scanned medical equipment's name. 2.1.5 Member types in duration used. 4.1 Verification of medical equipment is failed. 4.1.1 Organization states the reject reasons for the medical equipment registration. 4.1.2 System updates the verification status (rejected) to member. 4.1.3 Use case terminates.

Table 4.3: View Medical Equipment Registered Use Case

Use Case Name: View medical equipment registered	ID: 3	Importance Level: High
Primary Actor: Member	Use Case Type: Details, Essential	
Stakeholders and Interests: Member – wants to view medical equipment registered.		
Brief Description: View medical equipment registered use case describes how a member can view medical equipment list registered.		

Trigger: Member wants to view list of medical equipment registered details.
Relationships: Association: Member Include: N/A Extend: N/A Generalization: N/A
Normal Flow of Events: 1. Member chooses to view the medical equipment registered. 2. System retrieves the medical equipment registered from database. 3. System displays the list of medical equipment registered. 4. Member views the list of medical equipment details.
Sub Flows: N/A
Alternate/Exceptional Flows: N/A

Table 4.4: Donate Medical Equipment Use Case

Use Case Name: Donate medical equipment	ID: 4	Importance Level: High
Primary Actor: Member	Use Case Type: Details, Essential	
Stakeholders and Interests: Member – wants to donate medical equipment.		
Brief Description: Donate medical equipment use case describes how member can donate registered medical equipment to organization.		
Trigger: Member wants to donate medical equipment.		
Relationships: Association: Member Include: Select organization Extend: N/A Generalization: N/A		
Normal Flow of Events: 1. Member chooses to donate medical equipment. 2. Member selects medical equipment from registered medical items list. Perform sub flow 2.1 Search of organization by system. Perform exceptional flow 2.2 Organization record is not found. 3. Member selects organization to donate. 4. Member sends request for donation to the organization. 5. System displays “Donation request sent” message.		
Sub Flows: 2.1 Search of organization by system 2.1.1 System receives the medical equipment details member wants to donate. 2.1.2 System retrieves the organization list records. 2.1.3 System searches the organization available to receive the medical equipment in the database. 2.1.4 System displays the organization if record is found.		

Alternate/Exceptional Flows: 2.2 Organization record is not found. 2.2.2 System displays “No organization available for donation” message. 2.2.3 Use case terminates.

Table 4.5: Request Pickup Service Use Case

Use Case Name: Request pickup service	ID: 5	Importance Level: High
Primary Actor: Member	Use Case Type: Details, Essential	
Stakeholders and Interests: Member – wants to request pickup service for medical equipment donation.		
Brief Description: Request pickup service use case describes how a member can request pickup service from NGO or medical centre.		
Trigger: Member wants to request pickup service.		
Relationships: Association: Member Include: Make appointment Extend: N/A Generalization: N/A		
Normal Flow of Events: 1. Member chooses to request for pickup service to donate medical equipment. 2. Member selects verified medical equipment in the list of verified medical items for donation. 3. Member selects request pickup service. 4. Member selects available time and date of the pickup service provided. Perform exceptional flow 4.1 Member is not available on scheduled time. 5. Member confirms the appointment. 6. System displays “successfully scheduled” message.		
Sub Flows: N/A		
Alternate/Exceptional Flows: N/A		

Table 4.6: View Appointments Use Case

Use Case Name: View appointments	ID: 6	Importance Level: High
Primary Actor: Member	Use Case Type: Details, Essential	
Stakeholders and Interests: Member – wants to view appointments scheduled with organization.		
Brief Description: View appointments use case describes how a member can view appointments scheduled with organization.		
Trigger: Member wants to view appointments made.		
Relationships: Association: Member Include: N/A Extend: N/A		

Generalization: N/A
Normal Flow of Events: 1. Member chooses to view appointments made. 2. System retrieves the appointments records from database. 3. System displays the list of appointments such as time, date, organization details and medical equipment details.
Sub Flows: N/A
Alternate/Exceptional Flows: N/A

Table 4.7: Search Drop-off Points Use Case

Use Case Name: Search drop-off points	ID: 7	Importance Level: High
Primary Actor: Member	Use Case Type: Details, Essential	
Stakeholders and Interests: Member – wants to search the drop-off points of organization.		
Brief Description: Search drop-off points use case describes how a member can search the drop-off points of organization.		
Trigger: Member wants to search the drop-off points of organization.		
Relationships: Association: Member Include: N/A Extend: N/A Generalization: N/A		
Normal Flow of Events: 1. Member chooses to search drop-off points. 2. Member tap the organization name and photo. Perform sub flow 2.1 Search of organization's location by system. 3. System displays the map of the member's address area. 4. System displays the markers of the organization's drop-off points. 5. System displays the details such as name, photos, address, working hours, contact number and website link of the organization.		
Sub Flows: 2.1 Search of organization's location by system 2.1.1 System retrieves the organization list records. 2.1.2 System searches the organization's in the organization list records. 2.1.3 System displays the organization's location in map if record is found.		
Alternate/Exceptional Flows: N/A		

Table 4.8: View Information on Medical Equipment use case

Use Case Name: View information on medical equipment	ID: 8	Importance Level: High
Primary Actor: Member	Use Case Type: Details, Essential	
Stakeholders and Interests: Member – wants to know more about medical equipment related information.		

Brief Description: View information on medical equipment use case describes how a member can view information on medical equipment.
Trigger: Member wants to view information on medical equipment.
Relationships: Association: Member Include: N/A Extend: N/A Generalization: N/A
Normal Flow of Events: 1. Member chooses to view information on medical equipment. 2. System retrieves list of information for the medical equipment knowledges. 3. System displays the information.
Sub Flows: N/A
Alternate/Exceptional Flows: N/A

Table 4.9: Verify Medical Equipment's Registration Use Case

Use Case Name: Verify medical equipment's registration	ID: 9	Importance Level: High
Primary Actor: Organization	Use Case Type: Details, Essential	
Stakeholders and Interests: Organization - NGO or medical centre wants to verify and validate the medical equipment member wants to donate to them to ensure the medical equipment are in good condition. Member – requests for donation of medical equipment.		
Brief Description: Verify medical equipment's registration use case describes how NGO and medical centre can verify medical equipment through the system.		
Trigger: Member requests for medical equipment donation to the organization by providing details of the medical equipment.		
Relationships: Association: Organization Include: N/A Extend: N/A Generalization: N/A		
Normal Flow of Events: 1. Organization receives requests from member for medical equipment donation. 2. Organization verifies the details of medical equipment provided by members. 3. Organization checks the duration used and photos uploaded by member. Perform exceptional flow 3.1 Verification of medical equipment is failed. 4. Organization approves the donation if the medical equipment is still in good condition. 5. System updates the verification status (success) to member.		

Sub Flows: N/A
Alternate/Exceptional Flows: 4.2 Verification of medical equipment is failed. 4.2.1 Organization states the reasons of medical equipment is inappropriate for donation. 4.2.2 System updates the verification status (rejected) to member. 4.2.3 Use case terminates.

Table 4.10: Request Medical Equipment in Shortage Use Case

Use Case Name: Request medical equipment in shortage	ID: 10	Importance Level: High
Primary Actor: Organization	Use Case Type: Details, Essential	
Stakeholders and Interests: Organization - NGO or medical centre wants to request medical equipment in shortage to the members to get the medical equipment fast.		
Brief Description: Request medical equipment use case describes how NGO and medical centre can request medical equipment in shortage.		
Trigger: Organization wants to get donation of certain medical equipment in shortage.		
Relationships: Association: Organization Include: N/A Extend: N/A Generalization: N/A		
Normal Flow of Events: 1. Organization types in medical equipment details such as name and photo. 2. Organization publishes the request. 3. System receives the request medical equipment details. 4. System updates the database the details. 5. System displays “successful request” message. 6. Member receives the medical equipment’s shortage notification.		
Sub Flows: N/A		
Alternate/Exceptional Flows: N/A		

Table 4.11: Arrange Appointment Use Case

Use Case Name: Arrange appointment	ID: 11	Importance Level: High
Primary Actor: Organization	Use Case Type: Details, Essential	
Stakeholders and Interests: Organization – NGO or medical centre wants to confirm appointment with member to pick up the medical equipment.		
Brief Description: Arrange appointment use case describes how organization can arrange appointment with member for pickup service.		
Trigger: Member requests for pickup service.		

Relationships: Association: Organization Include: N/A Extend: N/A Generalization: N/A
Normal Flow of Events: 1. Organization selects the time and date available for pickup. 2. Organization receives pickup request from member. 3. Organization successfully schedules the pickup if member selects the scheduled date and time. Perform exceptional flow 3.1 Organization is not available on scheduled date and time. 4. System displays "Appointment made" message.
Sub Flows: N/A
Alternate/Exceptional Flows: 4.1 Organization is not available on schedule time 4.1.1 Organization rejects the schedule. 4.1.2 System updates the appointment status (appointment rejected). 4.1.3 Member needs to reschedule the appointment. 4.1.4 Use case terminates.

Table 4.12: View Donation History Use Case

Use Case Name: View donation history	ID: 12	Importance Level: High
Primary Actor: Organization, member	Use Case Type: Details, Essential	
Stakeholders and Interests: Organization - NGO or medical centre wants to view donation history. Member – wants to view donation history.		
Brief Description: View donation history use case describes how organization and member can view donation history.		
Trigger: Organization or member wants to view donation of medical items details.		
Relationships: Association: Organization Include: N/A Extend: Share to social media Generalization: N/A		
Normal Flow of Events: 1. User chooses to view the donation history. 2. System retrieves the donation records such as donated items' name, photo, date, time and, donor/ recipient from database. 3. System displays the list of donations. 4. User views the list of donations. Perform exceptional flow 4.1 Share to social media.		
Sub Flows: N/A		
Alternate/Exceptional Flows: 4.1 Share to social media		

4.1.1 User selects a donation record. 4.1.2 User selects the social media platform to share to. 4.1.3 User shares the donation to the social media.

Table 4.13: Send Message Use Case

Use Case Name: Send message	ID: 13	Importance Level: High
Primary Actor: Organization, member	Use Case Type: Details, Essential	
Stakeholders and Interests: Organization - NGO or medical centre wants to communicate with member to provide helps regarding donation related matter. Member – has enquiry regarding donation related matter.		
Brief Description: Send message use case describes how organization and member can send message to communicate.		
Trigger: Organization or member wants to contact with each other for some donation related matter.		
Relationships: Association: Organization, Member Include: N/A Extend: N/A Generalization: N/A		
Normal Flow of Events: 1. User searches the name for contact. Perform sub flow 1.1 Search contact person by system. Perform exceptional flow 1.2 No contact person is found. 2. User selects the contact person from search results. 3. System directs the user to chat box. 4. User sends message via chat box.		
Sub Flows: 1.1 Search contact person by system 1.1.1 System receives the name. 1.1.2 System searches the name in the database. 1.1.3 System retrieves the organization or member record. 1.1.4 System displays the search results.		
Alternate/Exceptional Flows: 1.2 No contact person is found. 1.2.1 System displays “No such organization/ member is found”. 1.2.2 Use case terminates.		

Table 4.14: Verify Organization Account Use Case

Use Case Name: Verify organization account	ID: 14	Importance Level: High
Primary Actor: Admin	Use Case Type: Details, Essential	
Stakeholders and Interests: Admin – wants to verify organization account before allowing organization to sign in.		

Brief Description: Verify organization account use case describes how an admin can verify organization account.
Trigger: Admin verifies the account after organization signs up the account.
Relationships: Association: Admin Include: N/A Extend: N/A Generalization: N/A
Normal Flow of Events: 1. Admin receives requests from organization for verification of account. 2. System retrieves the list of organizations requesting for sign up. 3. System displays the list of organizations. 4. Admin views the lists of pending verification of sign up from organization. 5. Admin verifies the details of organizations. 6. Admin checks the license of organization. Perform exceptional flow 6.1 Verification of organization is failed. 7. Admin approves the organization account. 8. System updates the verification status (success) to organization.
Sub Flows: N/A
Alternate/Exceptional Flows: 6.1 Verification of medical items is failed. 6.1.1 Admin states the reasons of failure. 6.1.2 System updates the verification status (rejected) to organization. 6.1.3 Use case terminates.

Table 4.15: View Monthly Reports of Donation Use Case

Use Case Name: View monthly reports of donation	ID: 15	Importance Level: High
Primary Actor: Admin	Use Case Type: Details, Essential	
Stakeholders and Interests: Admin – wants to view monthly reports of donation by members.		
Brief Description: View monthly reports of donation use case describes how an admin can view monthly reports of donation by members.		
Trigger: Admin views the monthly reports of donation.		
Relationships: Association: Admin Include: N/A Extend: N/A Generalization: N/A		
Normal Flow of Events: 1. Admin chooses to view the monthly report of donation. 2. System retrieves the donation records history such as date, time, medical equipment donated, donor and recipient. 3. Admin selects the graph type either in bar chart or pie graph.		

4. System displays the graph for medical equipment donated amounts and type of medical equipment.
Sub Flows: N/A
Alternate/Exceptional Flows: N/A

CHAPTER 5

SYSTEM DESIGN

5.1 Introduction

This chapter describes the system architecture design, database design and user interface design of this project. In system architecture design, a three-tier architecture is explained in detail, including all the frameworks and tools used in the system. Besides, database design is illustrated using data model diagram, which are data flow diagram, including context diagram, level 0 diagram and level 1 diagram. Lastly, user interface design is showed using a high fidelity prototype and screens navigation flow diagram.

5.2 System Design

5.2.1 System Architecture Design

A three-tier architecture is used as the system architecture for this mobile application. It is made up of three layers which are the front-end layer, business layer and data layer. All the user interfaces components are grouped in the front-end layer. It functions as delivering and displaying information to the end-user. The business layer is the middle layer between the front-end layer and the data layer. It contains all the business logic and allows data transactions between the front-end layer and data layer. The data layer in charge of storing data and processes the read-write access to the database. Figure 5.1 illustrates the three-tier architecture of the system and development tools used for implementations.

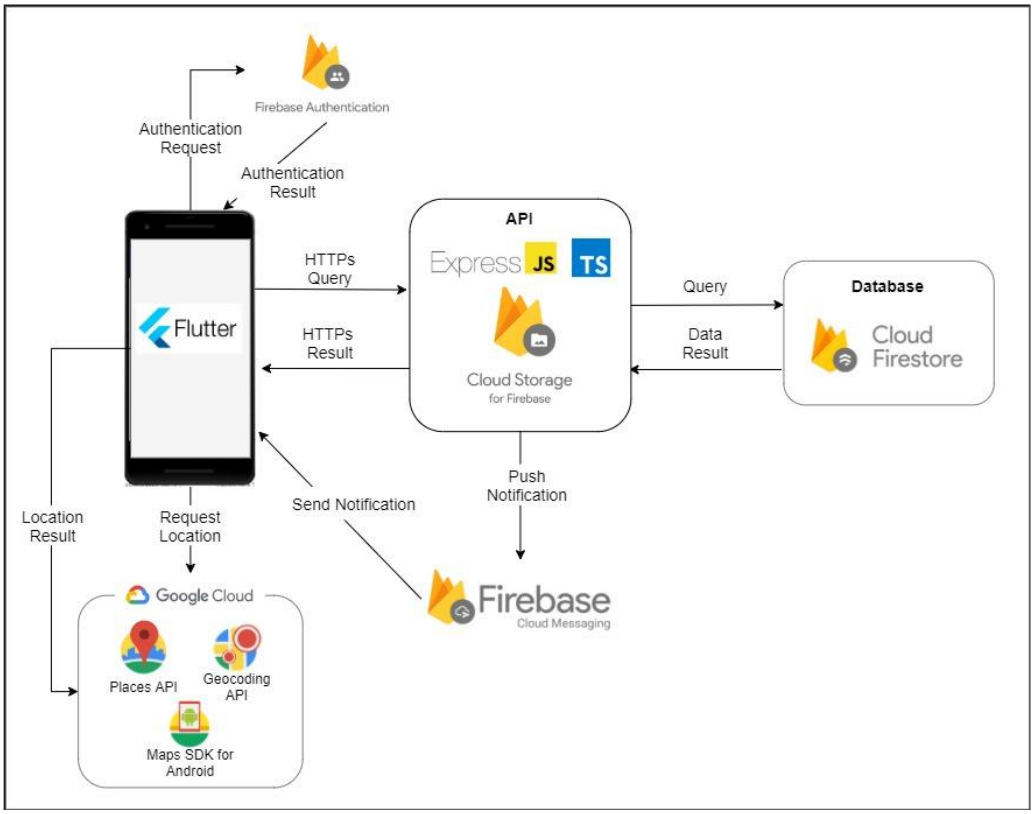

Figure 5.1: System Architecture Diagram

Flutter is the framework that is used for the user interface design. Development tools used in this application layer are ExpressJS, Typescripts and Firebase Cloud Function. ExpressJS is used for creating an Application Programming Interface (API) needed to communicate between the data layer and client side by sending HTTP requests. Firebase Cloud Function, which is the backend server, will respond by sending back the data result. Besides, Firebase Cloud Function will handle the services in Firebase. Typescripts is the language used in writing the API. To deploy the API written, Firebase CLI allows quick deployment of API to Firebase Cloud Function with only a single line of command.

For authentication of users, Firebase Authentication is the Firebase service selected to verify the user access. Firebase Authentication handles the validation part of the login and sign up. Thus, development time can be reduced for validation. In addition, users will receive notification sent by Cloud Firebase Messaging service implemented with the Firebase Cloud Function to remind members and organizations about the appointment. Cloud Firestore is chosen to store the data in JSON format documents in the data layer. It will respond to the query sent by the API and sent back either data if successful or error messages if failure.

Other API implemented in this project are Places API, Geocoding API and Maps SDK for Android API. They are Google Maps API used to location related features. Places API is called to use for Place Details and Place Photos service. Place details can be retrieved by sending Place Details requests a place id. Place Photo service is used to retrieve the place photos. Geocoding API is used to get back the location address by providing the latitude and longitude of the location. Lastly, Maps SDK for Android API enables android mobile app to use for the Google Map API.

5.3 Low Level Design

5.3.1 System Database Design

In this section, database structures are described using an entity relationship diagram and data flow diagrams. The entity relationship diagram shows the relationships between entities in the database. The data flow diagram shows the flow of data in the system.

