DEVELOPMENT OF DRONE-BASED SOLUTION FOR MEDICINE DELIVERY USING FACE RECOGNITION AND GUIDANCE LANDING SYSTEM

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[DEVELOPMENT OF DRONE-BASED SOLUTION FOR MEDICINE DELIVERY USING FACE RECOGNITION AND GUIDANCE LANDING SYSTEM]

ABSTRACT

This thesis presents the Development OF Drone-Based Solution for Medicine Delivery Using Face Recognition and Guidance Landing System. The drone is equipped with a Sanitiser Unit (SU) and a secure Delivery Box (DB) for contactless medication delivery using face recognition and the GLS. The development of the drone GLS system consists of two microcontroller sensor circuits that visualise the delivery area's lighting conditions to improve efficiency. In addition to the SU and DB, the drone GLS system also has a Motion Detection Unit (MDU) and a Voice Command Guiding Unit (VCGU) for medication delivery. The first development board is the Arduino Uno, which controls the face recognition camera, DB, SU, MDU, and VCGU units. The second development board is the ESP32 DevKitC V4, which controls the GLS. An Internet of Things (IoT) microcontroller is connected to the Internet using IoT mobile apps. GLS is combined with four light-dependent resistors and a light-intensity sensor. Those sensors visualise the light conditions to enhance face recognition, and a GY-30 light intensity sensor is used to measure the value of the illumination. The drone Facial Recognition Camera (FRC) and GLS system has been tested on 5001 animal faces, 5030 static human photos inclusive of 5000 photos from Flickr-Faces-HQ, 30 actual photos, and 35 real human volunteers' faces. The overall accuracy of the face recognition system is 98.53%. The GLS has enhanced the detection distance to almost double and increased the detection distance to 1.47 metres. A strong correlation was found between face recognition distance, light direction, illumination, and light colour temperature ($p<0.05$). The drone GLS system can detect real human face recognition with high accuracy, and the development is for the purpose of performing medication delivery outdoors.

Keywords: drone; face recognition; guidance landing system; light direction; light intensity

[PEMBANGUNAN KAEDAH PENGHANTARAN UBAT MENGGUNAKAN PENGIKTIRAF MUKA BERASASKAN DRONE DAN SISTEM PENDARATAN BIMBINGAN]

ABSTRAK

Tesis ini membentangkan Pembangunan Penghantaran Ubat Menggunakan Sistem Pengecaman Wajah dan Pendaratan Bimbingan Berasaskan Drone. Drone ini dilengkapi dengan Unit Sanitiser (SU) dan Peti Penghantaran (DB) selamat untuk penghantaran ubat tanpa sentuhan menggunakan pengecaman muka dan GLS. Pembangunan sistem drone GLS terdiri daripada dua litar penderia mikrokomputer yang menggambarkan keadaan pencahayaan kawasan penghantaran untuk meningkatkan kecekapan. Selain SU dan DB, sistem dron GLS juga mempunyai Unit Pengesanan Pergerakan (MDU) dan Unit Pemandu Perintah Suara (VCGU) untuk penghantaran ubat. Papan pembangunan pertama ialah Arduino Uno, yang mengawal kamera pengecaman muka, unit DB, SU, MDU dan VCGU. Papan pembangunan kedua ialah ESP32 DevKitC V4, yang mengawal GLS. Mikropengawal Internet of Things (IoT) disambungkan ke Internet menggunakan aplikasi mudah alih IoT. GLS digabungkan dengan empat perintang bergantung kepada cahaya dan sensor keamatan cahaya. Penderia tersebut menggambarkan keadaan cahaya untuk mempertingkatkan pengecaman muka, dan penderia keamatan cahaya GY-30 digunakan untuk mengukur nilai pencahayaan. Drone Facial Recognition Camera (FRC) dan sistem GLS telah diuji pada 5001 muka haiwan, 5030 foto manusia statik termasuk 5000 foto dari Flickr-Faces-HQ, 30 foto sebenar dan 35 muka sukarelawan manusia sebenar. Ketepatan keseluruhan sistem pengecaman muka ialah 98.53%. GLS telah meningkatkan jarak pengesanan kepada hampir dua kali ganda dan meningkatkan jarak pengesanan kepada 1.47 meter. Kolerasi yang kuat didapati antara jarak pengecaman muka, arah cahaya, pencahayaan, dan suhu warna cahaya ($p<0.05$). Sistem dron GLS boleh mengesan pengecaman muka manusia sebenar dengan ketepatan yang tinggi, dan pembangunan adalah untuk tujuan melaksanakan penghantaran ubat di luar rumah.