5.3.1.1 Entity Relationship Diagram

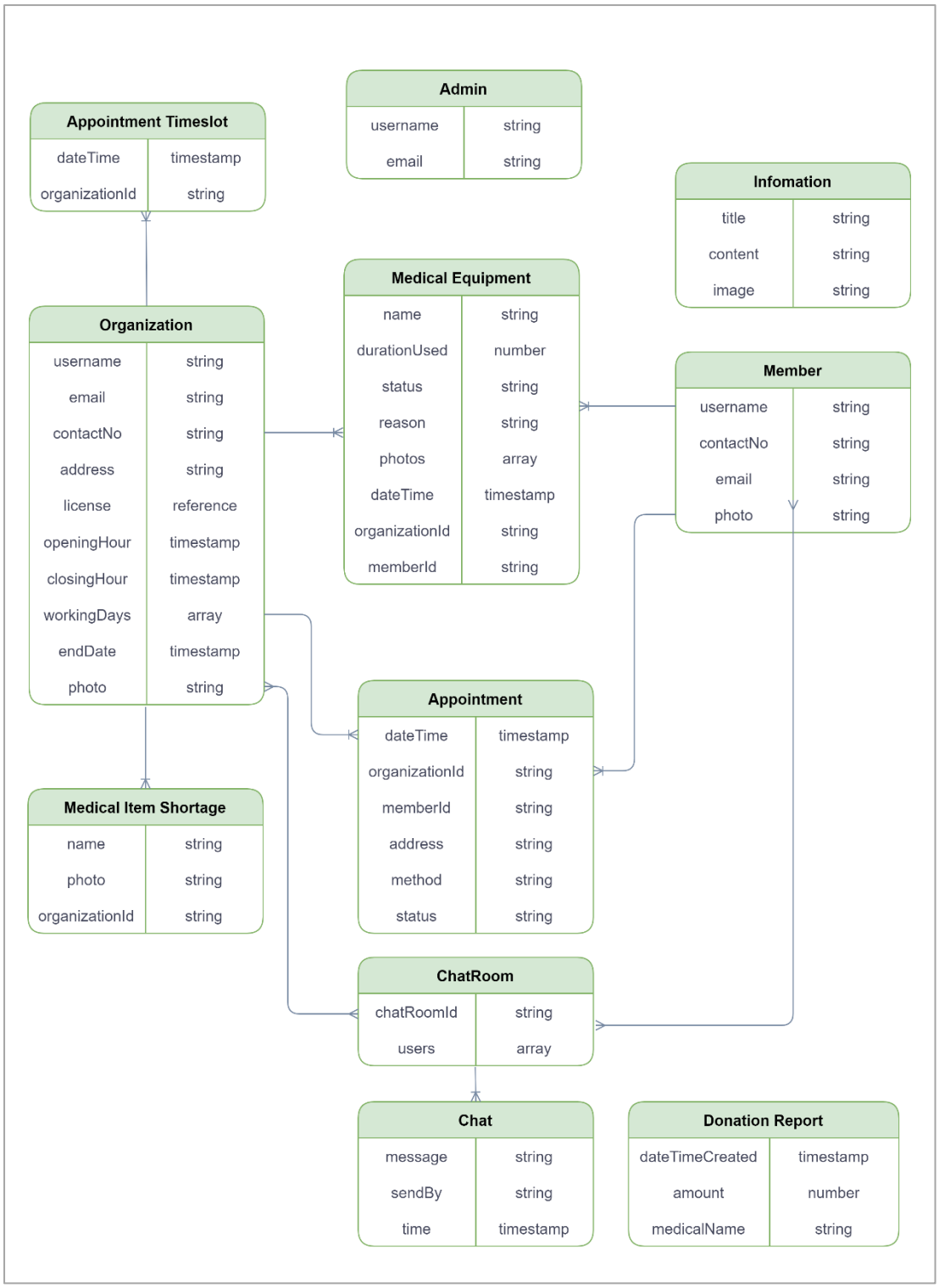

Figure 5.2: The Entity Relationship Diagram

5.3.2 Data Flow Diagram

5.3.2.1 Context Diagram

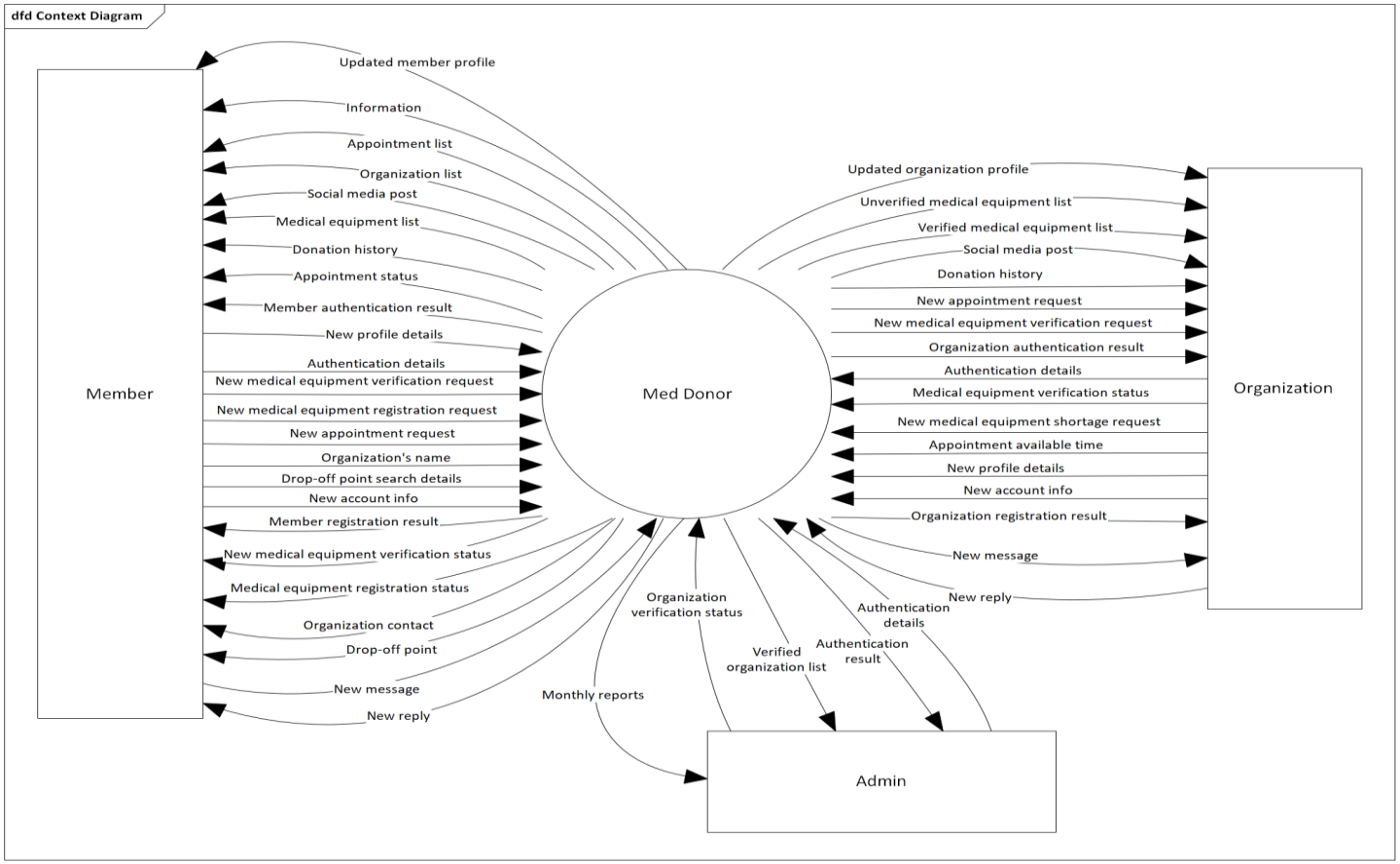

Figure 5.3: The Context Diagram

5.3.2.2 Level 0 Data Flow Diagram

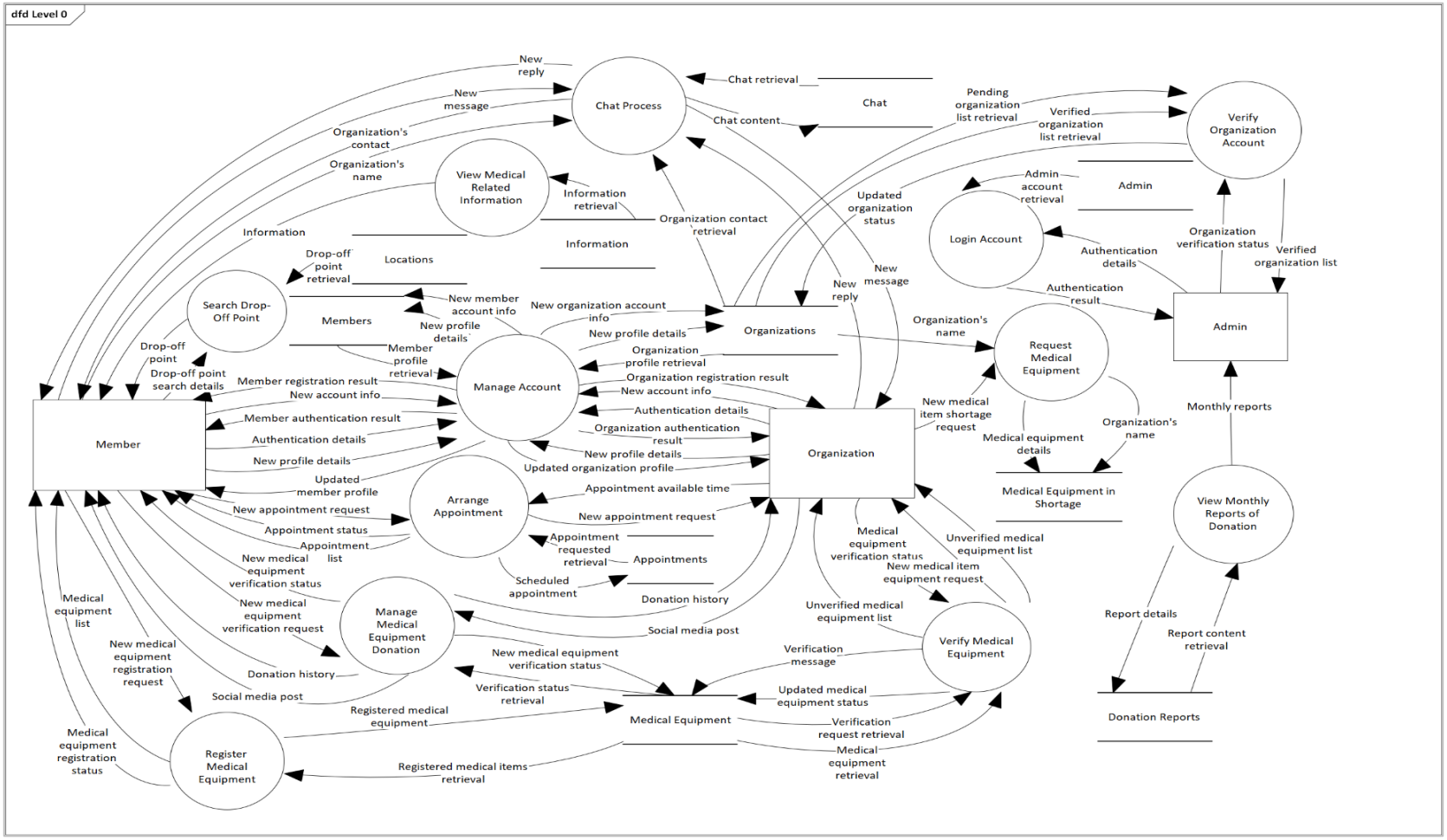

Figure 5.4: The Level 0 Data Flow Diagram

5.3.2.3 Level 1 Data Flow Diagram

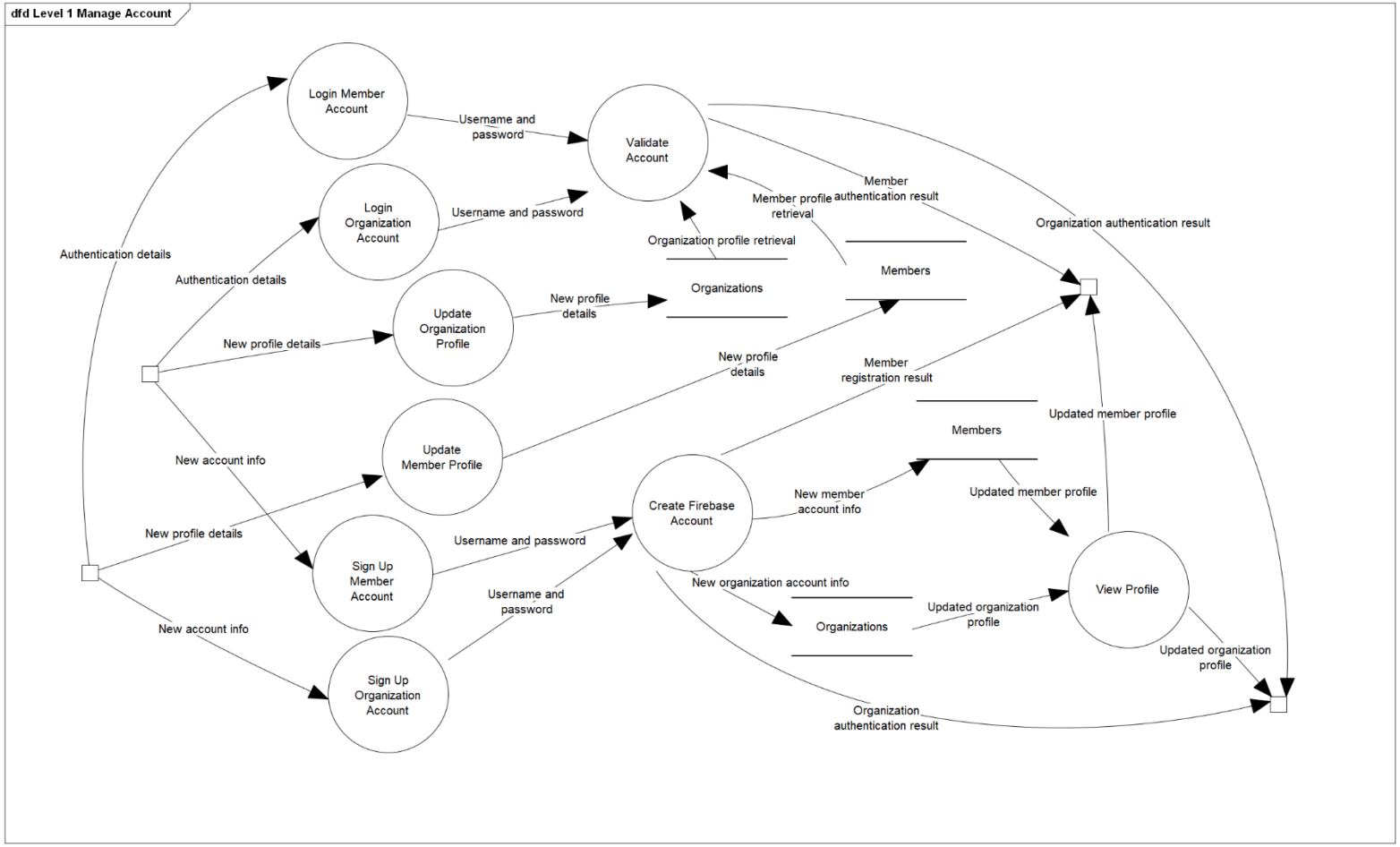

Figure 5.5: The Level 1 DFD for “Manage Account” Process

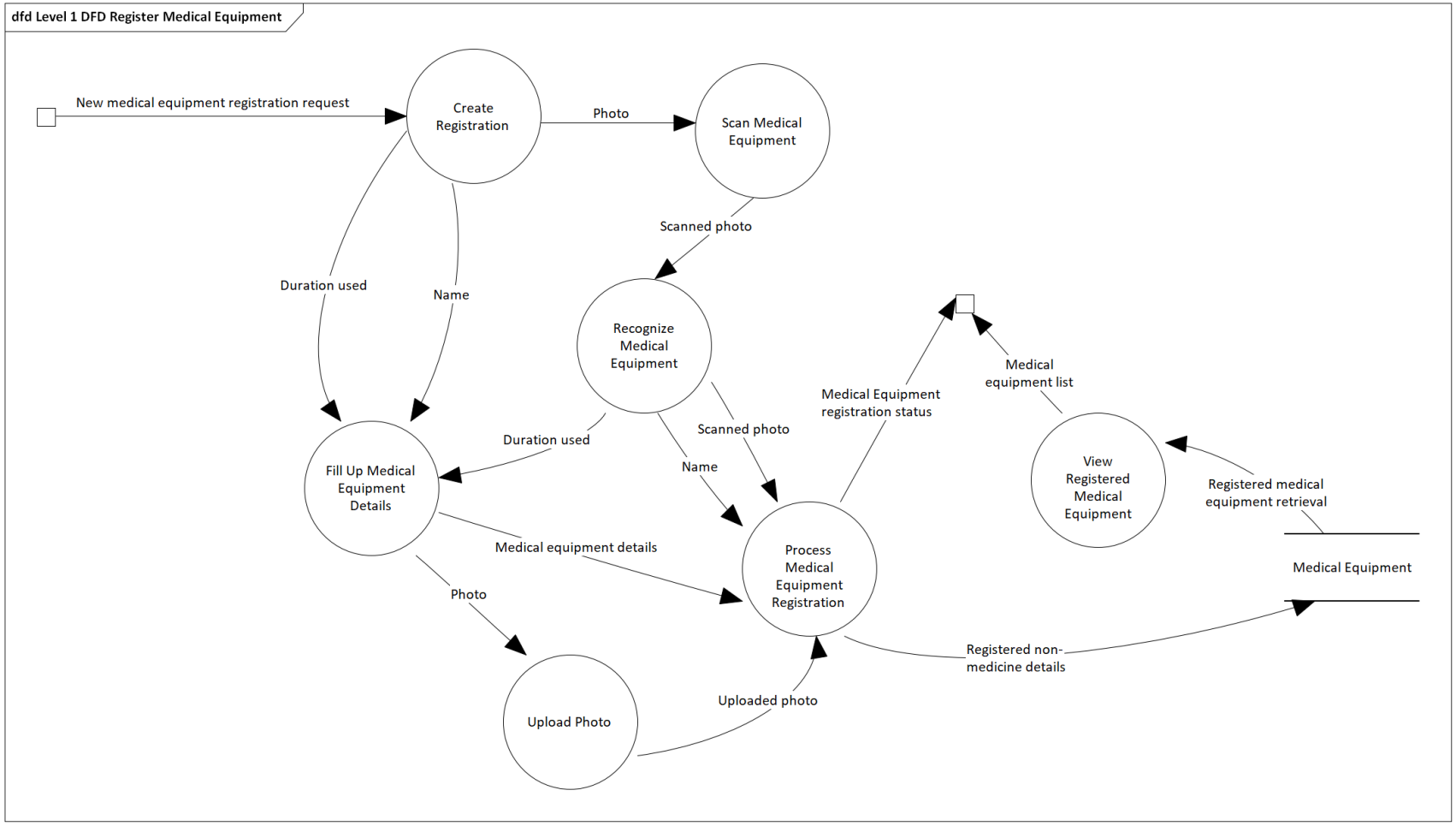

Figure 5.6: The Level 1 DFD for “Register Medical Equipment” Process

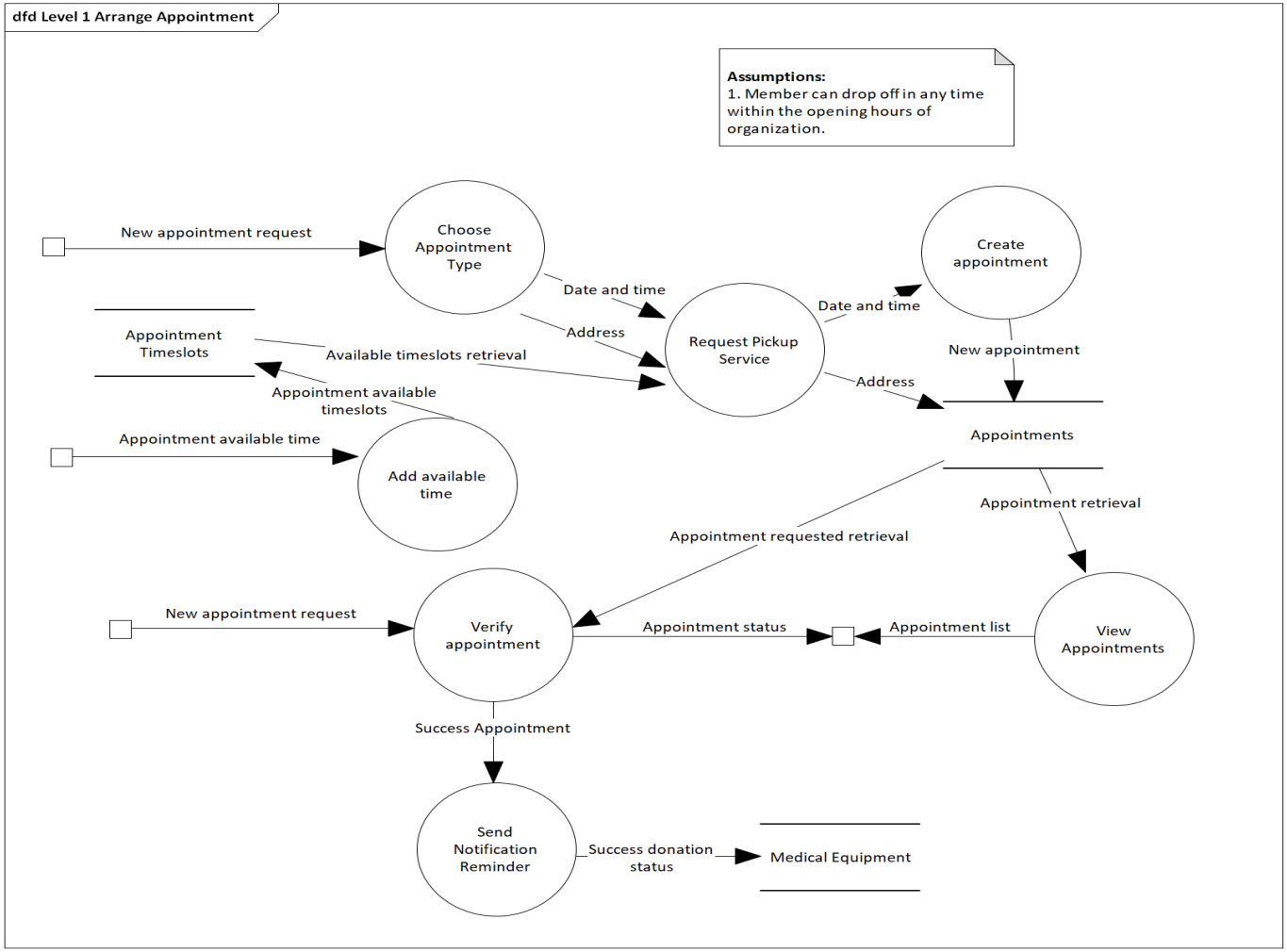

Figure 5.7: The Level 1 DFD for “Arrange Appointment” Process

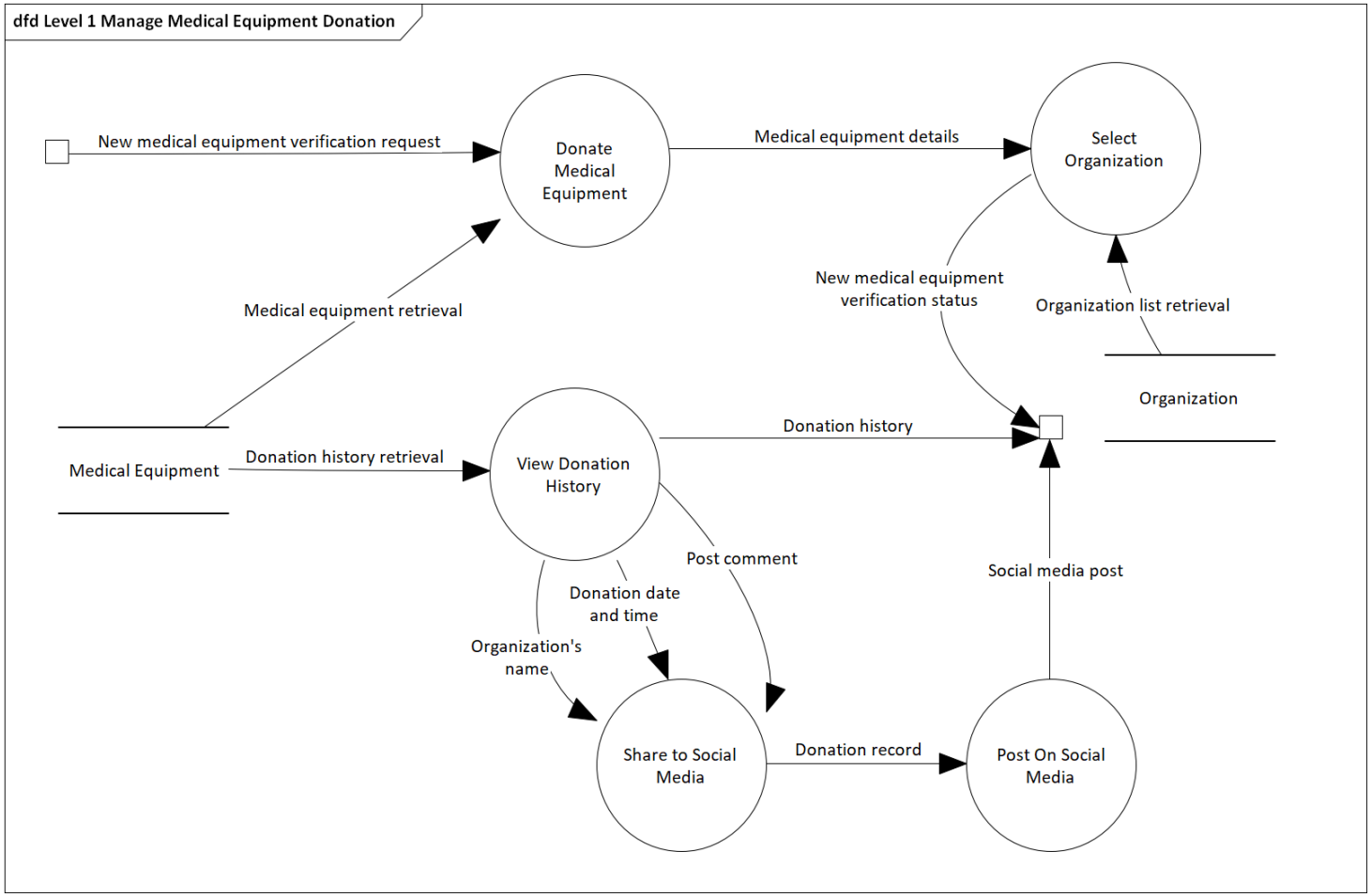

Figure 5.8: The Level 1 DFD for “Manage Donation History” Process

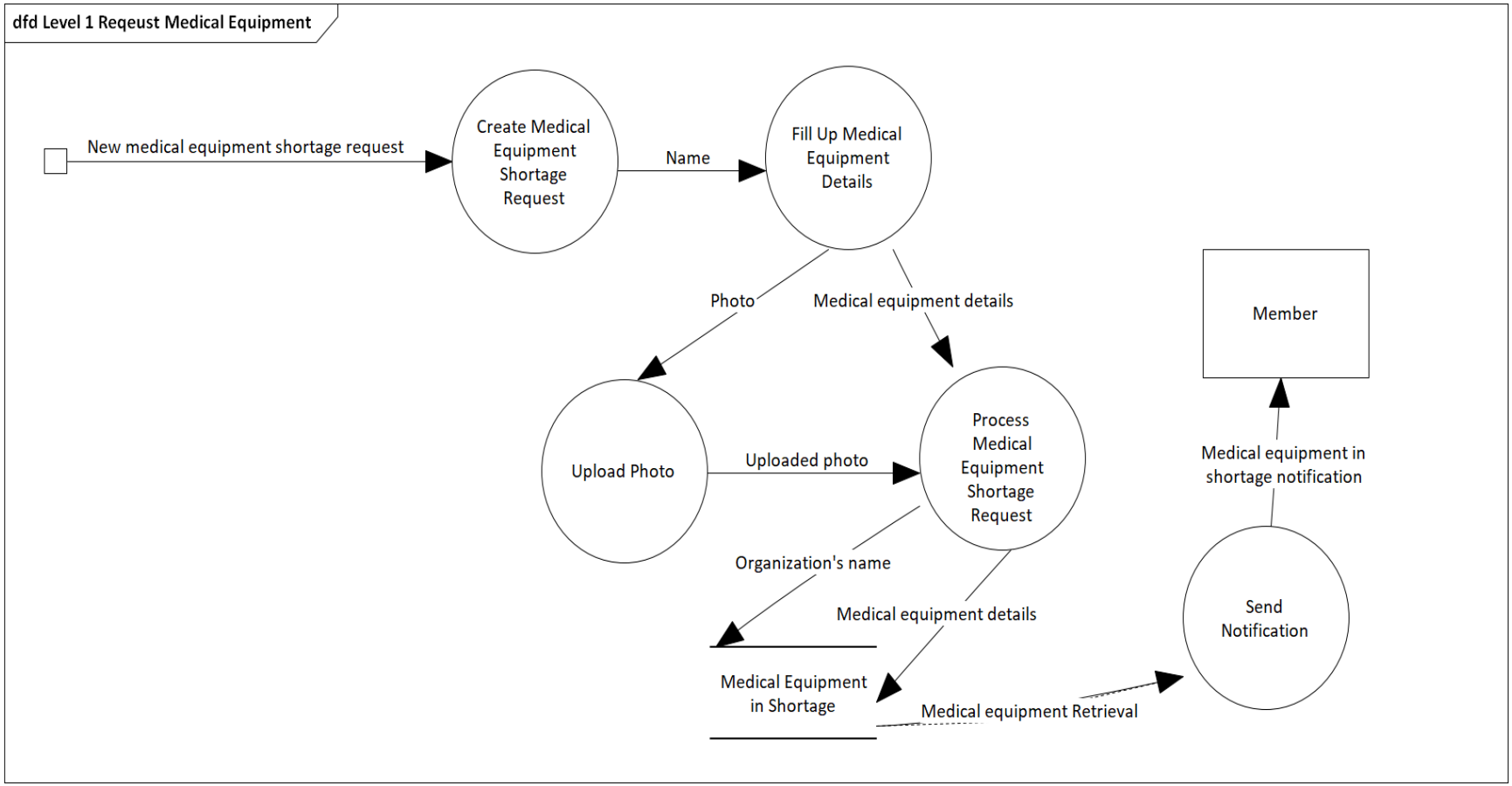

Figure 5.9: The Level 1 DFD for “Request Medical Equipment” Process

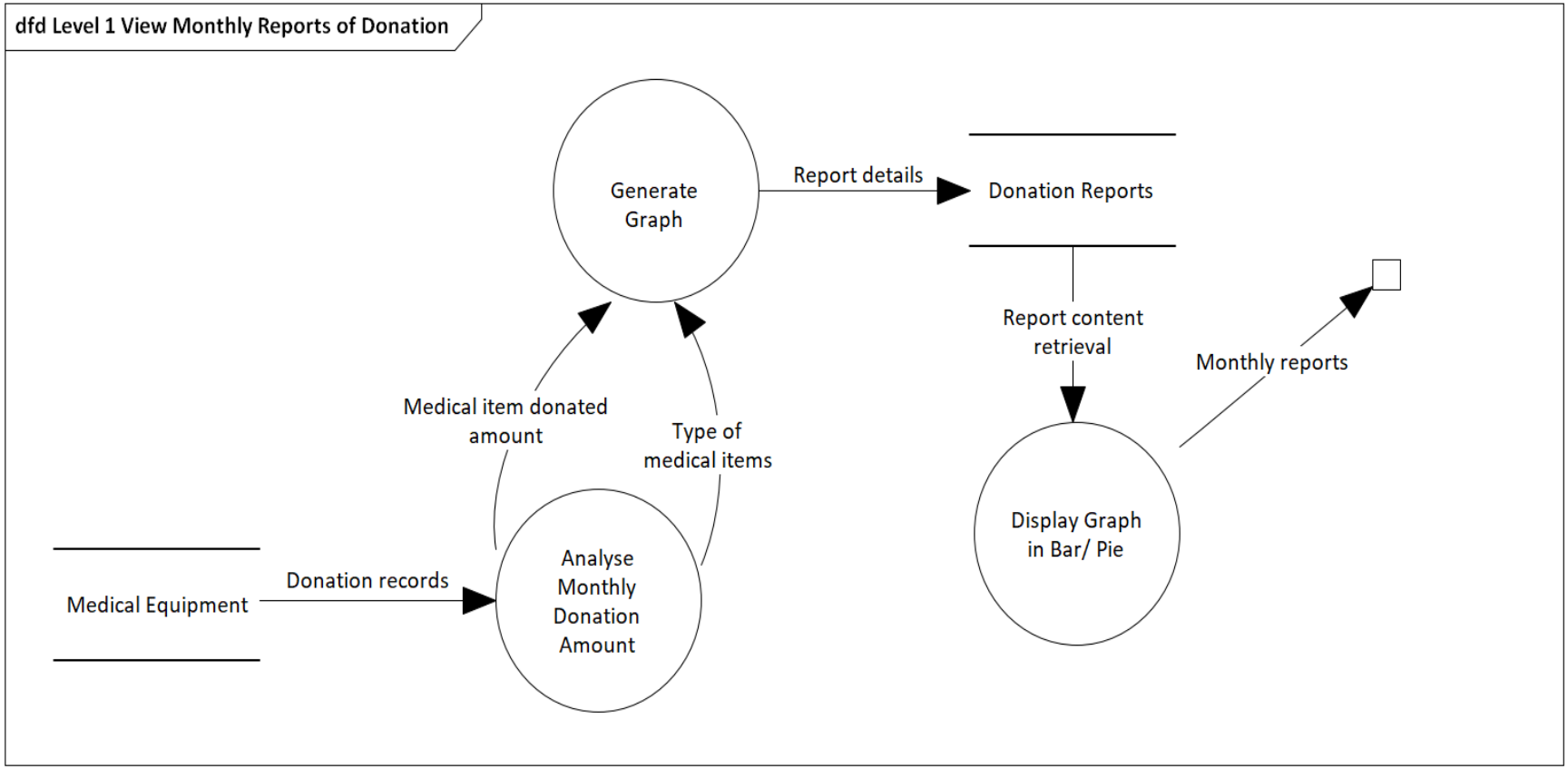

Figure 5.10: The Level 1 DFD for “View Monthly Reports of Donation” Process

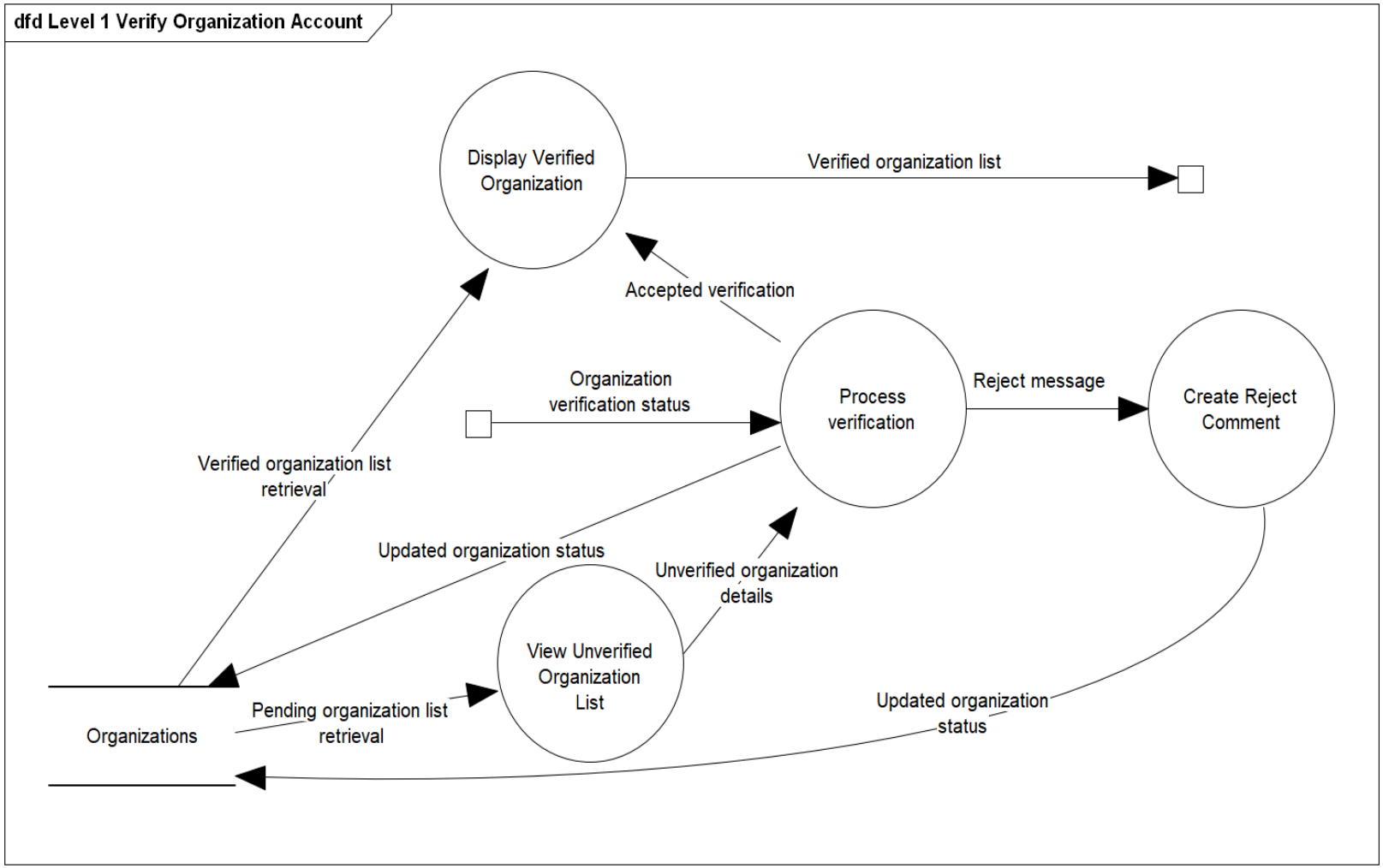

Figure 5.11: The Level 1 DFD for “Verify Organization Account” Process

5.4 User Interface Design

User interfaces for three types of users which are members, NGOs/medical centres and admin are shown and explained in this section. The interfaces design for the three roles is different. The user interfaces displayed are from high-fidelity prototypes drew by Axure RP 9. It gives an illustration of the screen flows and features.

5.4.1 Members Mobile Application Design

5.4.1.1 Login Screen

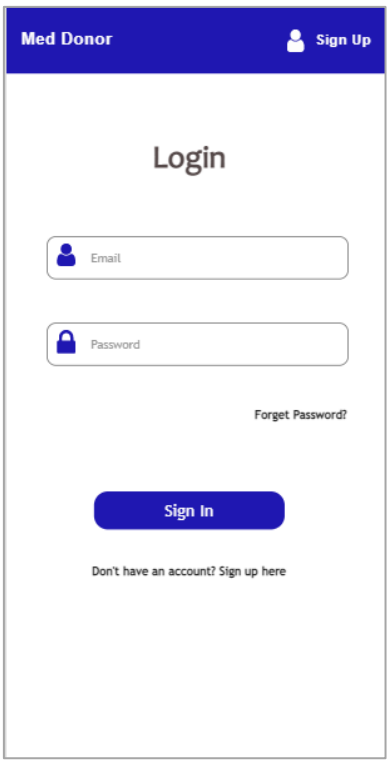

Figure 5.12: Login Screen (Member)

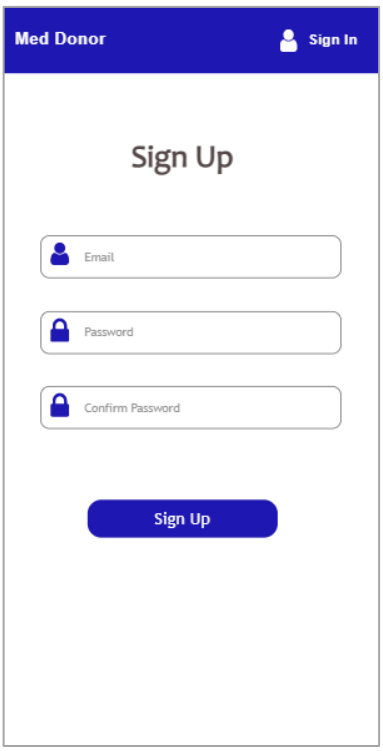

Figure 5.13: Sign Up Screen (Member)

5.4.1.2 Home Screen

Member home screen displays the medical items news, navigation of appointment made and organization list.

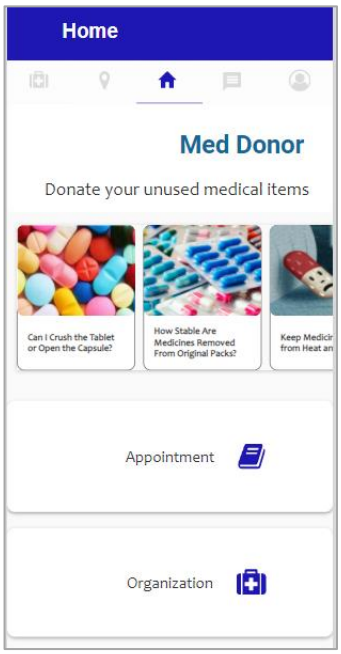

Figure 5.14: Member Home

5.4.1.3 Medical Items Screen

In the medical items tab, a member can tap the add button to register for new medical items by scanning or typing the items' details. Members can fill in the details if they choose type. After registration, the medical items list will be displayed as shown in Figure 5.5.

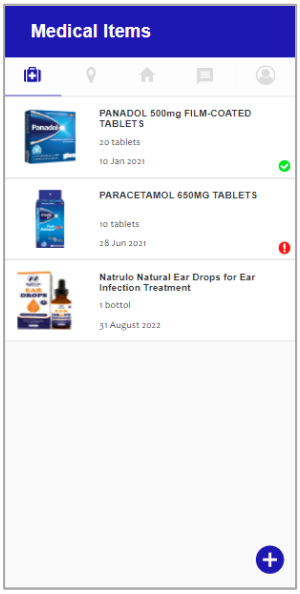

Figure 5.15: Medical Items Screen

Figure 5.16: Medical Items Registration

5.4.1.4 Donation Screen

Member can tap the medical item registered in Figure 5.5 to donate to an organization. Verification request will be sent to organization member selected for donation.

Figure 5.17: Donation Screen

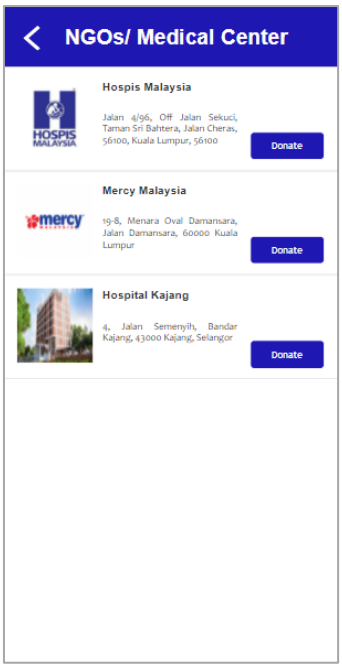

Figure 5.18: Organization List for Donation

After a request approved by the organization, a member can tap donate again to choose a donation method.

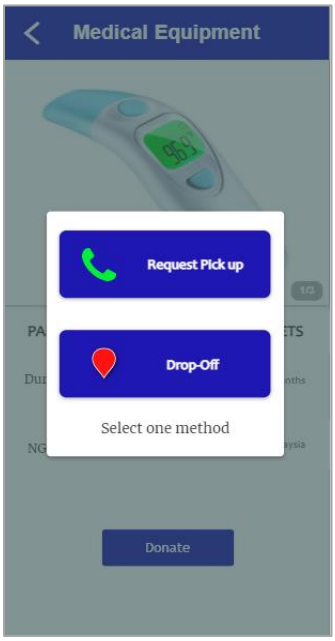

Figure 5.19: Donation Methods

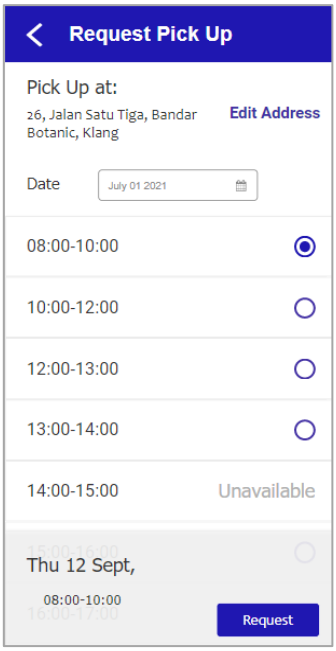

Figure 5.20: Request Pick Up

5.4.1.5 Donation History Screen

Members can share the donation on social media.

Figure 5.21: Donation History

5.4.1.6 Drop-Off Point Screen

Members can search for nearby drop-off point or organization location.

Figure 5.22: Drop-Off Point

5.4.1.7 Appointments Screen

Appointments made can be viewed navigated from the home screen.

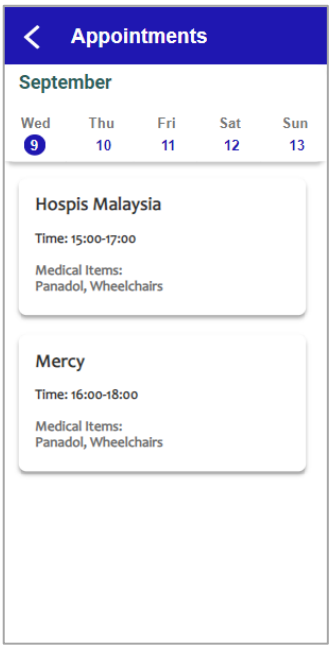

Figure 5.23: Drop-Off Point

5.4.1.8 Organization List Screen

Organization details can be viewed in organization navigated from the home screen.

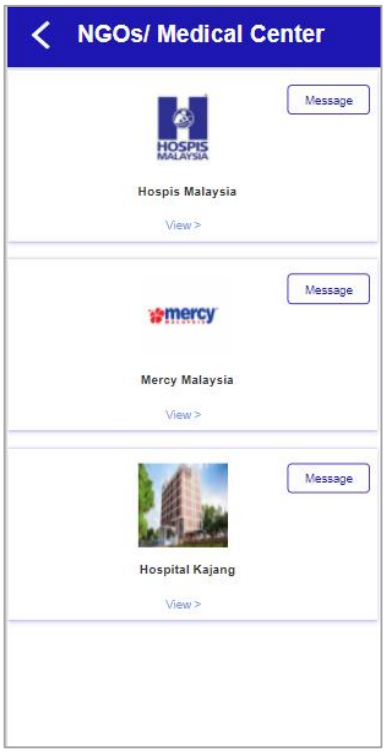

Figure 5.24: Organizations

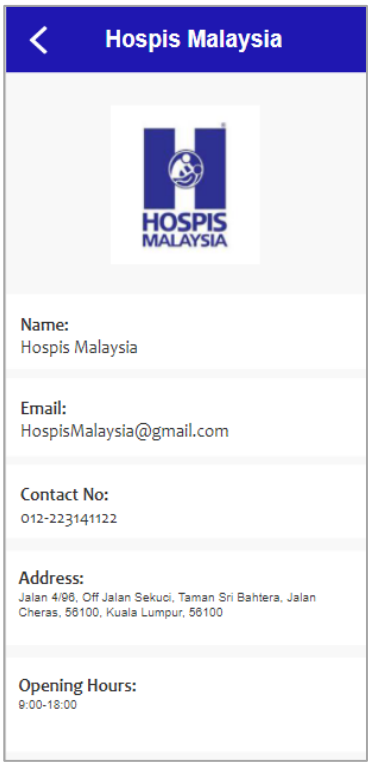

Figure 5.25: Organization's details

5.4.1.9 Messages Screen

Member can view notification and chat in the messages tab.

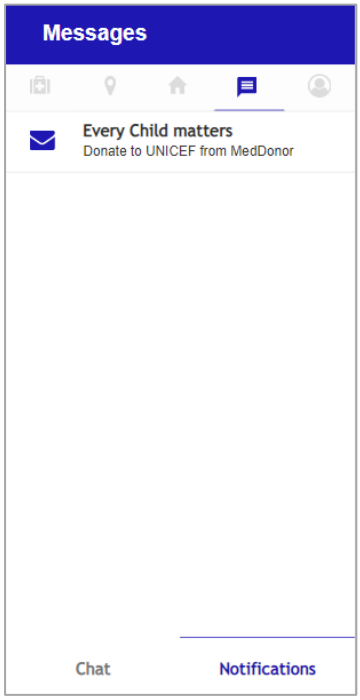

Figure 5.27: Notifications

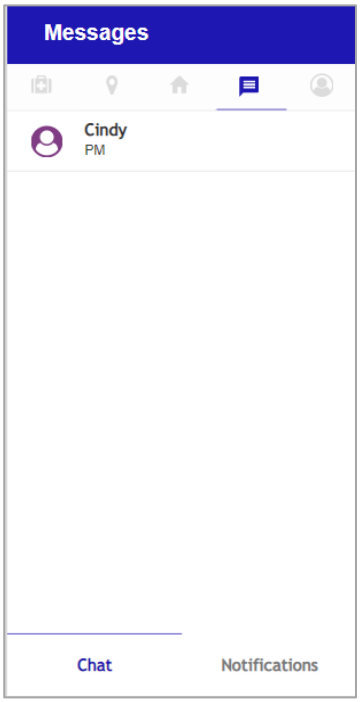

Figure 5.26: Chat

5.4.1.10 Profile Screen

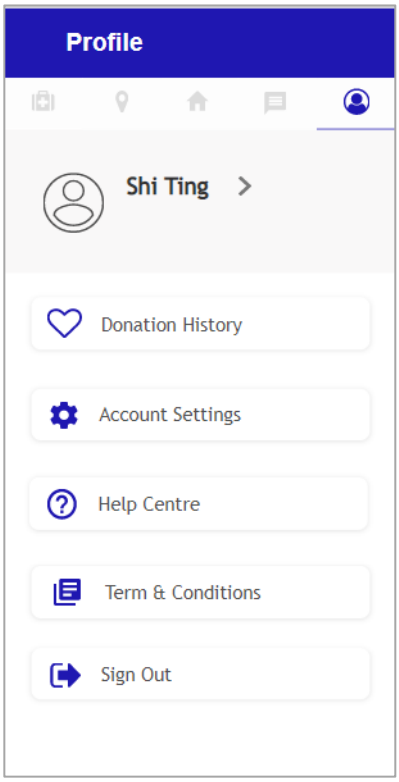

Figure 5.28: Profile (Member)

5.4.2 Screens Navigation Flows

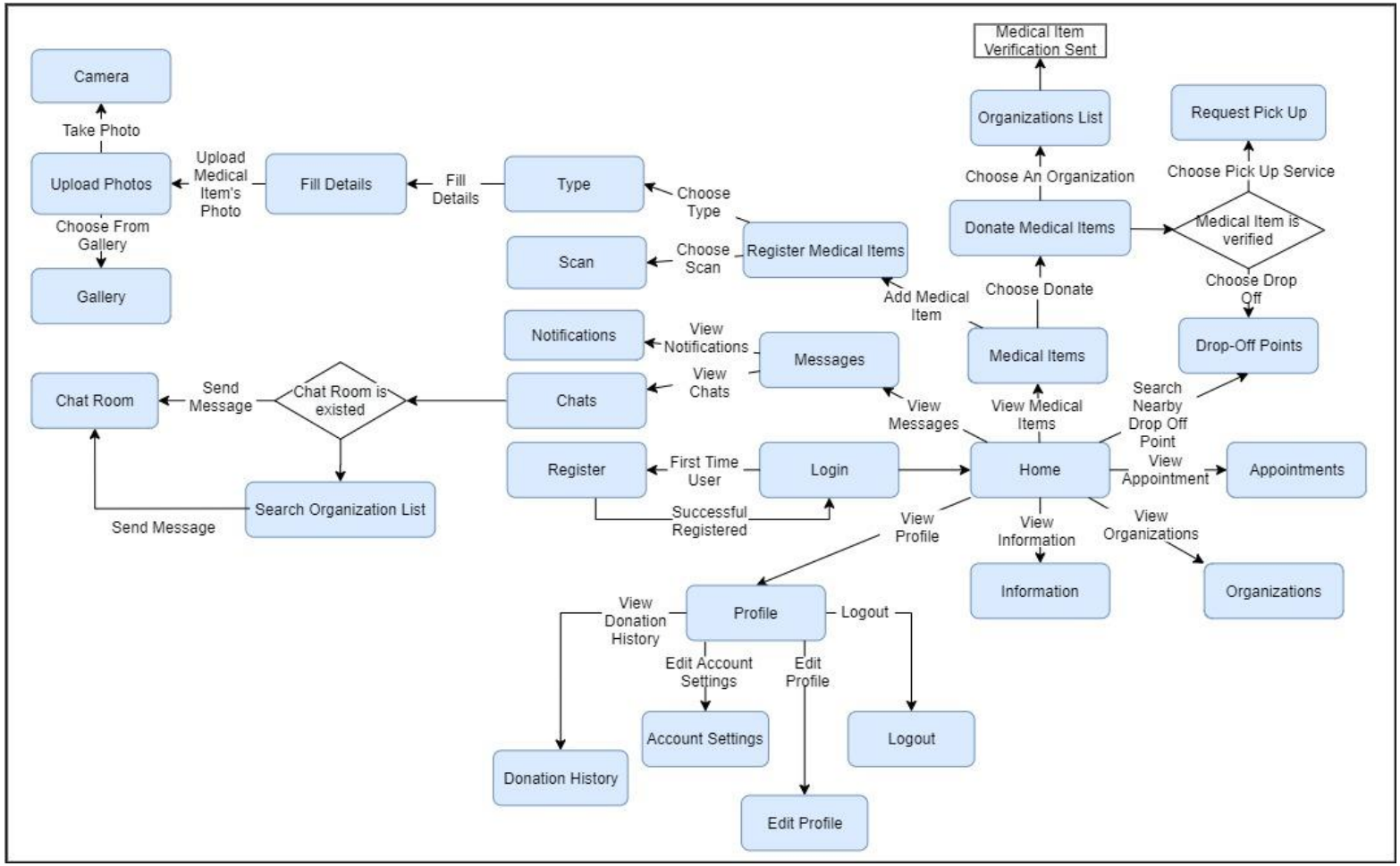

Figure 5.29: The Screens Navigation Flow (Members)

5.4.3 NGOs/Medical Centre Mobile Application Design

5.4.3.1 Medical Items Shortage Screen (Home)

Organization can request medical items on this screen. Besides, the medical items shortage screen is the home screen after the organization login to the app.