Kata kunci: dron; pengecaman muka; sistem pendaratan panduan; arah cahaya keamatan cahaya

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I would like to pray for my mother (Nadia). May God rest her soul in peace and grant her the highest place in Heaven. Furthermore, I sincerely thank my cousin Shajan Manni for her support. None of this would have happened without her generous support. I would also love to thank my aunties Nayla and Intisar for their continuous support. I would like to express my appreciation to my father (Osman Baloola), wife (Mazaa), daughters (Nadia & Intisar) and family for their continuous support. Words can't express my appreciation for all of you. We learnt from the COVID-19 pandemic that life will go on. We have to be dynamic and move with the flow.

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LIST OF SYMBOLS AND ABBREVIATIONS

UAV	:	Unmanned Air Vehicles
4IR	:	Fourth Industrial Revolution
AED	:	Automated External Defibrillator
IoT	:	Internet of Things
NB-IoT	:	Narrow Band IoT
GLS	:	Guidance Landing System
DB	:	Delivery Box
VCGU	:	Voice Commands Guiding Unit
MDU	:	Motion Detection Unit
UART	:	Universal Asynchronous Receiver Transmitter
IPA	:	Isopropyl Alcohol
PWM	:	Pulse Width Modulation
LDR	:	Light Dependent Resistor
CDMDS	:	Contactless Drone Medication Delivery System
PIR	:	Passive Infrared
SU	:	Sanitising Unit
EMS	:	Emergency Response Time
FRC	:	Face Recognition Camera

CHAPTER 1: INTRODUCTION

1.1 Background of the Study

The classification of drones depends on payload, weight, flight range, and velocity. It accelerates the Industrials 4.0 technology; the market of UAV applications market is growing rapidly and offers one hundred twenty-seven billion US dollars and 100 thousand job opportunities (Shakhatreh et al., 2019). Drones have a wide range of applications. A variety of drones are available on the market with affordable prices and advanced features that fit the requirements of beginners and professionals. Leading companies and governments use drones to provide futuristic services to citizens, and start-ups have been competing to provide cutting-edge applications.

The drone is known as Unmanned Arial Vehicle (UAV). Applications for UAVs in medicine to improve healthcare services have expanded quickly. For example, the outbreak of COVID-19 has led to the use of drones in the medical industry for street disinfection. Additionally, a thermal camera to detect infected patients prompts action to isolate them (Euchi, 2020).

Telehealth and the outbreak of COVID-19 have raised the dement in delivery due to lockdown and shortened healthcare service providers. All the rules and regulations encourage social distance; the drone can detect any violation and take action by sounding an alarm and sound messages (Euchi, 2020). For instance, researchers have developed a drone to carry medical kits to victims pre-arrival of the ambulance to reach them, especially during traffic jams with drone flight speeds of 40 km – 50 km (Sanjana et al., 2020).

The Internet of Things (IoT) mobile application is believed to bring assistance, ease acquiring the data, and simplify the operation (Monte et al., 2021). Furthermore, IoT sensors are improving UAV applications and increasing efficiency.

UAV cameras are used for monitoring, face recognition, imaging, and photogrammetry (Kortli et al., 2020) (Dering et al., 2019). Face recognition is a part of computer vision that is used in many applications like monitoring, identification, and punctuality (Kortli et al., 2020) (Tamilkodi, 2021). Based on the angle of depression and the distance between the camera and the face, face recognition efficiency while the drone hover is determined (Tamilarasu et al., 2019). In contrast, the precision of 2D face identification is impacted by facial posture, brightness, age, physical attractiveness, and cosmetics (Adjabi et al., 2020). Researchers stated in their review paper that three of the five techniques are photosensitive. (Shanthi et al., 2019).

That shows clearly that the face recognition cameras are sensitive to light, and most of the proposed techniques by researchers to overcome the illumination issues are software solutions, especially outdoors, where the illumination conditions are uncontrolled.

1.2 Problem Statement

Face recognition by UAVs is used for monitoring. However, even while the current facial recognition systems on drones can identify faces, the accuracy of face detection during flying is affected by the angle of depression and the distance from the UAV to the face (Tamilarasu et al., 2019). In addition to the facial positions, light intensity (including poor lighting and weather), individual features, and cosmetics (Adjabi et al., 2020).

According to a review of the relevant literature, most face recognition technique developers are building software solutions to overcome lighting concerns. When the sun is at an acute angle during sunrise, and sunset, in addition to night-time, when there's inadequate light, particularly once the illuminance is about Twenty and Fifty Lux, face recognition on the drone is very hard. The light's intensity and direction alter the precision with which we identify faces. Our approach in this thesis is to improve the IoT-Guidance Landing System (GLS) for UAV drug delivery depending on the angle and intensity of light.

1.3 Research Questions

This thesis aims to respond to the research objectives that have been identified. The research questions are;

(a) How to develop a drone incorporated with an IoT system that can precisely identify patients using face recognition for the purpose of medication delivery?

(b) How do we optimise the efficiency of the face recognition system on a drone considering the light intensity and light direction?