Figure 5.30: Medical Items Shortage

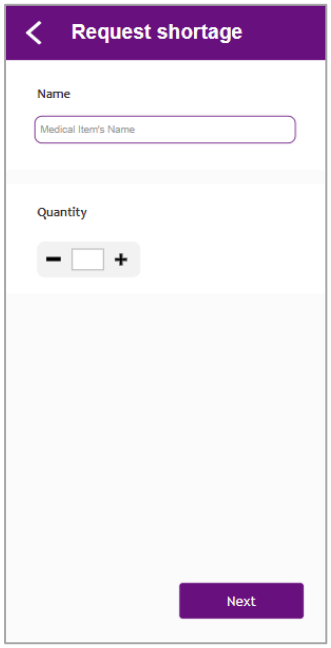

Figure 5.31: Request Medical Item

5.4.3.2 Medical Items Verification Screen

Figure 5.32: Verify Medical Items

Organization can accept or reject the medical item. If accept, a success verification message will be displayed else a comments screen will be shown.

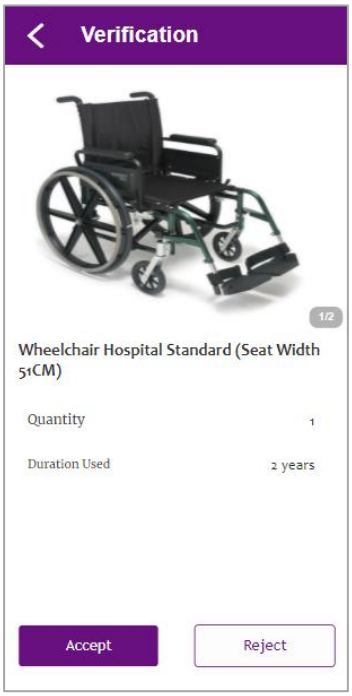

Figure 5.33: Medical Item Verification

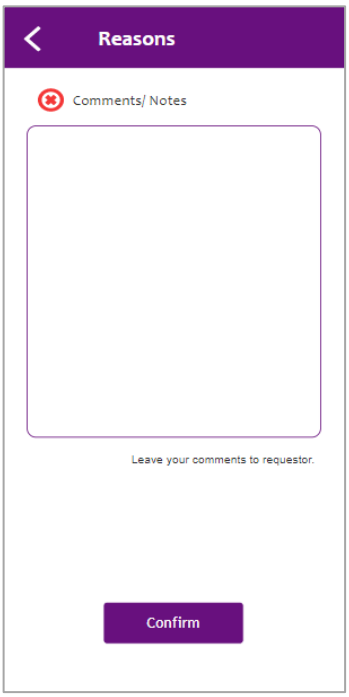

Figure 5.34: Reject Medical Item

5.4.3.3 Appointments Screen

The organization needs to set the available time for members to choose for pickup else the system will show unavailable when member requests for pickup.

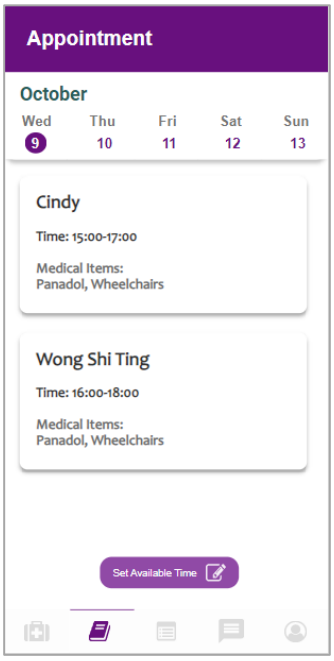

Figure 5.35: Upcoming Appointments

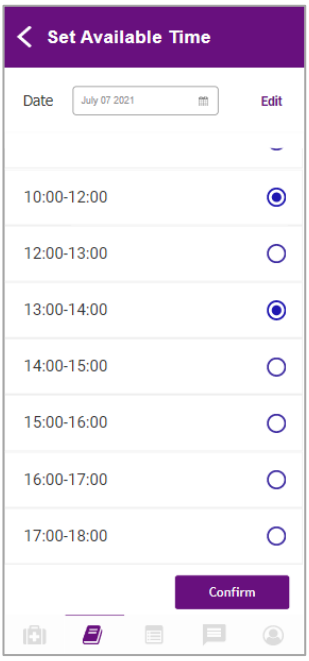

Figure 5.36: Set Available Time

5.4.3.4 Profile Screen

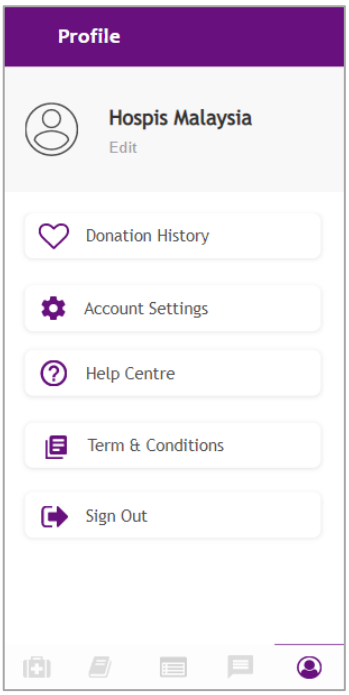

Figure 5.37: Profile (Organization)

5.4.3.5 Screen Navigation Flows

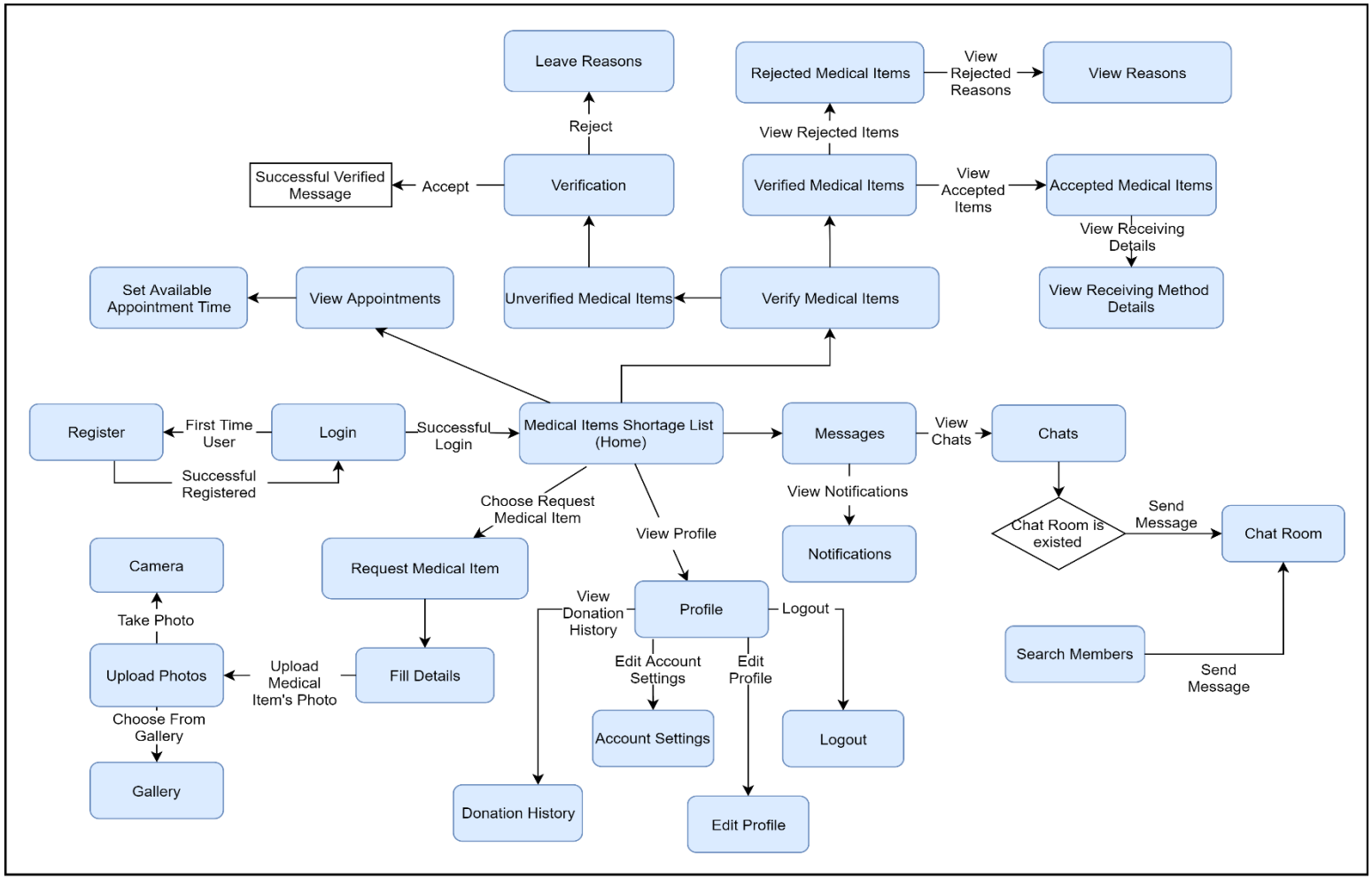

Figure 5.38: The Screens Navigation Flow (Organizations)

5.4.4 Admin Mobile Application Design

5.4.4.1 Home Screen

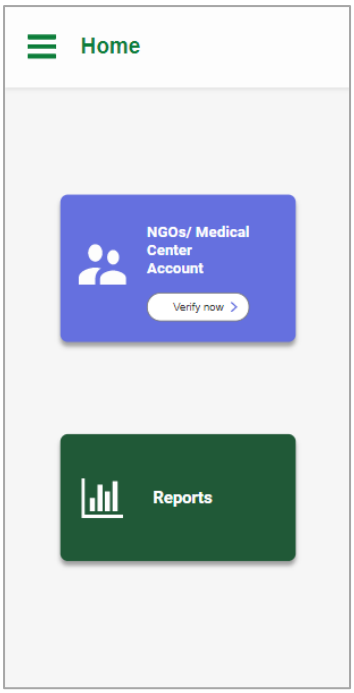

Figure 5.39: Admin Home

5.4.4.2 Organization Account Verification Screen

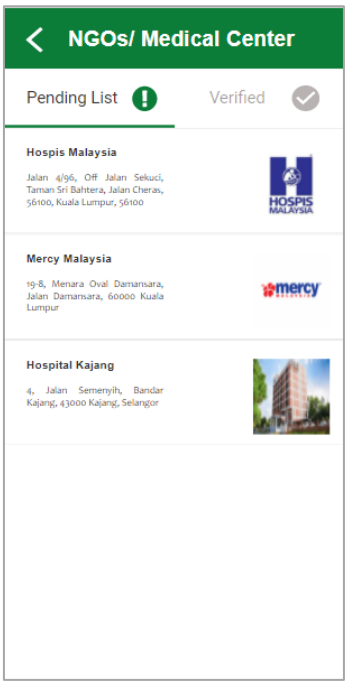

Figure 5.40: Organization Pending List

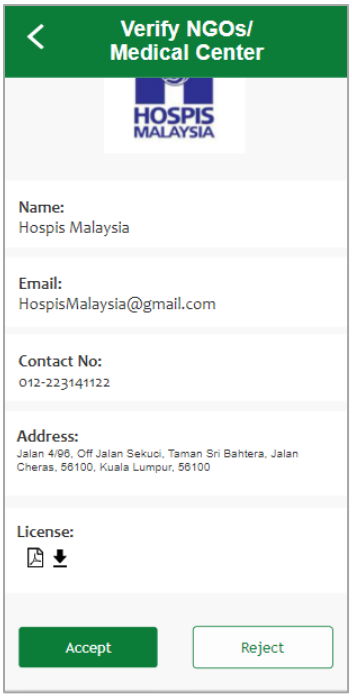

Figure 5.41: Organization Verification

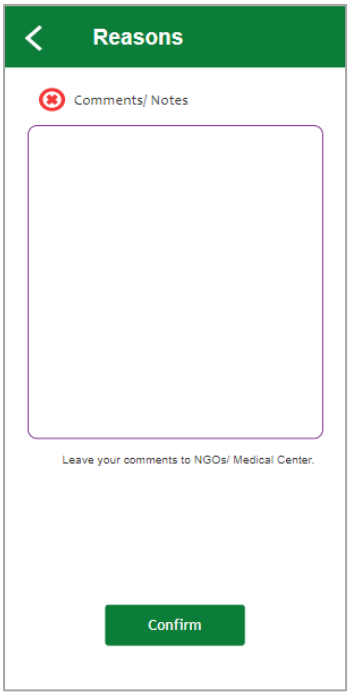

Figure 5.42: Reject Organization Verification

5.4.4.3 Reports Screen

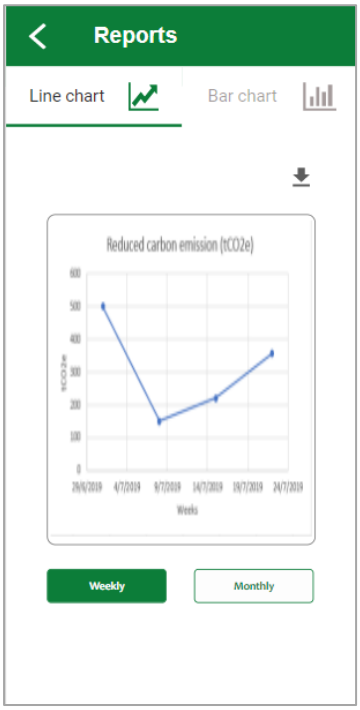

Figure 5.43: Donation Reports

5.4.4.4 Screen Navigation Flows

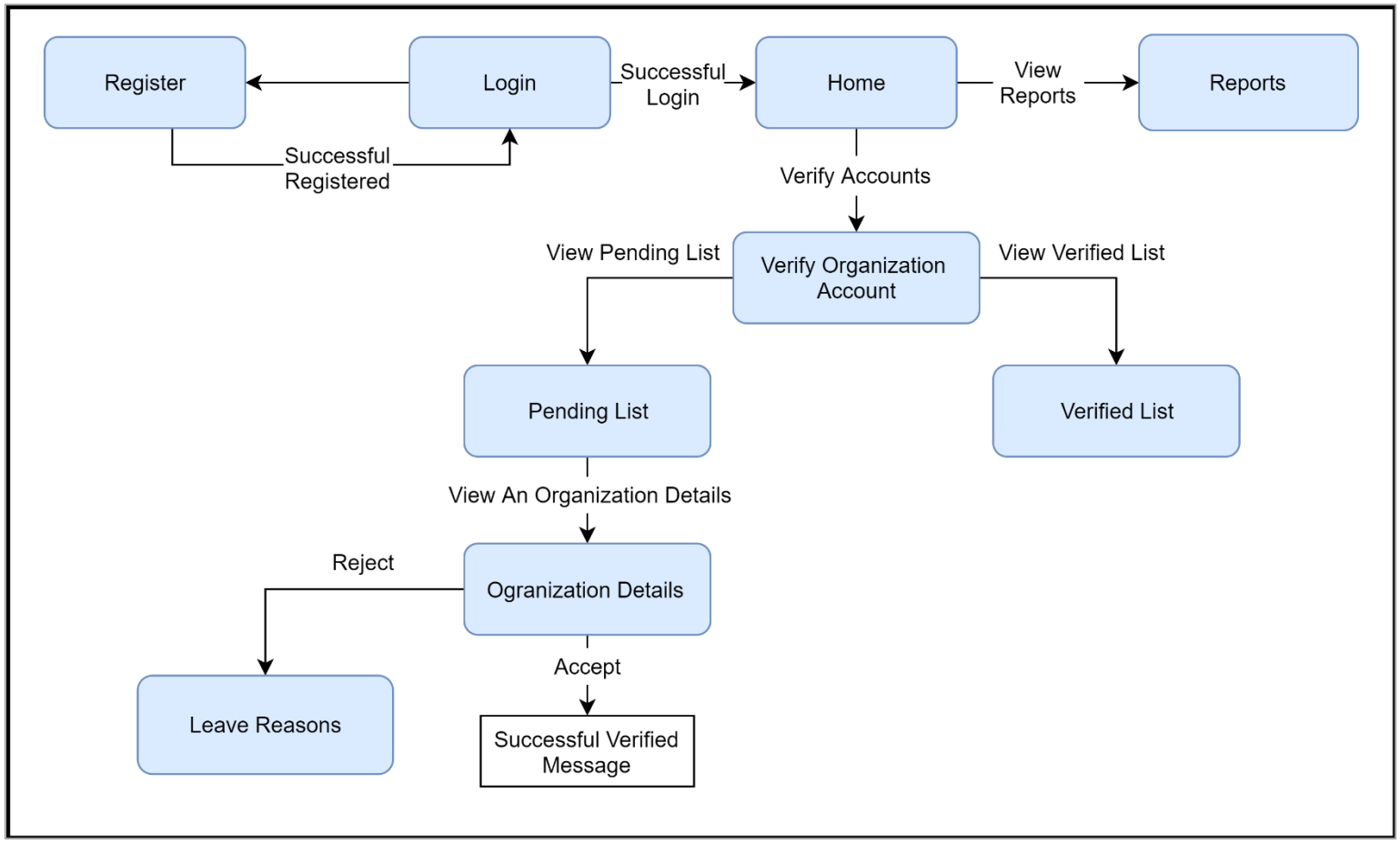

Figure 5.44: The Screens Navigation Flow (Admin)

CHAPTER 6

SYSTEM IMPLEMENTATION

6.1 Introduction

In this chapter, the modules for the entities NGOs/medical centres, members and admin are shown. Improvements in functionality are achieved during system development. Moreover, data validation and error handling implemented for users' input are mentioned. All the API lists used in this system are described according to their endpoints, functions, and parameters. Coding conventions and practices are included too. Lastly, medical equipment recognition results using models i.e., Vgg-16, ResNet-50, and Inception-v3 are discussed. The results of each model are tabulated and compared.

6.2 Modules for Members

6.2.1 Login module

The first-time user needs to sign up to the system with email, username, and password. Member must enter a password more than 6 characters long else an error message will be displayed as shown in Figure 6.1. In addition, password and confirm password must be the same. All input must not be empty. Then, firebase authentication's sign-up method is triggered to carry out verification on account's availability.

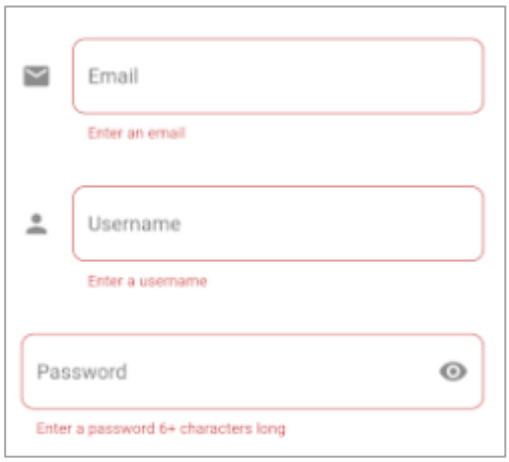

Figure 6.1: Sign Up Form Error Handling

After firebase authentication's sign-up method is triggered, members will receive an email for account verification. Login will only be allowed after email verification is

carried out. Besides, members can reset the password from the login screen by providing the registration email. An alert dialog is fired after the reset password email is successfully sent out.

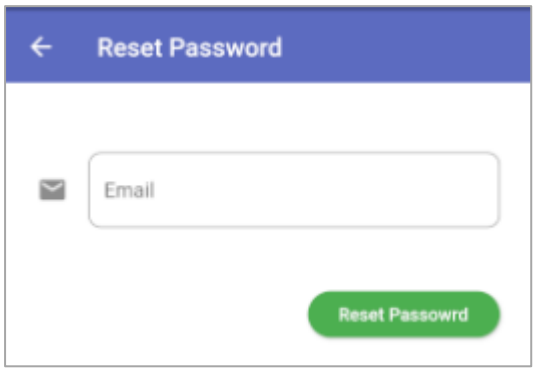

Figure 6.3: Reset Password Form

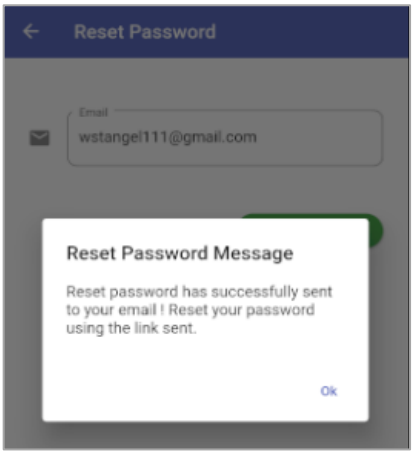

Figure 6.2: Reset Password Email Sent Message

6.2.2 Medical Items Donation

The status of a medical item can be categorized as “new”, “pending”, “success”, “appointment” and “rejected”. The scenarios of each status are explained below.

a) New

After a member registered the medical equipment, it is in “new” status. No icon is shown at the right corner of the medical item tile.

Figure 6.4: “New” Medical Equipment Tile

After tap in the medical equipment tile shown in Figure 6.6, members can view its images, name, and duration used. Member can donate the medical equipment by selecting an organization. Member will get a send donation request confirmation pop up. After tapping “Ok” button, donation request will be sent to the organization for approval. At this moment, the medical equipment status is “pending”.

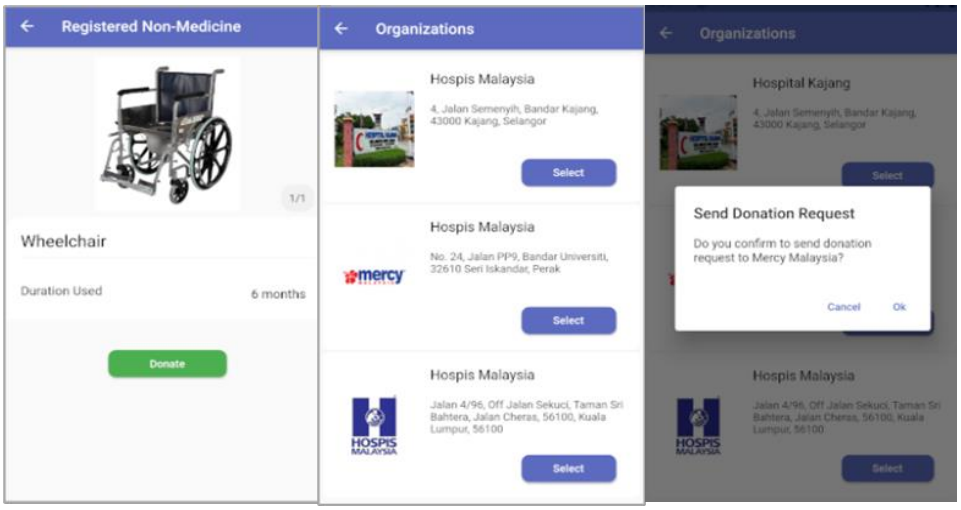

Figure 6.5: “New” Medical Equipment Donation Screens

b) Pending

After sending the donation request to the organization, the medical equipment is “pending”. A pending icon will be displayed.

Figure 6.6: “Pending” Medical Equipment Tile

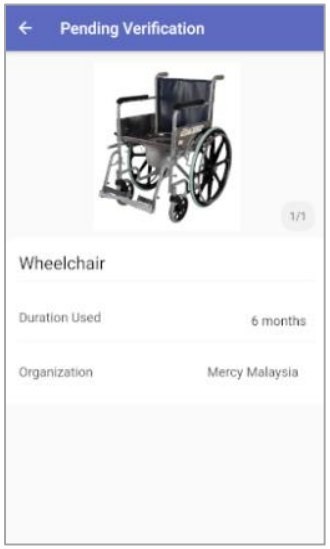

Figure 6.7: “Pending” Medical Equipment Details Screen

c) Success

After approval of medical equipment by the selected organization, the medical equipment is now in “success” status. A verified icon will be displayed.

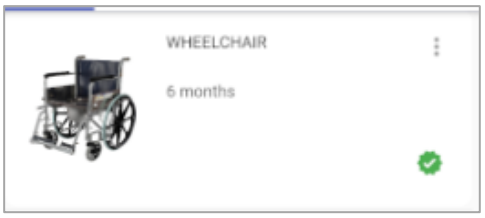

Figure 6.8: “Success” Medical Equipment Tile

Member can now request pickup service or search for drop-off point. Drop-off points of NGOs/medical centres will be discussed in 6.2.3, whereas pickup service will be illustrated in 6.2.4.

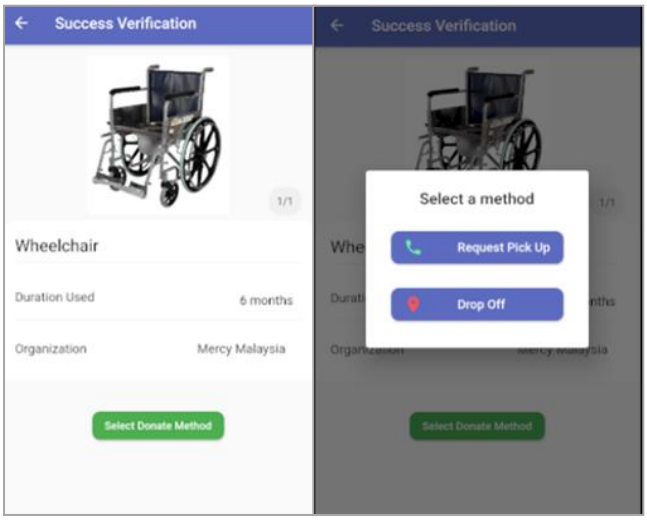

Figure 6.9: “Success” Medical Equipment Donation

d) Rejected

If the organization rejected the medical equipment donation request from members, the medical equipment is now in “rejected” status. A cross icon will be displayed.

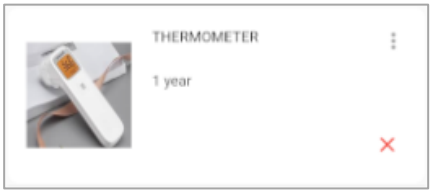

Figure 6.10: “Rejected” Medical Equipment Tile

Rejected reason will be shown to member.

Figure 6.11: “Rejected” Medical Equipment Screen

e) Appointment

After the member requested a pickup service, the medical equipment status is now in “appointment” status. A scheduled calendar icon will be displayed.

Figure 6.12: “Appointment” Medical Equipment Tile

Members can view medical equipment in appointment navigated from medical equipment tile or view all appointments from home.

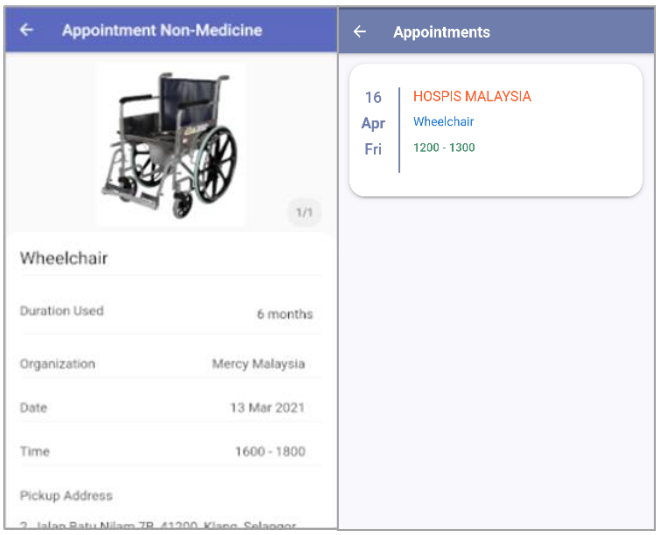

Figure 6.13: “Appointment” Medical Equipment Details

Members can delete the medical equipment in “new” and “rejected” status by tapping the vert icon.

Figure 6.14: Delete Medical Equipment

A delete confirmation pop up message will be shown to prevent a user from deleting the medical equipment without intention.

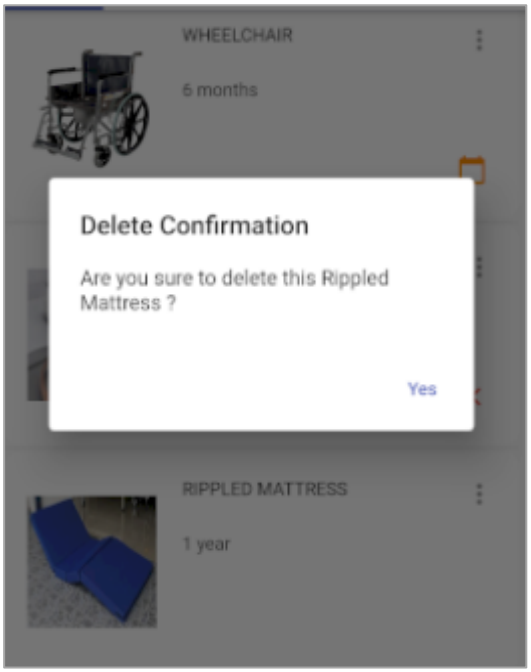

Figure 6.15: Medical Equipment Delete Confirmation

6.2.3 Drop-off Points of NGOs/Medical Centres

User interfaces for locating the organization drop-off points are improved as the figures below. A list of organizations is shown at the bottom of the screen. If the member taps the label 1, the app will get the location of the organization. If a member tap label 2, the app will navigate the member to the details of the organization as shown in Figure 6.17.

Figure 6.16: Drop Off Points Screen

Figure 6.17: Organization Details

6.2.4 Pickup Service

The time slots available for the member to select for pickup are the time slots set by the NGO/medical centre. Members can only schedule the pickup date after 10 days from the date they requests for pickup.

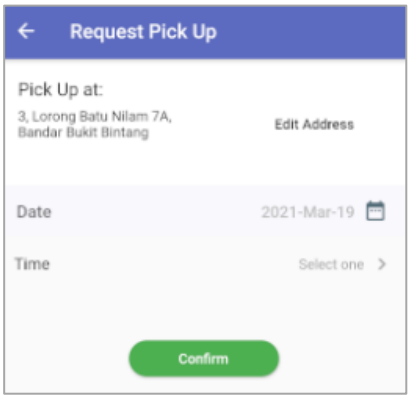

Figure 6.18: Request Pick Up

Figure 6.19: Success Pickup Request Message

Member will receive reminder notification 30 minutes before the actual appointment time.

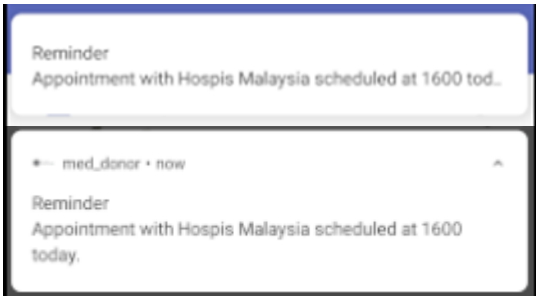

Figure 6.20: Appointment Reminder Notification

6.2.5 Chat Engine

Search for the NGO/medical centre to message function is originally at the NGO/medical centre list in the home screen. It is removed and added as a search floating action button at the right corner of the messages screen. Member can search for the organization to message at the messages screen.

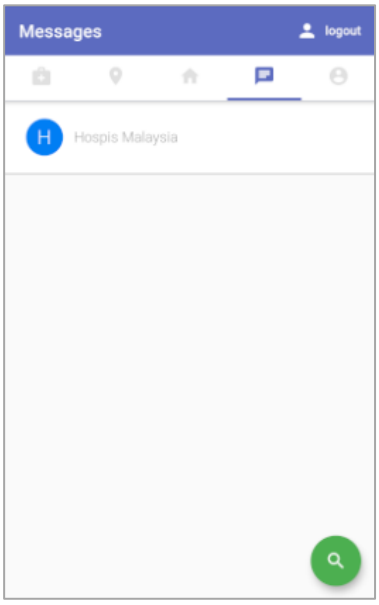

Figure 6.22: Messages Screen

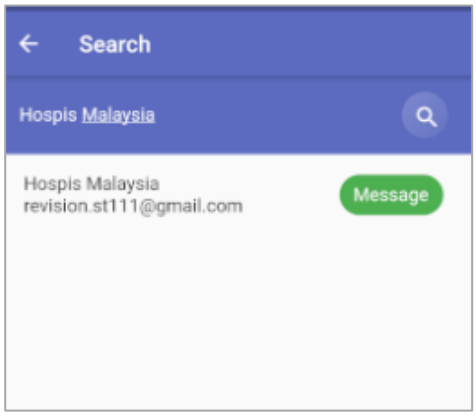

Figure 6.21: Search Result by Organization Name

6.2.6 Account settings

Member can tap the email in the profile screen to edit the profile details. Every profile detail can be edited except for the email address. A pop up form is used to let the member modify the respective detail. Update API will be called after member taps the "Confirm" button.

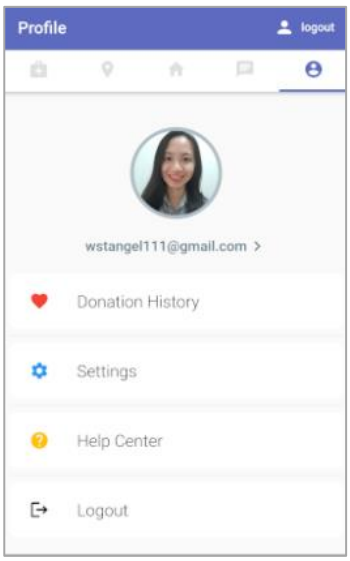

Figure 6.23: Profile Screen

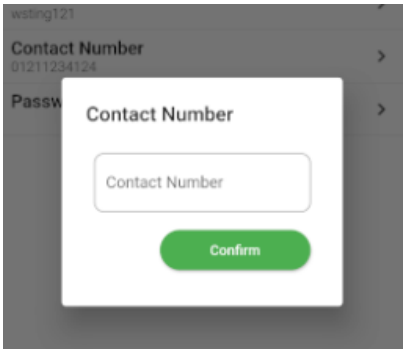

Figure 6.24: Popup Input Form

A successful message will be displayed if the profile detail is successfully updated else, an error message will be displayed.

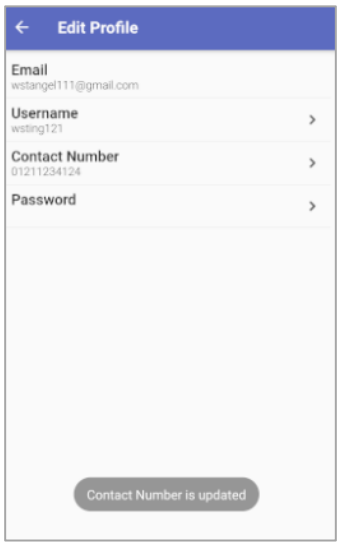

Figure 6.25: Edit Profile with Successful Message

Member will receive notification for appointment reminder or whenever NGO/medical centre requests for medical items in shortage. However, members can switch it off in the settings.

Figure 6.26: Settings

6.3 Modules for NGOs/Medical Centres

6.3.1 Registration of Medical Items

Member can either type in the medical equipment details or scan them. Image of medical equipment is recognised by the deep learning model. The image classification library is imported to get the image details and send it to the model in tflite format for recognition. The trained model saved in extension .h5 is then converted to a TensorFlow Lite file. TensorFlow Lite runs the model in the mobile application. For the inputs, only images with JPG format will be accepted by this scanning function. Then, JPG is decoded to bytes and formatted to float32 (1 x 200 x 200 x 3). At this stage, the model can read the inputs.

Figure 6.27: Medical Equipment Scanning

Figure 6.28: Scanned Result

Some guidelines are given to the member, such as “please place your medical equipment inside the frame” to increase medical equipment prediction accuracy.

6.3.2 Verify Medical Equipment Condition State

As mentioned in 6.2.2, the status of medical items can be categorized as “new”, “pending”, “success”, “rejected” and “appointment”. The status can be reflected in NGOs/medical centres as the following.

a) Pending

All the pending medical equipment will be grouped under the unverified tab. The organization can accept or reject the medical equipment.

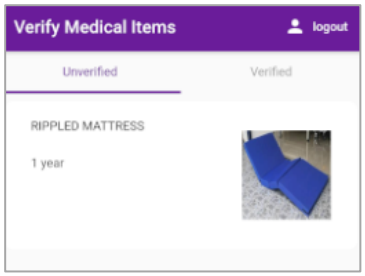

Figure 6.29: Unverified Medical Items

Before accepting or rejecting the medical item, a confirmation pop up will be shown. The NGO/medical centre needs to tap the “Ok” button to confirm the action.

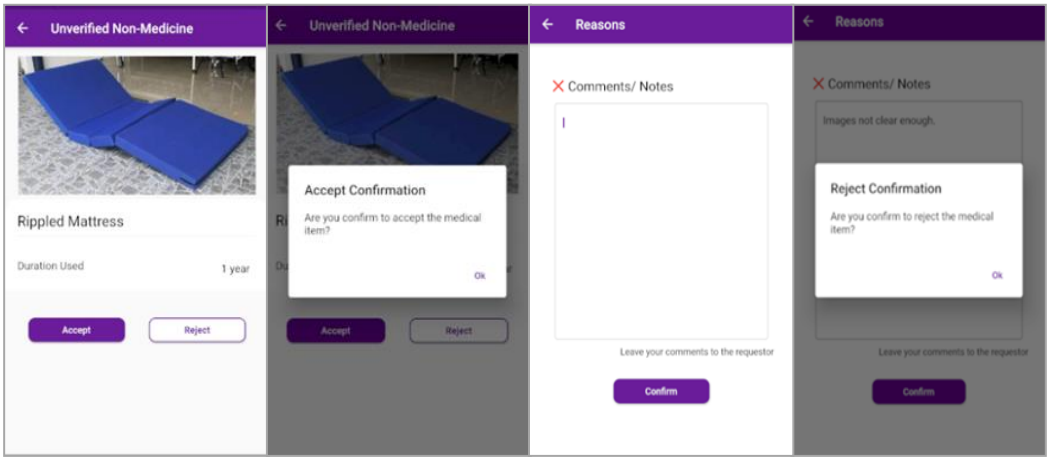

Figure 6.30: Verification of Medical Item Screens

b) Success and Rejected

Similar to Member’s interfaces, “success” and “rejected” medical item can be differentiated by the icons.

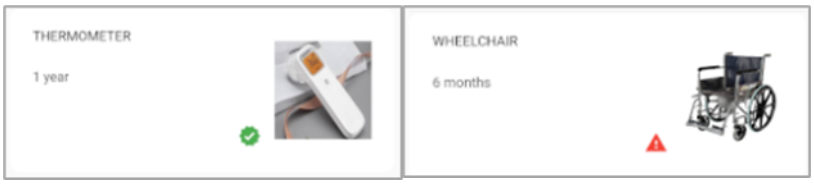

Figure 6.31: Verified Medical Equipment

c) Appointment

All the appointments for pickup service will be listed on the appointments screen. The appointments interface was replaced with the interface below after received the feedbacks from the users.

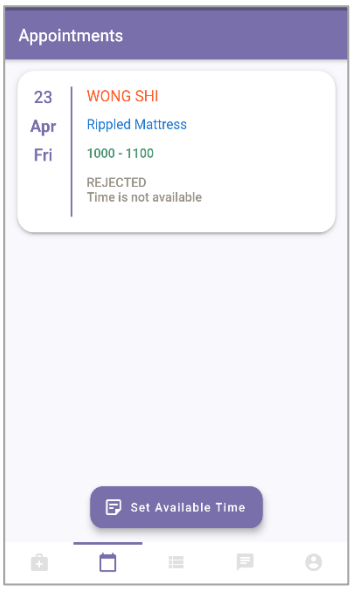

Figure 6.32: "Appointment" Medical Equipment Screen (Organization)

NGO/medical centre needs to set the available time slots for appointment by tapping the "Set Available Time" floating button.

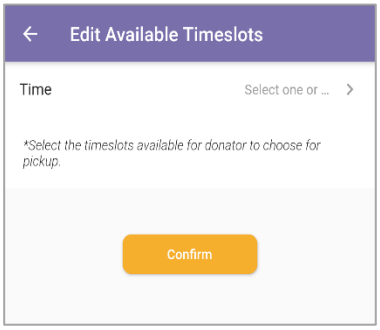

Figure 6.33: Set Available Timeslots

6.3.3 Request for Medical Equipment in Shortage

NGO/medical centre can request for medical equipment in shortage. Members will receive a notification that informs the name of medical equipment in shortage and the organization name. Cloud function is used to trigger the notification once the appointment record is created in firestore.

Figure 6.34: Medical Item in Shortage List

6.3.4 Account Settings

NGO/medical centre can edit its username, password and address in the edit profile.

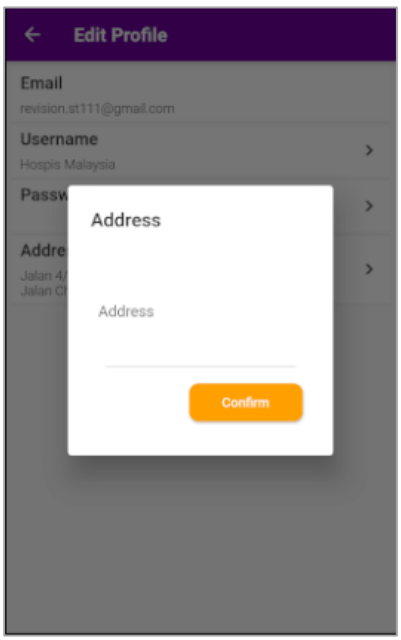

Figure 6.35: Edit Profile with Popup Form

6.4 Modules for Admin

6.4.1 Organization Account Verification

Admin can check to accept or reject the organization registered. Accept confirmation and reject confirmation pop up will be shown to confirm admin's action.

Figure 6.38: "New" Organization

Figure 6.36: "Approved" Organization

Figure 6.37: "Rejected" Organization

6.4.2 Reports

Admin can view the reports of medical equipment donated by members by month.

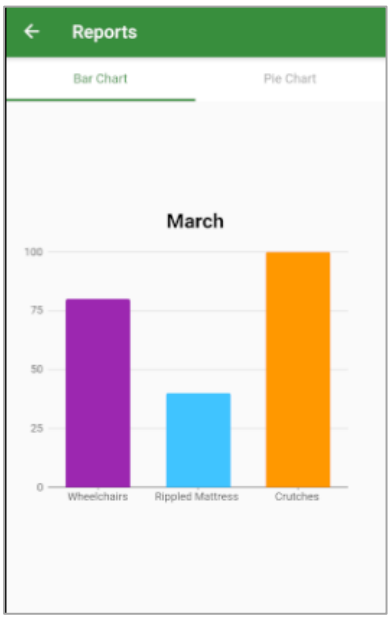

Figure 6.39: Bar Chart

Figure 6.40: Pie Chart

6.5 API List

All the http request endpoints, descriptions and parameters are listed out in the table below.

Table 6.1: API Endpoints

Module: Member		
Endpoint	**Description**	**Parameters**
/createMember	Create a new member account	Username, email, photo
/getAllMember	Retrieve all members record	
/getMember/: memberId	Retrieve a member record	
/updateMemberPhoto	Update a member profile photo	Member id, photo
Module: Organization		
Endpoint	**Description**	**Parameters**
/createOrganization	Create a new organization account	Username, email, photo, license, contact no, address, working days, opening hour, closing hour, status
/getOrganizationAvailable /donation/: status	Retrieve organization available with status “success” for donation	Status

/getOrganization/: organizationId	Retrieve an organization record	Organization id
Module: Medical Equipment		
Endpoints	**Description**	**Parameters**
/createMedicalEquipment	Create a new medical equipment record	Member id, name, duration used, status, images
/getAllMedicalEquipment	Retrieve all medical equipment records	
/getMedicalEquipment/: memberId	Retrieve a medical equipment record	Member id
/updateMedicalEquipment Pending/: medicalEquipmentId	Update medical equipment status from new to pending	Medical equipment id, status, organization name
/updateMedicalEquipment Success/: medicalEquipmentId	Update medical equipment status from pending to success	Medical equipment id, status
/updateMedicalEquipment Rejected/: medicalEquipmentId	Update medical equipment status from pending to rejected	Medical equipment id, status, reason
/updateMedicalEquipment Appointment/: medicalEquipmentId	Update medical equipment status from success to appointment	Medical equipment id, status
/deleteMedicalEquipment/: medicalEquipmentId	Delete a medical equipment record	Medical equipment id
Module: Pick up timeslots		
Endpoints	**Description**	**Parameters**
/createPickupTimeslots	Create or update organization pickup timeslots if timeslots exist	Organization id, timeslots
/getPickupTimeslots /: organizationName	Retrieve organization pickup timeslots by organization name	
/getPickupTimeslotsOrgId /: organizationId	Retrieve organization pickup timeslots by organization id	
Module: Appointment		
Endpoints	**Description**	**Parameters**
/createAppointment	Create a new appointment record	Member id, organization id, address, date, time, medical equipment id, status
/getAppointment/: date /: memberId	Retrieve appointments by date	Member id, date
/updateAppointmentRejected /: appointmentId	Update appointment status to rejected	Appointment id, status, reason

/rescheduleAppointment /: appointmentId	Update rescheduled appointment details	Appointment id, date, address, time, status
Module: Medical Equipment in Shortage		
Endpoints	**Description**	**Parameters**
/createMedicalItemShortage	Create a new medical item in shortage request	Organization id, name, image
/getMedicalItemShortage /: organizationId	Retrieve medical item in shortage by organization id	Organization id
/deleteMedicalItemShortage /: medicalItemId	Delete a medical item in shortage request	Medical equipment id
Module: Info		
Endpoints	**Description**	**Parameters**
/getInformation	Retrieve medical items related information	
Module: Notification		
Endpoints	**Description**	**Parameters**
medicalShortageSendToDevice	Trigger notification when new medical item shortage request is created.	Medical equipment id

6.5.1 API Template

Sample code segments of get, post, update and delete request for API written in typescripts are shown as following.

a) Get

```
export const getMem = member.get(
    '/:memberId',
    async (request: Request, response: Response) => {
        const memberId = request.params.memberId
        database
            .collection(memberCollection)
            .doc(memberId)
            .get()
            .then((member) => {
                if (!member.exists) throw new Error('Member is not found.')
                response.status(200).json({
                    id: member.id, data: member.data()
                })
            })
            .catch((error) => response.status(500).send(error))
    }
);
```

Figure 6.41: Code Segment for Get Request

b) Post

```
export const createMem = member.post(
    '',
    async (request: Request, response: Response) => {
        await database
            .collection(memberCollection)
            .doc(request.body.id)
            .set({
                username: request.body.username,
                email: request.body.email,
                photo: request.body.photo
            }, { merge: true })
            .then(() => response.status(201).send(`Created a new user: ${request.body.id}`))
            .catch((error) => response.status(500).send(error))
    }
);
```

Figure 6.42: Code Segment for Post Request

c) Update

```
export const updateMemPhoto = member.post(
    '',
    async (request: Request, response: Response) => {
        await database
            .collection(memberCollection)
            .doc(request.body.id)
            .update({
                photo: request.body.photo
            })
            .then(() => response.status(201).send(`Updated a new member photo: ${request.body.id}`))
            .catch((error) => response.status(500).send(error))
    }
);
```

Figure 6.43: Code Segment for Update Request

d) Delete

```
export const deleteNonMed = express().delete(
    '/:nonMedicineId',
    async (request: express.Request, response: express.Response) => {
        database
            .collection(nonMedicineCollection)
            .doc(request.params.nonMedicineId)
            .delete()
            .then(() =>
                response
                    .status(204)
                    .json(`Non Medicine successfully deleted: ${request.params.nonMedicineId}`)
            )
            .catch((error) => response.status(500).send(error))
    }
);
```

Figure 6.44: Code Segment for Delete Request

6.6 Medical Equipment Recognition

Training and testing results on deep learning models for VGG-16, ResNet-50 and Inception-v3 are tabulated. Results for hyperparameters tuning using the grid search method are also included. Besides, the models are tested with images from the same distribution and photos uploaded by the user. Analysis of the results gained are performed. Lastly, photo requirements for medical equipment recognition are listed.