1.4 Objectives of the Study

The objectives of this research are:

1. To develop a drone-based system for medication delivery.

2. To integrate a Guidance Landing System (GLS), Internet of Things (IoT) and precise face recognition on the drone.

3. To investigate the effect of the direction and intensity of light on face recognition and GLS.

Chapter two contains a literature review on the UAV, Internet of Things, face recognition and the effect of light's direction and intensity on face recognition accuracy.

Then, Chapter Three concentrates on the software and hardware of the designed drone's systems and the experiments conducted. Next, Chapter four contains the results and discussions. Finally, chapter five concludes the findings of the study and future works.

1.5 Significance of the Study

The gap found in the literature review is that all the studies and researches focus on the development of the software of face recognition algorithms and techniques to overcome the illumination challenges. Our proposed system includes hardware development that will support all face recognition algorithms and techniques to overcome the illumination variation challenge to ensure precise medication delivery.

CHAPTER 2: LITREATURE REVIEW

2.1 Introduction

This literature review covers drones, the Internet of Things (IoT), face recognition, and the effect of light on face recognition.

The first section discusses the drone's features and applications, especially the drone's applications in the medical field. Then the second section is about the IoT and its applications. Next, the third section is about face recognition and the applications of face recognition on the UAV. Finally, the fourth section covers a literature review about the light effect on photography and face recognition.

2.2 Drones

Global drone classification is based on weight, flying distance, speed, and payload. UAV applications have become an essential element of a growing number of services. Due to technical advancements, drones play a crucial part in the Industrial Revolution 4.0. The investment in the UAV business reached 127 Billion U.S. Dollars, and one hundred thousand employment possibilities are anticipated by 2025 (Shakhatreh et al., 2019). Drones have a wide range of applications. A variety of drones are available on the market with affordable prices and advanced features that fit the requirements of beginners and professionals. Leading companies and governments use drones to provide futuristic services to citizens, and start-ups have been competing to provide cutting-edge applications. The classification of drones increases proportionally with the global increase in on-demand applications in civilian and military uses. The classification identifies a group of drones with the same characteristics: weight, payload, flight distance, flight time, functions, fuel type and flight attitude.

DJI drones are the most popular and reliable manufacturer globally for photography, agriculture, surveillance, and surveying. Table 2.1 shows the compression of the specifications of DJI's drones (DJI - Official Website, 2022).

Table 2.1: Compare the Specifications of DJI Drones (DJI - Official Website, 2022)

	Drone Weight (Grams)	Maximum Velocity (Km/Hr)	Maximum Ascent Velocity (Km/Hr)	Maximum Descent Speed (Km/Hr)	Flight time (minutes)	Max. Flight Distance (Metres)	Remote Control Distance (Metres)	Payload (Grams)
DJI Mini 2	249	57.6	18	12.6	31	-	10000	-
DJI Mavic Air 2	570	68.4	14.4	10.8	34	18500	10000	-
DJI Mavic Mini	249	46.8	14.4	10.8	30	-	4000	-
DJI Mavic 2 Pro	907	72	18	10.8	31	18000	10000	-
DJI Mavic 2 Zoom	905	72	18	10.8	31	18000	10000	-
DJI Phantom 4 Pro	1388	72	21.6	14.4	30	-	7000	-
DJI Phantom 4 Pro V2.0	1375	72	21.6	14.4	30	-	10000	-
DJI Inspire 2	3440	94	18	14.4	27	-	7000	810
DJI Matrice 300 RTK	6300	82.8	21.6	25.2	55	-	15000	2700
DJI Mavic 2 Dual Edition	899	72	18	10.8	31	-	10000	201
DJI Matrice 200 Series V2	4690	81	18	10.8	38	-	8000	1450
DJI Matrice 600 PRO	9500 - 10000	65	18	10.8	38	-	5000	5500 - 6000
DJI Phantom 4 RTK	1391	58	21.6	10.8	30	-	7000	-
DJI P4 Multispectral	1487	50	21.6	10.8	27	-	7000	-

Drones are classified based on weight, such as the NATO classification of UAVs based on weight which falls under three classes. Class 1 refers to drones under 20 kg. Class 2 refers to a tactical UAV that weighs less than 600 kg but more than 150 kg. Class 3 is a strike UAV and weighs more than 600 kg (Brooke-Holland, 2015), as shown in Table 2.2. In addition, NASA classified drones based on weight and speed. The first category is lighter than 25 kg and can withstand up to 70 kt of airspeed. The second category is lighter than 150 kg and more than 25 kg, and endurance is between 70 Kt – 200 Kt. The last category is for drones heavier than 150 Kg and with an endurance of above 200 Kt (Argrow et al., 2018).