6.6.1 Data set

6.6.1.1 Train Set

The first step to carry out object recognition for 10 classes is to collect data set. Around 200 images of each medical equipment class are saved from online resources. The images are resized to 200 px width x 200 px height. Other than the original images gathered, data augmentation is implemented to increase the number of images for training purpose. Total of 13,032 images are created from data augmentation to be the train set. Methods used in data augmentation are to flip the image horizontally and rotate the image by factor 0.2, which is in the range of -20% of 360 degrees to 20% of 360 degrees. The selected data set images are shown in Table 6.2, while the augmented data set is shown in Figure 6.45.

Table 6.2: Original Data Set

				
Commode	Wheelchair	Walking frame	Blood Pressure Set	Breast pump
				
Thermometer	Rippled mattress	Oximeter	Crutch	Therapeutic ultrasound machine

Figure 6.45: Augmented Images

6.6.1.2 Test Set

To evaluate the performance of the final models, test data set is prepared. Test data set for each class is about 40 images with 200 px width x 200 px height. Images in the data set contain higher noise level and blurrier quantity than the images chosen for training set.

Figure 6.46: Test Set Images

6.6.2 Grid Search

A grid search method is implemented to find the best combination of hyperparameters. The hyperparameters are first selected and tested on the three deep learning models. The grid search results are tabulated and compared. Different optimizers (SGD and Adam), batch size (16 and 32), dropout rate (0.0 and 0.2), number of epochs (1 and 6) and learning rate (0.001, 0.01, 0.02, and 0.1) for SGD optimizer whereas (0.009, 0.001, 0.002 and 0.01) for Adam optimizer are tested.

6.6.3 Results

Hyperparameters tuning results are shown. The models are tested with images from the same distribution and photos uploaded by users. Accuracy, loss and execution time are chosen to evaluate the performance of the models on 10 medical equipment.

6.6.3.1 VGG-16

Table 6.3: Hyperparameters Tuning for SGD (VGG-16)

Optimizer	Batch Size	Dropout rate	Epochs	Learning rate	Train Accuracy	Test Accuracy
SGD	16	0.0	1	0.001	0.694494	0.675049
				0.01	0.889354	0.878593
				0.02	0.873157	0.868746
				0.1	0.913560	0.896552
			6	0.001	0.915210	0.901267
				0.01	0.969533	0.948987
				0.02	0.963865	0.947094
				0.1	0.962917	0.943324
		0.2	1	0.001	0.749414	0.739719
				0.01	0.892289	0.881968
				0.02	0.918281	0.908377
				0.1	0.876478	0.855462
			6	0.001	0.940364	0.916871
				0.01	0.969060	0.956556
				0.02	**0.971186**	**0.955611**
				0.1	0.961148	0.943316
	32	0.0	1	0.001	0.529171	0.533308
				0.01	0.875886	0.866797
				0.02	0.888287	0.868225
				0.1	0.924537	0.913578
			6	0.001	0.880138	0.871994
				0.01	0.957487	0.940497
				0.02	0.962920	0.936710
				0.1	0.969060	0.955600
		0.2	1	0.001	0.505683	0.509613
				0.01	0.532955	0.521015
				0.02	0.732640	0.714228
				0.1	0.878836	0.865865
			6	0.001	0.910015	0.905062
				0.01	0.960205	0.948989
				0.02	0.957605	0.937188
				0.1	**0.967642**	**0.951353**

The best combination of VGG-16 using SGD optimizer is batch size 16, a dropout rate of 0.2, 6 epochs, and a learning rate of 0.02.

Table 6.4: Hyperparameters Tuning for Adam (VGG-16)

Optimizer	**Batch Size**	**Dropout rate**	**Epochs**	**Learning rate**	**Train Accuracy**	**Test Accuracy**
Adam	16	0.0	1	0.0009	0.793579	0.775614
				0.001	0.818492	0.811075
				0.002	0.909898	0.900340
				0.01	0.929263	0.914518
			6	0.0009	0.965282	0.937656
				0.001	0.964808	0.936240
				0.002	0.971894	0.950405
				0.01	0.968472	0.943782
		0.2	1	0.0009	0.784247	0.783671
				0.001	0.806803	0.793124
				0.002	0.901865	0.894682
				0.01	0.940363	0.933413
			6	0.0009	0.966226	0.947568
				0.001	0.964927	0.948043
				0.002	0.977444	0.953244
				0.01	**0.975083**	**0.954666**
	32	0.0	1	0.0009	0.660718	0.661808
				0.001	0.726967	0.714722
				0.002	0.873052	0.837989
				0.01	0.937769	0.928671
			6	0.0009	0.942607	0.926795
				0.001	0.949102	0.924899
				0.002	0.969531	0.948525
				0.01	0.973546	0.945697
		0.2	1	0.0009	0.658128	0.659891
				0.001	0.707604	0.715645
				0.002	0.873764	0.856394
				0.01	0.948985	0.932459
			6	0.0009	0.946741	0.938602
				0.001	0.953591	0.944738
				0.002	0.974374	0.954655
				0.01	0.965875	0.944249

The best combination of VGG-16 using Adam optimizer is batch size 16, a dropout rate of 0.2, 6 epochs, and a learning rate of 0.01.

6.6.3.2 Inception-V3

Table 6.5: Hyperparameters Tuning for SGD (Inception-V3)

Optimizer	Batch Size	Dropout rate	Epochs	Learning rate	Train Accuracy	Test Accuracy
SGD	16	0.0	1	0.001	0.663321	0.647150
				0.01	0.915803	0.913083
				0.02	0.936584	0.920183
				0.1	0.887819	0.888984
			6	0.001	0.913913	0.906482
				0.01	**0.966581**	**0.958433**
				0.02	0.970832	0.946616
				0.1	0.955123	0.943800
		0.2	1	0.001	0.612782	0.600401
				0.01	0.925486	0.918756
				0.02	0.908120	0.901775
				0.1	0.921349	0.907912
			6	0.001	0.915566	0.917823
				0.01	0.958315	0.950870
				0.02	0.968233	0.951830
				0.1	0.941901	0.931972
	32	0.0	1	0.001	0.395603	0.392089
				0.01	0.899270	0.886640
				0.02	0.920641	0.913577
				0.1	0.892056	0.885259
			6	0.001	0.872463	0.861612
				0.01	0.953945	0.943787
				0.02	0.967053	0.957961
				0.1	0.965163	0.946625
		0.2	1	0.001	0.442374	0.421819
				0.01	0.888639	0.882863
				0.02	0.909661	0.903653
				0.1	0.895004	0.880558
			6	0.001	0.873053	0.864446
				0.01	0.957724	0.944259
				0.02	0.962211	0.952766
				0.1	0.928197	0.914045

The best combination of Inception-V3 using SGD optimizer is batch size 16, a dropout rate of 0.0, 6 epochs, and a learning rate of 0.01.

Table 6.6: Hyperparameters Tuning for Adam (Inception-V3)

Optimizer	Batch Size	Dropout rate	Epochs	Learning rate	Train Accuracy	Test Accuracy
Adam	16	0.0	1	0.0009	0.939656	0.928207
				0.001	0.936232	0.925835
				0.002	0.930684	0.922994
				0.01	0.869379	0.855510
			6	0.0009	0.967527	0.945673
				0.001	0.964456	0.950876
				0.002	0.959257	0.944742
				0.01	0.956541	0.933401
		0.2	1	0.0009	0.928319	0.914985
				0.001	0.932334	0.920184
				0.002	0.929146	0.914509
				0.01	0.899510	0.890393
			6	**0.0009**	**0.972839**	**0.961275**
				0.001	0.970122	0.955131
				0.002	0.961855	0.948044
				0.01	0.950994	0.933395
	32	0.0	1	0.0009	0.921351	0.912630
				0.001	0.929972	0.917805
				0.002	0.930559	0.913582
				0.01	0.909073	0.899857
			6	0.0009	0.967997	0.957484
				0.001	0.965754	0.951817
				0.002	0.966935	0.948040
				0.01	0.945798	0.930562
		0.2	1	0.0009	0.915564	0.911197
				0.001	0.917217	0.912632
				0.002	0.924658	0.920184
				0.01	0.927726	0.911685
			6	0.0009	0.970240	0.952773
				0.001	0.962682	0.952295
				0.002	0.963511	0.949455
				0.01	0.949812	0.930572

The best combination of Inception-V3 using Adam optimizer is batch size 16, a dropout rate of 0.2, 6 epochs and a learning rate of 0.009.

6.6.3.3 ResNet-50

Table 6.7: Hyperparameters Tuning for SGD (ResNet-50)

Optimizer	Batch Size	Dropout rate	Epochs	Learning rate	Train Accuracy	Test Accuracy
SGD	16	0.0	1	0.001	0.663321	0.647150
				0.01	0.915803	0.913083
				0.02	0.936584	0.920183
				0.1	0.887819	0.888984
			6	0.001	0.945442	0.937653
				0.01	0.979924	0.966469
				0.02	0.985239	0.965995
				0.1	0.984647	0.963642
		0.2	1	0.001	0.673606	0.684881
				0.01	0.949812	0.945209
				0.02	0.946738	0.940966
				0.1	0.897963	0.899413
			6	0.001	0.940247	0.939538
				0.01	0.974847	0.963634
				0.02	**0.983704**	**0.973554**
				0.1	0.976971	0.956556
	32	0.0	1	0.001	0.454761	0.453509
				0.01	0.923125	0.918274
				0.02	0.947804	0.940015
				0.1	0.945208	0.943310
			6	0.001	0.895368	0.877209
				0.01	0.968824	0.959853
				0.02	0.977917	0.967884
				0.1	0.979569	0.965056
		0.2	1	0.001	0.442247	0.431288
				0.01	0.934341	0.932458
				0.02	0.941424	0.928227
				0.1	0.945554	0.932481
			6	0.001	0.898204	0.901759
				0.01	0.968942	0.959853
				0.02	0.975202	0.961750
				0.1	0.977680	0.963641

The best combination of ResNet-50 using SGD optimizer is batch size 16, a dropout rate of 0.2, 6 epochs and a learning rate of 0.02.

Table 6.8: Hyperparameters Tuning for Adam (ResNet-50)

Optimizer	Batch Size	Dropout rate	Epochs	Learning rate	Train Accuracy	Test Accuracy
Adam	16	0.0	1	0.0009	0.961975	0.953241
				0.001	0.957370	0.951352
				0.002	0.967998	0.955597
				0.01	0.925371	0.910230
			6	0.0009	0.987364	0.972133
				0.001	**0.990081**	**0.975916**
				0.002	0.989608	0.972604
				0.01	0.959262	0.923935
		0.2	1	0.0009	0.953591	0.942371
				0.001	0.960084	0.953722
				0.002	0.961502	0.947566
				0.01	0.941779	0.927747
			6	0.0009	0.988190	0.973086
				0.001	0.986065	0.967412
				0.002	0.987954	0.972611
				0.01	0.973786	0.953228
	32	0.0	1	0.0009	0.952054	0.941902
				0.001	0.953116	0.943797
				0.002	0.961739	0.955605
				0.01	0.959851	0.944256
			6	0.0009	0.986538	0.971192
				0.001	0.985239	0.971661
				0.002	0.987364	0.972136
				0.01	0.979690	0.958430
		0.2	1	0.0009	0.948039	0.948990
				0.001	0.948041	0.932927
				0.002	0.964454	0.958909
				0.01	0.959142	0.948502
			6	0.0009	0.982995	0.966464
				0.001	0.984294	0.970241
				0.002	0.988782	0.970713
				0.01	0.979570	0.957488

The best combination of Inception-V3 using Adam optimizer is batch size 16, a dropout rate of 0.0, 6 epochs and a learning rate of 0.001.

Results:

Table 6.9: Grid Search Results Comparison

No.	Pre-trained Model	Optimizer	Batch Size	Dropout rate	Epochs	Learning rate	Mean Train Accuracy	Mean Test Accuracy
1	VGG-16	SGD	16	0.2	6	0.02	0.971186	0.955611
2		Adam	16	0.2	6	0.01	0.975083	0.954666
3	ResNet-50	SGD	16	0.2	6	0.02	0.983704	0.973554
4		Adam	16	0.0	6	0.001	**0.990081**	**0.975916**
5	Inception-V3	SGD	16	0.0	6	0.01	0.966581	0.958433
6		Adam	16	0.2	6	0.0009	0.972839	0.961275

Table 6.10: Results Tested on User Uploaded Images

	Train Set			Test Set					
				Same Distribution Images			Photos Uploaded by User		
	Accuracy	Loss	Training Time (ms/step)	Accuracy	Loss	Testing Time (ms/step)	Accuracy	Loss	Testing Time (ms/step)
VGG-16_SGD	0.9258	0.7465	31	0.9539	0.5206	54	0.8689	1.2422	53
VGG-16_Adam	0.9414	0.5256	31	0.9608	0.3913	51	0.8306	2.3979	51
ResNet-50_SGD	0.9700	0.1010	32	**0.9724**	0.1392	47	**0.9235**	0.2472	46
ResNet-50_Adam	0.9855	0.0635	31	**0.9862**	0.0576	48	0.8989	0.2600	45
Inception-V3_SGD	0.9824	0.0882	27	0.9632	0.1479	37	0.9126	0.2652	39
Inception-V3_Adam	0.9929	0.0386	28	0.9609	0.1236	38	**0.9372**	0.2174	39

Table 6.11: Model Saved File Size (.h5)

	VGG-16_SGD	VGG-16_Adam	ResNet-50_SGD	ResNet-50_Adam	Inception-V3_SGD	Inception-V3_Adam
Model File Size (.h5)	57,560	57,604	92,537	92,701	85,739	85,904

6.6.4 Discussions and Analysis

6.6.4.1 Epoch Size

During grid search to get the best combination of hyperparameters, the number of epochs 1 and 6 are used. The accuracy for 1 epoch is lesser than 6 epochs. Passing all the data only once to a model for training is too big to compute. The data should be divided into several batches for few epochs. Therefore, 6 epochs performed better than 1 epoch.

6.6.4.2 Model Architecture Structures

Based on the results shown in Table 6.10, the execution time for Inception-v3 is the fastest, followed by ResNet-50 and VGG-16. ResNet-50 has the largest file size, followed by Inception-v3 and VGG-16. ResNet-50 is the deepest convolutional neural network among the models. It has 50 layers. Inception-v3 has 48 layers, whereas VGG-16 only consists of 16 layers. Thus, the deeper the network, the larger the storage size as there are more weights. Both VGG-16 models with SGD and Adam optimizer have higher loss value compared to the other models when testing with the same distribution images as train set or user uploaded images. Although ResNet-50 trained with the Adam optimizer performed the best when testing with images from the same distribution, Inception-v3 performed better with the highest accuracy of **0.9372** when dealing with images uploaded by users (blurry and noisy images from smartphones). The Inception-v3 model used Adam optimizer, batch size 16, a dropout rate of 0.2, 6 epochs, and a learning rate of 0.0009 for the hyperparameters.

6.6.4.3 Photo Requirements for Recognition

To know the photo requirements needed for recognition, the testing results with correct and wrong labels are investigated.

Table 6.12: Photos Tested with Wrong Labels

No.	Photo	√	×	Explanations
1		Blood Pressure Set	Breast Pump	The box for blood pressure set should not be included in the photo.
2		Blood Pressure Set	Therapeutic ultrasound machine	Only the monitor of the blood pressure set is taken in this photo. The arm cuff should be included.
3		Wheelchair	Commode	Wheelchair is similar as commode, but commode has an opening in the middle of the chair. Thus, the photo should be taken at the front angle of the commode.
4		Thermometer	Oximeter	Both thermometer and oximeter have a monitor for showing results, but the length of the thermometer is longer than oximeter. The photo tested does not include the whole thermometer body which leads to an inaccurate result.
5		Rippled Mattress	Therapeutic ultrasound machine	The photo tested includes many background objects which confuse the recognition model. Thus, the rippled mattress should be

				taken in plain background and less unrelated objects.

CHAPTER 7

SYSTEM TESTING

7.1 Introduction

Testing is required to ensure the functionalities are working as expected and fulfil the users' requirements. Thus, several tests are carried out, including unit test and usability test to verify and validate the system. Five users with medical background are invited to carry out usability testing for the member entity system.

7.2 Unit Test

In total, 20 unit tests executed. Test cases with test summary, test steps, test data, expected results, actual results and status of test are recorded.

7.2.1 Test Cases

Table 7.1: Test Case #1 – Create Member Account

Test Case #	1	**Test Case Name**	Create Member Account	**Module**	Member
Test Case Summary	To test whether a member account can be created.				
Pre-Conditions	Member requires a valid email to sign up.				
Executed By	Wong Shi Ting	**Execution Date**	10 March 2021		

Test Summary	**Test Steps**	**Test Data**	**Expected Result**	**Actual Result**	**Status (PASS/FAIL)**
Sign up a member account with valid email, username and password.	1. Enter an email.	Valid email	Successful sign up	Successful sign up	Pass
	2. Enter a username.	Valid username			
	3. Enter a password.	Valid password			
	4. Enter a confirm password.	Valid password			
	5. Tap Sign Up button	N/A			
Sign up a member account with invalid email	1. Enter an email.	Invalid email	Unsuccessful sign up with invalid email message display	Unsuccessful sign up with invalid email message display	Pass
	2. Enter a username.	Valid username			
	3. Enter a password.	Valid password			
	4. Enter a confirm password.	Valid password			
	5. Tap Sign Up button	N/A			
Sign up a member account with invalid password	1. Enter an email.	Valid email	Unsuccessful sign up with invalid password message display	Unsuccessful sign up with invalid password message display	Pass
	2. Enter a username.	Valid username			
	3. Enter a password.	Invalid password			
	4. Enter a confirm password.	Invalid password			
	5. Tap Sign Up button	N/A			

Table 7.2: Test Case #2 – Login Member Account

Test Case #	2	**Test Case Name**	Login Member Account	**Module**	Member
Test Case Summary	To test whether a member can login to his account.				
Pre-Conditions	Member requires a valid member account to login.				
Executed By	Wong Shi Ting	**Execution Date**	10 March 2021		

Test Summary	**Test Steps**	**Test Data**	**Expected Result**	**Actual Result**	**Status (PASS/FAIL)**
Login a member account with valid email, and password.	1. Enter an email. 2. Enter a password. 3. Tap Login button.	Valid email Valid password N/A	Successful login	Successful login	Pass
Login a member account with valid email, and invalid password.	1. Enter an email. 2. Enter a password. 3. Tap Login button.	Invalid email Valid password N/A	Unsuccessful login with invalid credential information provided message	Unsuccessful login with invalid credential information provided message	Pass
Login a member account with valid email, and invalid password.	1. Enter an email. 2. Enter a password. 3. Tap Login button.	Invalid email Valid password N/A	Unsuccessful login with invalid credential information provided message	Unsuccessful login with invalid credential information provided message	Pass

Table 7.3: Test Case #3 – Register Medical Equipment

Test Case #	3	**Test Case Name**	Register Medical Equipment	**Module**	Member
Test Case Summary	To test whether a member can register a medical equipment.				
Pre-Conditions	-				
Executed By	Wong Shi Ting	**Execution Date**	10 March 2021		

Test Summary	**Test Steps**	**Test Data**	**Expected Result**	**Actual Result**	**Status (PASS/FAIL)**
Register a medical equipment through scanning.	1. Tap Scan/ Upload.	N/A	Successful registration	Successful registration	Pass
	2. Take the medical equipment's photo.	Photo			
	3. Tap Next button.	N/A			
	4. Enter a duration used.	Duration used			
	5. Tap Confirm button.	N/A			
Register a medical equipment through typing and upload photo through camera.	1. Tap Type.	N/A	Successful registration	Successful registration	Pass
	2. Enter medical equipment's name.	Name			
	3. Enter a duration used.	Duration used			
	4. Upload a medical equipment photo through camera.	Photo			
	5. Tap Confirm button.	N/A			
Register a medical equipment through typing and upload photo through gallery.	1. Tap Type.	N/A	Successful registration	Successful registration	Pass
	2. Enter medical equipment's name.	Name			
	3. Enter a duration used.	Duration used			
	4. Upload a medical equipment photo through gallery.	Photo			
	5. Tap Confirm button.	N/A			
Register a medical equipment through typing with invalid medical equipment's name.	1. Tap Type.	N/A	Error message display.	Error message display.	Pass
	2. Enter medical equipment's name.	Invalid name			

Table 7.4: Test Case #4 – View Medical Equipment

Test Case #	4	**Test Case Name**	View Medical Equipment	**Module**	Member
Test Case Summary	To test whether a member can view medical equipment with different status.				
Pre-Conditions	Medical equipment is required to be registered				
Executed By	Wong Shi Ting	**Execution Date**	10 March 2021		

Test Summary	**Test Steps**	**Test Data**	**Expected Result**	**Actual Result**	**Status (PASS/FAIL)**
View new registered medical equipment	1. Tap medical equipment tile with new status (no icon shown).	N/A	New registered medical equipment's details are displayed.	New registered medical equipment's details are displayed.	Pass
View pending verification medical equipment	1. Tap medical equipment tile with pending status (pending icon shown).	N/A	Pending verification medical equipment's details are displayed.	Pending verification medical equipment's details are displayed.	Pass
View success verification medical equipment	1. Tap medical equipment tile with success status (verified icon shown).	N/A	Success verification medical equipment's details are displayed.	Success verification medical equipment's details are displayed.	Pass
View rejected verification medical equipment	1. Tap medical equipment tile with rejected status (cross icon shown).	N/A	Rejected verification medical equipment's details are displayed.	Rejected verification medical equipment's details are displayed.	Pass
View appointment medical equipment	1. Tap medical equipment tile with appointment status (scheduled calendar icon shown).	N/A	Appointment medical equipment's details are displayed.	Appointment medical equipment's details are displayed.	Pass

Table 7.5: Test Case #5 – Send Medical Equipment Verification for Donation Request

Test Case #	5	**Test Case Name**	Send Medical Equipment Verification	**Module**	Member
Test Case Summary	To test whether a member can send medical equipment verification for donation request.				
Pre-Conditions	Medical equipment is required to be registered				
Executed By	Wong Shi Ting	**Execution Date**	10 March 2021		

Test Summary	**Test Steps**	**Test Data**	**Expected Result**	**Actual Result**	**Status (PASS/FAIL)**
Send medical equipment verification for donation request	1. Tap medical equipment tile with new status (no icon shown).	N/A	Verification sent to the organization selected. The medical equipment's status changed to pending.	Verification sent to the organization selected. The medical equipment's status changed to pending.	Pass
	2. Tap Donate button.	N/A			
	3. Select an organization.	N/A			
	4. Tap Send button for confirmation.	N/A			

Table 7.6: Test Case #6 – Request Pickup Service

Test Case #	6	**Test Case Name**	Request Pickup Service	**Module**	Member
Test Case Summary	To test whether a member can request pickup service.				
Pre-Conditions	Medical equipment is required to be verified.				
Executed By	Wong Shi Ting	**Execution Date**	10 March 2021		

Test Summary	**Test Steps**	**Test Data**	**Expected Result**	**Actual Result**	**Status (PASS/FAIL)**
Request pickup service	1. Tap medical equipment tile with success status (verified icon shown).	N/A	Appointment request sent to the organization. The medical equipment's status changed to appointment.	Appointment request sent to the organization. The medical equipment's status changed to appointment.	Pass
	2. Tap Select Donate Method button.	N/A			
	3. Enter address.	Valid address			
	4. Select date and time.	Date and time			
	5. Tap Confirm button.				

Table 7.7: Test Case #7 – Reject Appointment

Test Case #	7	**Test Case Name**	Request Pickup Service	**Module**	Organization
Test Case Summary	To test whether an organization can reject the appointment.				
Pre-Conditions	Member requested for pickup service.				
Executed By	Wong Shi Ting	**Execution Date**	10 March 2021		

Test Summary	**Test Steps**	**Test Data**	**Expected Result**	**Actual Result**	**Status (PASS/FAIL)**
Reject appointment	1. Tap Reject button on appointment list.	N/A	Successfully rejected the appointment. Member is required to request for pickup service again.	Successfully rejected the appointment. Member is required to request for pickup service again	Pass
	2. Tap Confirm button to reject the appointment.	N/A			

Table 7.8: Test Case #8 – Reschedule Appointment

Test Case #	8	**Test Case Name**	Request Pickup Service	**Module**	Member
Test Case Summary	To test whether a member can reschedule appointment with organization.				
Pre-Conditions	Organization rejected the appointment.				
Executed By	Wong Shi Ting	**Execution Date**	10 March 2021		

Test Summary	**Test Steps**	**Test Data**	**Expected Result**	**Actual Result**	**Status (PASS/FAIL)**
Reschedule pickup service	1. Tap medical equipment tile with appointment rejected status (scheduled calendar icon shown).	N/A	Appointment request sent to the organization. The medical equipment's status changed to appointment.	Appointment request sent to the organization. The medical equipment's status changed to appointment.	Pass
	2. Tap Select Rescheduled the appointment button.	N/A			
	3. Enter address.	Valid address			
	4. Select date and time.	Date and time			
	5. Tap Confirm button.				

Table 7.9: Test Case #9 – Search Drop-off Points

Test Case #	9	**Test Case Name**	Search Drop-off Points	**Module**	Member
Test Case Summary	To test whether a member can search drop-off points.				
Pre-Conditions	-				
Executed By	Wong Shi Ting	**Execution Date**	10 March 2021		

Test Summary	**Test Steps**	**Test Data**	**Expected Result**	**Actual Result**	**Status (PASS/FAIL)**
Search drop-off points through select donate method.	1. Tap Select Donate Method button.	N/A	Options of pickup service and drop off are displayed.	Options of pickup service and drop off are displayed.	Pass
	2. Tap Drop Off.	N/A	Google maps with organization's location markers are displayed.	Google maps with organization's location markers are displayed.	
	3. Tap the organization	N/A	Location of the organization and direction on the map is displayed.	Location of the organization and direction on the map is displayed.	
	4. Tap View button on the organization tile	N/A	Organization details are displayed.	Organization details are displayed.	
Search drop-off points through navigation bar.	1. Tap drop-off icon at the navigation bar.	N/A	Google maps with organization's location markers are displayed.	Google maps with organization's location markers are displayed.	Pass
	2. Tap the organization photo.	N/A	Location of the organization and direction on the map is displayed.	Location of the organization and direction on the map is displayed.	
	3. Tap View button on the organization tile.	N/A	Organization details are displayed.	Organization details are displayed.	

Table 7.10: Test Case #10 – View Information

Test Case #	10	**Test Case Name**	View Information	**Module**	Member
Test Case Summary	To test whether a member can view information.				
Pre-Conditions	Member login to his account.				
Executed By	Wong Shi Ting	**Execution Date**	10 March 2021		

Test Summary	**Test Steps**	**Test Data**	**Expected Result**	**Actual Result**	**Status (PASS/FAIL)**
View information.	1. Tap the information tile in the home screen.	N/A	Information are displayed.	Information are displayed.	Pass

Table 7.11: Test Case #11 – Message Organization

Test Case #	11	**Test Case Name**	Message Organization	**Module**	Member, organization
Test Case Summary	To test whether a member can message the organization for enquiries.				
Pre-Conditions	Member or organization login to his account.				
Executed By	Wong Shi Ting	**Execution Date**	10 March 2021		

Test Summary	**Test Steps**	**Test Data**	**Expected Result**	**Actual Result**	**Status (PASS/FAIL)**
Member searches an organization to send enquiries.	1. Tap the search floating icon in the message screen.	N/A	Search screen is displayed.	Search screen is displayed.	Pass
	2. Enter organization's name.	Organization's name			
	3. Tap Message button.	N/A	Chat room is displayed.	Chat room is displayed.	
	4. Enter messages.	Messages			
	5. Tap send icon.	N/A	Successfully sent the messages.	Successfully sent the messages.	
Organization replies the member's enquiries	1. Tap the chat room.	N/A	Chat room is displayed.	Chat room is displayed.	Pass
	2. Enter messages.	Messages			
	3. Tap send icon.	N/A	Successfully sent the messages.	Successfully sent the messages.	

Table 7.12: Test Case #12 – View Donation History

Test Case #	12	**Test Case Name**	View Donation History	**Module**	Member, organization
Test Case Summary	To test whether a member and organization can view the donation history.				
Pre-Conditions	Member have donated the medical equipment.				
Executed By	Wong Shi Ting	**Execution Date**	10 March 2021		

Test Summary	**Test Steps**	**Test Data**	**Expected Result**	**Actual Result**	**Status (PASS/FAIL)**
View donation history from profile screen.	1. Tap Donation History in the profile screen.	N/A	Donation history with medical equipment details are displayed.	Donation history with medical equipment details are displayed.	Pass
	2. Tap share icon.	N/A	Share options are displayed.	Share options are displayed.	
	3. Select channel to share to social media.	N/A	Successfully shared the donation history to social media.	Successfully shared the donation history to social media.	

Table 7.13: Test Case #13 – Verify Medical Equipment

Test Case #	13	**Test Case Name**	Verify Medical Equipment	**Module**	Organization
Test Case Summary	To test whether an organization can verify medical equipment.				
Pre-Conditions	Member requested for verification of the medical equipment.				
Executed By	Wong Shi Ting	**Execution Date**	10 March 2021		

Test Summary	**Test Steps**	**Test Data**	**Expected Result**	**Actual Result**	**Status (PASS/FAIL)**
Accept the medical equipment.	1. Tap unverified tab of the medical items screen.	N/A	Pending verification medical equipment's details are displayed.	Pending verification medical equipment's details are displayed.	Pass
	2. Tap Accept button.	N/A	Confirmation message is displayed.	Confirmation message is displayed.	
	3. Tap Accept button for confirmation.	N/A	Successfully accepted the medical equipment.	Successfully accepted the medical equipment.	
Reject the medical equipment.	1. Tap unverified tab of the medical items screen.	N/A	Pending verification medical equipment's details are displayed.	Pending verification medical equipment's details are displayed.	Pass
	2. Tap Reject button.	N/A	Navigate to reasons screen.	Navigate to reasons screen.	
	3. Enter reasons for rejection.	Reasons			
	4. Tap Confirm button.	N/A	Confirmation message is displayed.	Confirmation message is displayed.	
	4. Tap Reject button.	N/A	Successfully rejected the medical equipment.	Successfully rejected the medical equipment.	

Table 7.14: Test Case #14 – View Verified Medical Equipment

Test Case #	14	**Test Case Name**	View Verified Medical Equipment	**Module**	Organization
Test Case Summary	To test whether an organization can view verified medical equipment.				
Pre-Conditions	Organization have verified the medical equipment.				
Executed By	Wong Shi Ting		**Execution Date**	10 March 2021	

Test Summary	**Test Steps**	**Test Data**	**Expected Result**	**Actual Result**	**Status (PASS/FAIL)**
View accepted medical equipment.	1. Tap medical equipment tile with success status (verified icon shown).	N/A	Accepted medical equipment's details are displayed.	Accepted medical equipment's details are displayed.	Pass
View rejected medical equipment.	1. Tap medical equipment tile with rejected status (cross icon shown).	N/A	Rejected medical equipment's details are displayed.	Rejected medical equipment's details are displayed.	Pass

Table 7.15: Test Case #15 – Request Medical Equipment in Shortage

Test Case #	15	**Test Case Name**	Request Medical Equipment in Shortage	**Module**	Member, organization
Test Case Summary	To test whether an organization can view request medical equipment in shortage.				
Pre-Conditions	N/A				
Executed By	Wong Shi Ting		**Execution Date**	10 March 2021	

Test Summary	**Test Steps**	**Test Data**	**Expected Result**	**Actual Result**	**Status (PASS/FAIL)**
Request Medical Equipment and upload photo through camera.	1. Tap Request button in home screen.	N/A	Successfully post request and member get a notification about the medical equipment shortage.	Successfully post request and member get a notification about the medical equipment shortage.	Pass
	2. Enter medical equipment's name.	Medical equipment's name			
	3. Upload photo through camera.	Photo			

Request Medical Equipment and upload photo through gallery.	1. Tap Request button in home screen.	N/A	Successfully post request and member get a notification about the medical equipment shortage.	Successfully post request and member get a notification about the medical equipment shortage.	Pass
	2. Enter medical equipment's name.	Medical equipment's name			
	3. Upload photo through gallery.	Photo			

Table 7.16: Test Case #16– Upload Profile Photo

Test Case #	16	**Test Case Name**	Upload Profile Photo	**Module**	Member, organization
Test Case Summary	To test whether member and organization can upload profile photo.				
Pre-Conditions	N/A				
Executed By	Wong Shi Ting		**Execution Date**	10 March 2021	

Test Summary	**Test Steps**	**Test Data**	**Expected Result**	**Actual Result**	**Status (PASS/FAIL)**
Upload profile photo through camera.	1. Tap the profile photo in profile screen.	N/A	Successfully uploaded profile photo.	Successfully uploaded profile photo.	Pass
	2. Upload profile photo through camera.	Profile photo			
Upload profile photo through gallery.	1. Tap the profile photo in profile screen.	N/A	Successfully uploaded profile photo.	Successfully uploaded profile photo.	Pass
	2. Upload profile photo through gallery.	Profile photo			

Table 7.17: Test Case #17 – Edit Profile Details

Test Case #	17	**Test Case Name**	Upload Profile Photo	**Module**	Member, organization
Test Case Summary	To test whether member and organization can edit profile details.				
Pre-Conditions	N/A				
Executed By	Wong Shi Ting	**Execution Date**	10 March 2021		

Test Summary	**Test Steps**	**Test Data**	**Expected Result**	**Actual Result**	**Status (PASS/FAIL)**
Member edits username and contact number.	1. Tap the email in profile screen.		Successfully edited the profile details.	Successfully edited the profile details	Pass
	2. Tap the username.				
	3. Enter username.	Valid username			
	4. Tap Confirm button.				
	5. Tap the contact number.				
	6. Enter contact number.	Valid contact number			
	7. Tap Confirm button.				
Member edits username and address.	1. Tap the email in profile screen.		Successfully edited the profile details.	Successfully edited the profile details	Pass
	2. Tap the username.				
	3. Enter username.	Valid username			
	4. Tap Confirm button.				
	5. Tap the address.				
	6. Enter address.	Valid address			
	7. Tap Confirm button.				

Table 7.18: Test Case #18 – Reset Password

Test Case #	18	**Test Case Name**	Upload Profile Photo	**Module**	Member, organization
Test Case Summary	To test whether member and organization can reset password.				
Pre-Conditions	N/A				
Executed By	Wong Shi Ting	**Execution Date**	10 March 2021		

Test Summary	**Test Steps**	**Test Data**	**Expected Result**	**Actual Result**	**Status (PASS/FAIL)**
Reset with valid password in profile.	1. Tap the email in profile screen.		Successfully reset the password.	Successfully reset the password.	Pass
	2. Tap the password.				
	3. Enter password.	Valid password			
	4. Enter confirmed password.	Valid password			
	5. Tap Confirm button.				
Reset with invalid password in profile.	1. Tap the email in profile screen.		Unsuccessfully reset the password with error message display.	Unsuccessfully reset the password with error message display.	Pass
	2. Tap the password.				
	3. Enter password.	Invalid password			
	4. Enter confirmed password.	Invalid password			
	5. Tap Confirm button.				
Reset with valid email in login screen (forget password).	1. Tap the forget password in login screen.		Successfully sent reset password email to the email provided.	Successfully sent reset password email to the email provided.	Pass
	2. Enter email.	Valid email			
	3. Tap Confirm button.				
Reset with invalid email in login screen (forget password).	1. Tap the forget password in login screen.		Unsuccessfully sent reset password email with error message display.	Unsuccessfully sent reset password email with error message display.	Pass
	2. Enter email.	Invalid email			
	3. Tap Confirm button.				

Table 7.19: Test Case #19 – Verify Organization Account

Test Case #	19	**Test Case Name**	Verify Organization Account	**Module**	Admin
Test Case Summary	To test whether admin can verify organization account.				
Pre-Conditions	Organization sign up his account.				
Executed By	Wong Shi Ting	**Execution Date**	10 March 2021		

Test Summary	**Test Steps**	**Test Data**	**Expected Result**	**Actual Result**	**Status (PASS/FAIL)**
Accept the organization.	1. Tap unverified tab of the organization screen.				Pass
	2. Tap the organization tile.		Pending verification organization's details are displayed.	Pending verification organization's details are displayed.	
	3. Tap Accept button.		Confirmation message is displayed.	Confirmation message is displayed.	
	4. Tap Accept button for confirmation.		Successfully accepted the organization.	Successfully accepted the organization.	
Reject the organization.	1. Tap unverified tab of the organization screen.				Pass
	2. Tap the organization tile.		Pending verification organization's details are displayed.	Pending verification organization's details are displayed.	
	3. Tap Reject button.		Navigate to reasons screen.	Navigate to reasons screen.	
	4. Enter reasons for rejection.	Reasons			
	5. Tap Confirm button.		Confirmation message is displayed.	Confirmation message is displayed.	
	6. Tap Reject button.		Successfully rejected the organization	Successfully rejected the organization	

Table 7.20: Test Case #20 – View Monthly Donation Reports

Test Case #	20	**Test Case Name**	View Monthly Donation Reports	**Module**	Admin
Test Case Summary	To test whether admin can view monthly donation reports.				
Pre-Conditions	N/A				
Executed By	Wong Shi Ting		**Execution Date**	10 March 2021	

Test Summary	**Test Steps**	**Test Data**	**Expected Result**	**Actual Result**	**Status (PASS/FAIL)**
View monthly donation reports through pie chart.	1. Tap view monthly reports. 2. Tap pie chart tab.		Monthly donation reports in pie chart is displayed.	Monthly donation reports in pie chart is displayed.	Pass
View monthly donation reports through bar chart.	1. Tap view monthly reports. 2. Tap bar chart tab.		Monthly donation reports in bar chart is displayed.	Monthly donation reports in bar chart is displayed.	Pass

7.3 Usability Test

The users will be given 6 different scenarios to test the system. Refer to Appendix E. After conducting the usability testing, a user satisfaction form will be filled by the testers. The usability testing results are included in Appendix F. The test results are tabulated in the table below. Overall, the member role mobile app achieved 84% of the SUS Score. Feedbacks on the most like and least like features are received. The analysis is carried out on the feedbacks to improve the functionalities and user interfaces of the mobile app.

Table 7.21: Usability Testing Results

Participant #	**Score by Question #**										**Total**	**SUS Score**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
1	4	3	3	2	3	3	3	3	3	3	30	75
2	3	4	4	3	3	4	2	4	4	4	35	87.5
3	4	3	3	3	3	4	3	3	3	4	33	82.5
4	4	4	3	3	4	4	4	4	3	3	36	90
5	3	2	3	3	4	4	4	3	4	4	34	85
Average	3.6	3.2	3.2	2.8	3.4	3.8	3.2	3.4	3.4	3.6	33.6	***84***

Comments received from the participants are as following:

1. Scan and type for registration of medical equipment, which are separated using two buttons, can be combined as one workflow.
2. Searching of organizations account by username for chat engine should receive both uppercase and lowercase.
3. Registration of medical equipment can be included in the home screen so that the user can find it more easily.
4. An appointment can be made for medical equipment drop-off. Currently, appointment only can be made for pickup service.
5. Some users cannot find the donate button after registering the medical equipment. There should be a donation button for the user to tap on the home screen.

6. The mobile app should be able to track the current location of the user for the address of pickup service request. Currently, users need to type in their address when requesting the pickup service.
7. More user guidelines should be included when users perform the details input processes.

As a result of the testers' feedback, changes to the functionalities and user interfaces are made. However, due to time constraints, only comments 1, 2, and 7 have been chosen for improvement. Other suggestions will be taken into account for potential improvements in the future.

7.4 User Acceptance Test

The user acceptance test is carried by 5 users with medical backgrounds. Scenarios are given to the users to perform the tests. The UAT test results are included in appendix G.

Table 7.22: UAT Tests Listing

UAT ID	Modules	Test Scenario	Results (Pass/Fail)	Comments
UAT_1	User Authentication	• Sign up the member account • Login the member account		
UAT_2	Medical Equipment Registration	• Add a new medical equipment		
UAT_3	Medical Equipment Donation	• Donate medical equipment by pickup service • Donate medical equipment by pickup service		
UAT_4	Search Drop-off Points of NGOs/Medical Centres	• Locate the NGO drop off point		
UAT_5	View Medical Related Information	• View the medical equipment related knowledges		
UAT_6	Chat engine	• Send message to a NGO to drop enquiries		
UAT_7	Appointments	• View appointments made		

UAT_8	Donation History	• View the donation history • Share the donation to the social media		
UAT_9	Edit profile	• Edit the profile details		
UAT_10	Settings	• Turn off the notification		

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

A mobile application to recognise unused medical equipment for three entities: NGOs/medical centres, member and admin has been developed. This mobile application ease the donation process between NGOs/medical centres and members. It encourages the public to donate their unused medical equipment. The donated medical equipment can be reused and recycled to reduce medical waste.

Transfer learning with three deep learning models. i.e., VGG-16, ResNet-50, and Inception-v3 are designed and implemented for medical equipment recognition. Analysis and investigation are executed to compare the performance of the deep learning models. Hyperparameters tuning using the grid search method is carried out to find the best combination of hyperparameters for each model, such as optimizer, batch size, number of epochs, dropout rate, and learning rate. Besides, a data set of 10 medical equipment, including commode, wheelchairs, walking frame, blood pressure set, breast pump, thermometer, rippled mattress, oximeter, crutch, and therapeutic ultrasound machine are collected for the training and testing of the models. When experimenting with images from the same distribution, ResNet-50 trained with the Adam optimizer performed best, but Inception-v3 performed better with the highest accuracy of 0.9372 when dealing with images uploaded by users (blurry and noisy images from smartphones).

8.2 Recommendations for Future Work

Recommendations for future work will be discussed based on the functionality and usability of the mobile applications, and medical equipment recognition.

8.2.1 Functionality and Usability of Mobile Applications

Mobile applications have their limitations and improvements can be included in the future. Table 8.1 has shown recommendations for future enhancements to improve the functionality and usability of the mobile applications.

Table 8.1: Recommendations for Future Work (Mobile Application)

No.	Limitations	Recommendations
1	Appointments only can be made for pickup service.	Appointments should be implemented for both the pickup and drop-off donation methods.
2	Some members cannot find the donate button after registering the medical equipment.	There should be a donate button for the user to tap on the home screen to navigate the user to the donation screen.
3	Member needs to type in the address when requesting the pickup service.	Current location tracking of the user should be implemented when inputting the address for a pickup service request.
	Notification schedule cannot be selected.	Currently, users cannot select how frequent the notifications are sent to them. Options such as before 1 hour, before 1 day and on the spot should be given for the users to select as the appointment reminder.
4	No rewards after donation.	A rewards system should be implemented to encourage the users to donate the unused medical equipment.
5	No interaction between members.	Community or friends feature can be implemented to make the apps more interactive. The donation of medical items among members can be implemented. Members can publish medical items request to get other members donation.
6	Only medical equipment can be donated.	Other medical items can be included in the scope, such as medical supplements, supplies etc.
7	No help centre for users to drop enquiries.	Help centre should be included in the settings to allow users to drop any enquires.

8.2.2 Medical Equipment Recognition

There are still rooms for improvement for the medical equipment recognition model trained by the deep learning models. Currently, only 10 classes for medical equipment can be recognised. Photos for the recognition must be in the right angles and high resolutions. In the future, the accuracy to recognise the user uploaded photo can be improved. Thus, some suggestions are provided to achieve the target.

a) Data set

To recognise more medical equipment classes, more data set can be gathered for training. More data set with different patterns for a class should be collected to recognise the images more accurately. Deep learning can perform better with more data set.

b) Data augmentations

In this project, only data augmentation with flipping horizontally and rotate by 0.2 factor are implemented. More data augmentation methods should be implemented to recognise the images with different angles and resolutions. Data augmentation methods that can be applied are scaling, cropping, padding, translation, brightness, contrast saturation and hue. Colour augmentation can alter the colour properties in the images. Thus, more colour pattern can be recognised by the deep learning model.

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APPENDICES

APPENDIX A: Questionnaire

Unused Medical Items Donation for NGOs Mobile App Questionnaire

I am Wong Shi Ting from Software Engineering, a final year student who is currently working on my Final Year Project (FYP) to implement an unused medical items donation for non-governmental organization (NGOs) mobile app. The main users of this app will be public and NGOs. I would like to conduct this questionnaire to gather more data to analyse awarness level of public towards waste of medical items and conclude what features are needed in this project.

The main purposes of this mobile app are to provide a platform for donation of medical items from public to NGOs or medical center, reduce waste and prevent improper disposal of medical items to achieve environment friendly goals.

I appreciate your participation as well as your time. Thank you.
* Required

Part I - Demographic Data

1. 1. Age *

Mark only one oval.

- ◯ below 18
- ◯ 19-30
- ◯ 31-40
- ◯ 41-50
- ◯ above 50

2. 2. Gender *

Mark only one oval.

- ◯ Female
- ◯ Male

3. 3. Occupation *

Part II - Awarness level on medical waste

4. 1. Do you know that you can donate unused medical supplies and medical equipment such as medicine, wheelchair and walking aids to NGOs/ hospital? *

Mark only one oval.

- ◯ Yes
- ◯ No

5. 2. If yes, what medical item(s) you know can be donated?

_____

6. 3. Reason of leftover medicine? (Expired/ non-expired) *

Mark only one oval.

- ◯ End of treatment
- ◯ Quit medications as find it ineffective
- ◯ Change the treatment
- ◯ Experience side effects

7. 4. How do you handle the leftover medicines (Non-expired)? *

Mark only one oval.

- ◯ Dispose them into dustbin
- ◯ Donate them to NGOs
- ◯ Give them to friends, family or others
- ◯ Return them to pharmacy or clinic which sell them to you
- ◯ Usually do not aware of the leftover medicines at home

8. 5. How do you handle the leftover medicines (Expired)? *

Mark only one oval.

- ◯ Dispose them into dustbin
- ◯ Follow the instructions on the label on medicine box to dispose them
- ◯ Flush them into toilet bowl without checking the medicine disposal instructions
- ◯ Return to nearest hospital or clinics

9. 6. Do you have any leftover medicine at home currently? *

Mark only one oval.

- ◯ Yes
- ◯ No

10. 7. If yes, please specify the name of the medicine(s).

_____

_____

_____

Part III - Features ideas for the unused medical items donations app

11. 1. An unused medical items donations mobile application can encourage you to donate the items to NGOs. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

12. 2. Delivery and pick up service to your house can ease the process of donation. *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

13. 3. What is necessary in the mobile app? You may select more than one option. *

Check all that apply.

- ☐ Search of drop-off points of NGOs for donation
- ☐ Chat engine for NGOs and public users to communicate
- ☐ Information on items that can be donated
- ☐ Team features for users to meet new friends with same interest
- ☐ Achivements or badges to earn for donation
- ☐ Rewards for donations such as vouchers, coupons or cashback

Other: ☐ _____

14. 4. Will you use the mobile application for donation if it is launched? *

Mark only one oval.

- ◯ Yes
- ◯ No

15. 5. Why yes? / Why No? *

_____

_____

_____

16. 6. Suggest us any ideas in delivering this mobile app.

_____

_____

APPENDIX B: Interview Questions

1. How does the hospital/medical center/pharmacy collect the unused medicine?
2. What are the procedures if one wishes to donate the unused medicine?
3. How is the verification of medicine carried out to prevent improper or expired medicine?
4. Do you face any problems regarding return of medicine from public? (Ex: Difficult to collect, time consuming)
5. Besides unused medicine, what else the hospital/medical center/pharmacy will collect for recycle or reuse?
6. What happens to all the donated items?
7. Are the donated medical items further donate to the poor or needy?
8. Who will manage the donated items?
9. Do you think it is necessary to launch an unused medicine and medical equipment donation mobile application?
10. If the mobile application is launched, what kind of feature do you think is a must?
11. Are delivery and pick up service can be considered to collect the medical items?
12. Any further information to share?

APPENDIX C: Work Breakdown Structure

0.0 Unused Medical Items Donation Mobile App

1.0 Project Initiation

- **1.1 Requirement Gathering**
  - **1.1.1** Questionnaire and Interview
  - **1.1.2** Literature Review
- **1.2 Project Plan**
  - **1.2.1** Problem Formulation
  - **1.2.2** Project Objectives
  - **1.2.3** Project Solution
  - **1.2.4** Project Approach
  - **1.2.5** Project Scope
  - **1.2.6** Work Breakdown Structure
  - **1.2.7** Gantt Chart
- **1.3 Project Specification**
  - **1.3.1** Use Case Diagram
  - **1.3.2** Use Case Description
  - **1.3.3** Functional and Non-Functional Requirements
  - **1.3.4** Analysis on Facts Finding
- **1.4 Quick Design**
  - **1.4.1** Prototype 1

2.0 Iteration

- **2.1 First Iteration**
  - **2.1.1** Design
  - **2.1.2** Prototyping
  - **2.1.3** Evaluation
  - **2.1.4** Review
- **2.2 Second Iteration**
  - **2.2.1** Design
  - **2.2.2** Prototyping
  - **2.2.3** Evaluation
  - **2.2.4** Review
- **2.3 Third Iteration**
  - **2.3.1** Design
  - **2.3.2** Prototyping
  - **2.3.3** Evaluation
  - **2.3.4** Review

3.0 Development

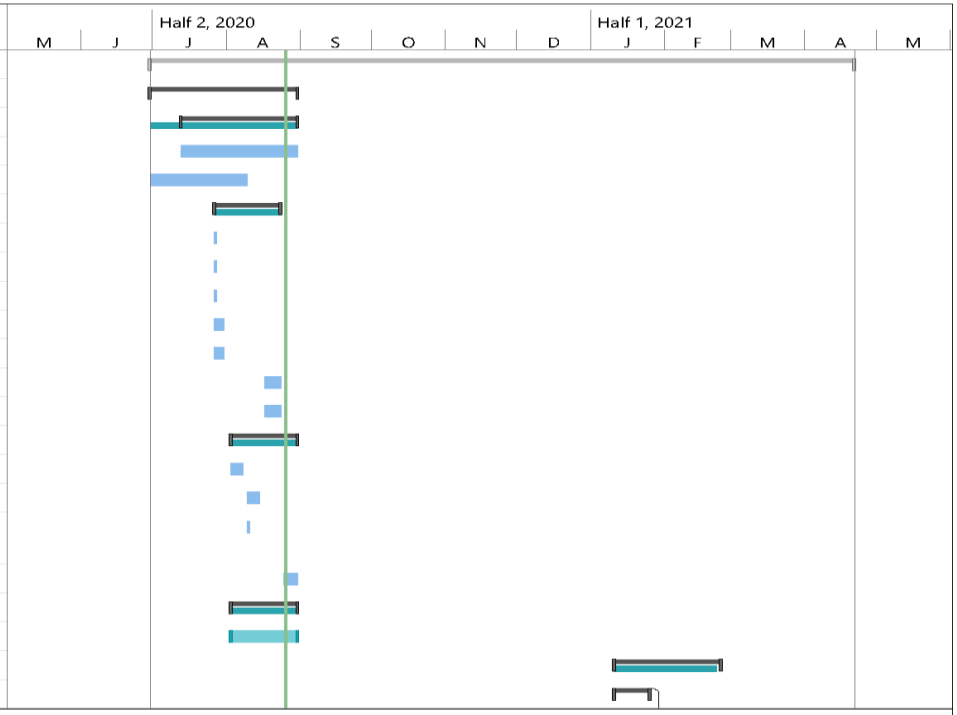
- **3.1** Front-End Development
- **3.2** Back-End Development

4.0 Testing

- **4.1** Unit Testing
- **4.2** User Acceptance Testing

APPENDIX D: Gantt Chart

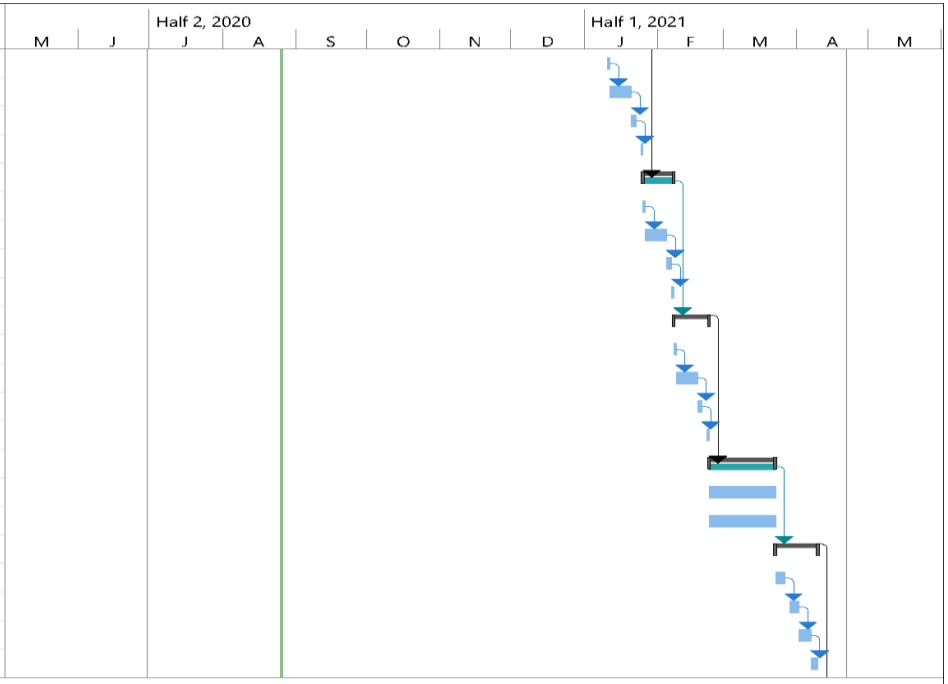
Task Name	Duration	Start	Finish
Unused Medical Items Donation Mobile App	**216 days**	**Tue 30/6/20**	**Wed 21/4/21**
1 Project Initiation	**46 days**	**Tue 30/6/20**	**Sun 30/8/20**
1.1 Requirement Gathering	**37 days**	**Mon 13/7/20**	**Sun 30/8/20**
1.1.1 Questionnaire and Interview	37 days	Mon 13/7/20	Sun 30/8/20
1.1.2 Literature Review	30 days	Tue 30/6/20	Sun 9/8/20
1.2 Project Plan	**22 days**	**Mon 27/7/20**	**Sun 23/8/20**
1.2.1 Problem Formulation	1 day	Mon 27/7/20	Mon 27/7/20
1.2.2 Project Objectives	1 day	Mon 27/7/20	Mon 27/7/20
1.2.3 Project Solution	1 day	Mon 27/7/20	Mon 27/7/20
1.2.4 Project Approach	4 days	Mon 27/7/20	Thu 30/7/20
1.2.5 Project Scope	4 days	Mon 27/7/20	Thu 30/7/20
1.2.6 Work Breakdown Structure	5 days	Mon 17/8/20	Sun 23/8/20
1.2.7 Gantt Chart	5 days	Mon 17/8/20	Sun 23/8/20
1.3 Project Specification	**22 days**	**Mon 3/8/20**	**Sun 30/8/20**
1.3.1 Use Case Diagram	5 days	Mon 3/8/20	Fri 7/8/20
1.3.2 Use Case Description	5 days	Mon 10/8/20	Fri 14/8/20
1.3.3 Functional and Non-Functional Requirements	1 day	Mon 10/8/20	Mon 10/8/20
1.3.4 Analysis on Facts Finding	5 days	Tue 25/8/20	Sun 30/8/20
1.4 Quick Design	**22 days**	**Mon 3/8/20**	**Sun 30/8/20**
1.4.1 Prototype 1	22 days	Mon 3/8/20	Sun 30/8/20
2 Iteration	**35 days**	**Mon 11/1/21**	**Wed 24/2/21**
2.1 First Iteration	**11 days**	**Mon 11/1/21**	**Mon 25/1/21**



Project: Unused Medical Items
Date: Wed 26/8/20

Task
Split
Milestone
Summary
Project Summary
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
External Tasks
External Milestone
Deadline
Progress
Manual Progress

Task Name	Duration	Start	Finish
2.1.1 Design	1 day	Mon 11/1/21	Mon 11/1/21
2.1.2 Prototyping	7 days	Tue 12/1/21	Wed 20/1/21
2.1.3 Evaluation	2 days	Thu 21/1/21	Fri 22/1/21
2.1.4 Review	1 day	Mon 25/1/21	Mon 25/1/21
2.2 Second Iteration	**11 days**	**Tue 26/1/21**	**Sun 7/2/21**
2.2.1 Design	1 day	Tue 26/1/21	Tue 26/1/21
2.2.2 Prototyping	7 days	Wed 27/1/21	Thu 4/2/21
2.2.3 Evaluation	2 days	Fri 5/2/21	Sat 6/2/21
2.2.4 Review	1 day	Sun 7/2/21	Sun 7/2/21
2.3 Third Iteration	**11 days**	**Mon 8/2/21**	**Mon 22/2/21**
2.3.1 Design	1 day	Mon 8/2/21	Mon 8/2/21
2.3.2 Prototyping	7 days	Tue 9/2/21	Wed 17/2/21
2.3.3 Evaluation	2 days	Thu 18/2/21	Fri 19/2/21
2.3.4 Review	1 day	Mon 22/2/21	Mon 22/2/21
3 Development	**20 days**	**Tue 23/2/21**	**Mon 22/3/21**
3.1 Front-End Development	20 days	Tue 23/2/21	Mon 22/3/21
3.2 Back-End Development	20 days	Tue 23/2/21	Mon 22/3/21
4 Testing	**14 days**	**Tue 23/3/21**	**Fri 9/4/21**
4.1 Unit Testing	4 days	Tue 23/3/21	Fri 26/3/21
4.2 Integration Testing	4 days	Mon 29/3/21	Thu 1/4/21
4.3 User Acceptance Testing	3 days	Fri 2/4/21	Tue 6/4/21
4.4 Usability Testing	3 days	Wed 7/4/21	Fri 9/4/21



Project: Unused Medical Items
Date: Wed 26/8/20

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

Task Name	Duration	Start	Finish
5 Deployment	8 days	Mon 12/4/21	Wed 21/4/21

Project: Unused Medical Items
Date: Wed 26/8/20

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

APPENDIX E: Usability Test Scenarios

TEST SCENARIO - Members

Scenario #1: Login to member account

Imagine that you are a member who wishes to use the medical equipment donation mobile application. You want to **login to the member account** to donate the medical equipment.

How do you login to the mobile application?

Scenario #2: Register a medical equipment

Imagine that you are a member who wishes to register a medical equipment for donation. You want to **register a medical equipment** with **duration used 1 year**.

How do you register the medical equipment?

Scenario #3: Donate a medical equipment by pickup service

Imagine that you are a member who wishes to donate a medical equipment to an organization. You want to **donate a medical equipment registered** to Hospis Malaysia.

How do you donate the medical equipment?

Scenario #4: Search for the drop-off points of NGOs/ Medical Center

Imagine that you are a member who wishes to get the location and details of an NGO. You want to **search for Hospis Malaysia's location and details**.

How do you search the drop-off points?

Scenarios #5: View information

Imagine that you are a member who wishes to view medical related information. You want to **view the information** provided by the app.

How do you view the information?

Scenario #6: Chat engine to communicate with NGOs/ Medical Center

Imagine that you are a member who wishes to ask an NGO about enquiries on donation. You want to **ask Hospis Malaysia** about what kind of medical equipment they accept.

How do you ask the NGO?

Scenario #7: View Donation History

Imagine that you are a member who wishes to view the donation history. You want to **view the donation history and share a donation to social media**.

How do you view the donation history and share it to social media?

APPENDIX F: User Satisfaction Results

Participant # 1

System design group:

User Satisfaction survey ***(adapted from System Usability Scale, Brooke, J. (1986))***

	Strongly Disagree 1	**2**	**Neural 3**	**4**	**Strongly Agree 5**
1. I think that I would like to use this donation app to donate medical equipment frequently.					/
2. I found the system unnecessarily complex.		/			
3. I thought the system was easy to use				/	
4. I think that I would need the support of a technical person to be able to use this system.			/		
5. I found the various functions in this system were well integrated.				/	
6. I thought there was too much inconsistency in this system.		/			
7. I would imagine that most people would learn to use this system very quickly.				/	
8. I found the system very awkward to use.		/			
9. I felt very confident using the system.				/	
10. I needed to learn a lot of things before I could get going with this system.		/			

What did you like best about the system? Not complicated to use

What did you like least about the system? Nothing

Do you have any other final comments or questions? Can improve more on the design to attract users

Participant # 2

System design group:

User Satisfaction survey ***(adapted from System Usability Scale, Brooke, J. (1986))***

	Strongly Disagree 1	**2**	**Neural 3**	**4**	**Strongly Agree 5**
1. I think that I would like to use this donation app to donate medical equipment frequently.				/	
2. I found the system unnecessarily complex.	/				
3. I thought the system was easy to use					/
4. I think that I would need the support of a technical person to be able to use this system.		/			
5. I found the various functions in this system were well integrated.				/	
6. I thought there was too much inconsistency in this system.	/				
7. I would imagine that most people would learn to use this system very quickly.			/		
8. I found the system very awkward to use.	/				
9. I felt very confident using the system.					/
10. I needed to learn a lot of things before I could get going with this system.	/				

What did you like best about the system? Donation

What did you like least about the system? Chat

Do you have any other final comments or questions? Can improve more on user interfaces such as button colour

Participant # 3

System design group:

User Satisfaction survey ***(adapted from System Usability Scale, Brooke, J. (1986))***

	Strongly Disagree 1	**2**	**Neural 3**	**4**	**Strongly Agree 5**
1. I think that I would like to use this donation app to donate medical equipment frequently.					/
2. I found the system unnecessarily complex.		/			
3. I thought the system was easy to use				/	
4. I think that I would need the support of a technical person to be able to use this system.		/			
5. I found the various functions in this system were well integrated.				/	
6. I thought there was too much inconsistency in this system.	/				
7. I would imagine that most people would learn to use this system very quickly.				/	
8. I found the system very awkward to use.		/			
9. I felt very confident using the system.				/	
10. I needed to learn a lot of things before I could get going with this system.	/				

What did you like best about the system? Scan Medical Equipment Feature

What did you like least about the system? Appointments. Better alignment and layout can be done.

Do you have any other final comments or questions? Can add more medical items type for donation.

Participant # 4

System design group:

User Satisfaction survey ***(adapted from System Usability Scale, Brooke, J. (1986))***

	Strongly Disagree 1	**2**	**Neural 3**	**4**	**Strongly Agree 5**
1. I think that I would like to use this donation app to donate medical equipment frequently.					/
2. I found the system unnecessarily complex.	/				
3. I thought the system was easy to use				/	
4. I think that I would need the support of a technical person to be able to use this system.		/			
5. I found the various functions in this system were well integrated.					/
6. I thought there was too much inconsistency in this system.	/				
7. I would imagine that most people would learn to use this system very quickly.					/
8. I found the system very awkward to use.	/				
9. I felt very confident using the system.				/	
10. I needed to learn a lot of things before I could get going with this system.		/			

What did you like best about the system?	There is a chat box for users to ask about any enquiries.
What did you like least about the system?	Design can become more attractive.
Do you have any other final comments or questions?	It may be more appropriate if scan/upload and type button can combine together

Participant # 5

System design group:

User Satisfaction survey ***(adapted from System Usability Scale, Brooke, J. (1986))***

	Strongly Disagree 1	**2**	**Neural 3**	**4**	**Strongly Agree 5**
1. I think that I would like to use this donation app to donate medical equipment frequently.				/	
2. I found the system unnecessarily complex.			/		
3. I thought the system was easy to use				/	
4. I think that I would need the support of a technical person to be able to use this system.		/			
5. I found the various functions in this system were well integrated.					/
6. I thought there was too much inconsistency in this system.	/				
7. I would imagine that most people would learn to use this system very quickly.					/
8. I found the system very awkward to use.		/			
9. I felt very confident using the system.					/
10. I needed to learn a lot of things before I could get going with this system.	/				

What did you like best about the system? donate a medical equipment

What did you like least about the system? can add more information

Do you have any other final comments or questions? Nothing

APPENDIX G: User Aceeptance Tests Results

Tester #	1			
Testing date	20 March 2021			
UAT ID	Modules	Test Scenario	Results (Pass/Fail)	Comments
UAT_1	User Authentication	• Sign up the member account • Login the member account	Pass	
UAT_2	Medical Equipment Registration	• Add a new medical equipment	Pass	
UAT_3	Medical Equipment Donation	• Donate medical equipment by pickup service	Pass	
UAT_4	Search Drop-off Points of NGOs/Medical Centres	• Locate the NGO drop off point	Pass	
UAT_5	View Medical Related Information	• View the medical equipment related knowledges	Pass	
UAT_6	Chat engine	• Send message to a NGO to drop enquiries	Pass	Can remove case sensitive for the search field
UAT_7	Appointments	• View appointments made	Pass	
UAT_8	Donation History	• View the donation history • Share the donation to the social media	Pass	
UAT_9	Edit profile	• Edit the profile details	Pass	
UAT_10	Settings	• Turn off the notification	Pass	

Tester #	2			
Testing date	20 March 2021			
UAT ID	Modules	Test Scenario	Results (Pass/Fail)	Comments
UAT_1	User Authentication	• Sign up the member account • Login the member account	Pass	
UAT_2	Medical Equipment Registration	• Add a new medical equipment	Pass	
UAT_3	Medical Equipment Donation	• Donate medical equipment by pickup service	Pass	
UAT_4	Search Drop-off Points of NGOs/Medical Centres	• Locate the NGO drop off point	Pass	
UAT_5	View Medical Related Information	• View the medical equipment related knowledges	Pass	
UAT_6	Chat engine	• Send message to a NGO to drop enquiries	Pass	
UAT_7	Appointments	• View appointments made	Pass	
UAT_8	Donation History	• View the donation history • Share the donation to the social media	Pass	
UAT_9	Edit profile	• Edit the profile details	Pass	
UAT_10	Settings	• Turn off the notification	Pass	

Tester #	3			
Testing date	20 March 2021			
UAT ID	Modules	Test Scenario	Results (Pass/Fail)	Comments
UAT_1	User Authentication	• Sign up the member account • Login the member account	Pass	
UAT_2	Medical Equipment Registration	• Add a new medical equipment	Pass	
UAT_3	Medical Equipment Donation	• Donate medical equipment by pickup service	Pass	
UAT_4	Search Drop-off Points of NGOs/Medical Centres	• Locate the NGO drop off point	Pass	
UAT_5	View Medical Related Information	• View the medical equipment related knowledges	Pass	
UAT_6	Chat engine	• Send message to a NGO to drop enquiries	Pass	
UAT_7	Appointments	• View appointments made	Pass	
UAT_8	Donation History	• View the donation history • Share the donation to the social media	Pass	
UAT_9	Edit profile	• Edit the profile details	Pass	
UAT_10	Settings	• Turn off the notification	Pass	

Tester #	4			
Testing date	21 March 2021			
UAT ID	Modules	Test Scenario	Results (Pass/Fail)	Comments
UAT_1	User Authentication	• Sign up the member account • Login the member account	Pass	
UAT_2	Medical Equipment Registration	• Add a new medical equipment	Pass	
UAT_3	Medical Equipment Donation	• Donate medical equipment by pickup service	Pass	
UAT_4	Search Drop-off Points of NGOs/Medical Centres	• Locate the NGO drop off point	Pass	
UAT_5	View Medical Related Information	• View the medical equipment related knowledges	Pass	
UAT_6	Chat engine	• Send message to a NGO to drop enquiries	Pass	
UAT_7	Appointments	• View appointments made	Pass	
UAT_8	Donation History	• View the donation history • Share the donation to the social media	Pass	
UAT_9	Edit profile	• Edit the profile details	Pass	
UAT_10	Settings	• Turn off the notification	Pass	

Tester #	5			
Testing date	21 March 2021			
UAT ID	Modules	Test Scenario	Results (Pass/Fail)	Comments
UAT_1	User Authentication	• Sign up the member account • Login the member account	Pass	
UAT_2	Medical Equipment Registration	• Add a new medical equipment	Pass	
UAT_3	Medical Equipment Donation	• Donate medical equipment by pickup service	Pass	
UAT_4	Search Drop-off Points of NGOs/Medical Centres	• Locate the NGO drop off point	Pass	
UAT_5	View Medical Related Information	• View the medical equipment related knowledges	Pass	
UAT_6	Chat engine	• Send message to a NGO to drop enquiries	Pass	
UAT_7	Appointments	• View appointments made	Pass	
UAT_8	Donation History	• View the donation history • Share the donation to the social media	Pass	
UAT_9	Edit profile	• Edit the profile details	Pass	
UAT_10	Settings	• Turn off the notification	Pass	