Table 2.2: Drone Classifications based on NATO (Brooke-Holland, 2015)

NATO Classification	Sub-Classification	Size	Weight (Grams)
Class 1	A	Nano	< 200
	B	Micro	< 2000
	C	Mini	2,000 – 20,000
	D	Small	> 20,000
Class 2	-	Tactical	> 150,000
Class 3	-	Strike	> 600,000

The use of drones in the medical industry to improve patient care has expanded quickly. For example, the recent outbreak of COVID-19 has led to UAV applications in the healthcare industry, such as street decontamination, to stop the virus's transmission. Furthermore, thermography has been utilised to identify an infected person's abnormal temperature in a busy location, resulting in isolation (Euchi, 2020).

Table 2.3: Types of landing

landing Direction	Landing Precision	Wings	UAV example
Vertical Landing	High	rotary	Multi-rotor drone
Horizontal Landing	Low	Fixed	aircraft

Research conducted showed that the drone uses a camera for an automated landing, which helps the autonomous system control the drone during the landing (Demirhan & Premachandra, 2020). In case of an emergency landing, the drone has to find a safe place to land, which is known as a Safe Landing Zone (SLZ); the drone uses sensors and a camera for detection to determine the best spot to land (Shah Alam & Oluoch, 2021). A review paper by Ducard & Allenspach (2021) showed the different types of landing, such as horizontal and vertical landing, as shown in Table 2.3 and Figure 2.1.

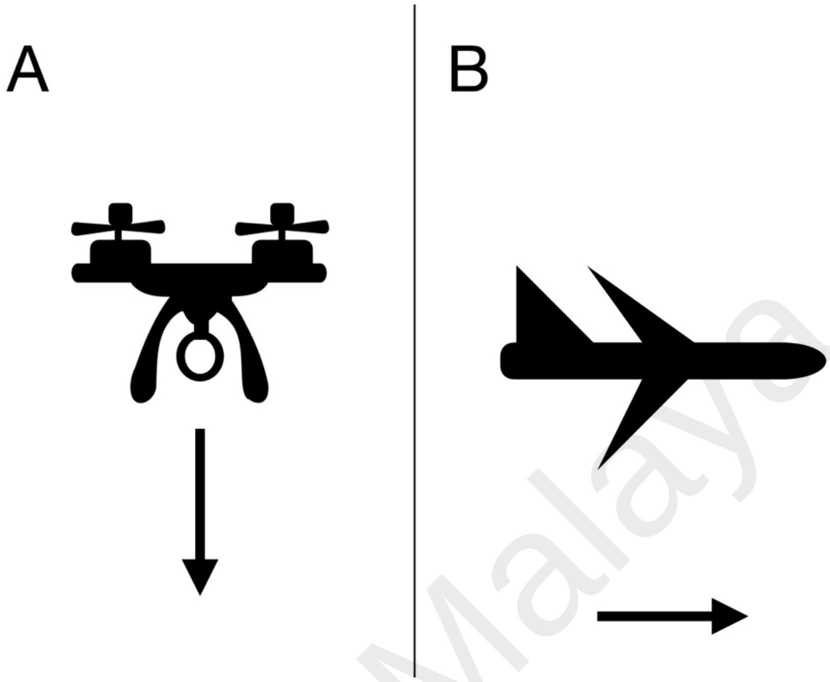

Figure 2.1: Vertical and horizontal landing

2.2.1 Drone Applications in the Medical Field

Telemedicine and home-care have increased considerably due to the outbreak of the COVID-19 pandemic, exhibiting a 15-times increase in three weeks from 100,000 users on March 16, 2020, to more than 1,500,000 users on April 6, 2020 (Barr et al., 2020). Telehealth and lockdowns have promoted the use of drones to supply medicines to patients. Social distance is one of the most critical variables in preventing virus transmission. Drones play a vital role since their cameras can detect violators; speakers may also be attached to drones to encourage people to maintain a safe distance (Euchi, 2020). For instance, researchers have developed a drone to carry medical kits to victims pre-arrival of the ambulance to reach them, especially during traffic jams with drone flight speeds of 40–50 km/hr (Sanjana et al., 2020). Ackerman and Koziol (2019) reported that two entrepreneurs in Rwanda launched a company to deliver blood across the country by zipline drone, which reduced the average delivery time to hospitals from hours to minutes. Beck's study has also concentrated on UAVs delivering life-saving anti-allergy shots. The study examines the effects of the injection chemicals under various conditions, including vibrations, ambient temperatures, and flying duration (Beck et al., 2020). Balasingam stated that NASA had tested UAV drug delivery to deliver asthmatic, hypertension, and diabetic medicines (Balasingam, 2017). A review paper by Scott and Scott (2018) compared the various types of medical drones, payloads, and flight distances. The Matternet drone is used to deliver medication and blood with a payload of 2 kilograms and a flight range of 10 kilometres. The DHL parcel drone delivers medication and blood with a payload of 2 kilograms and a flight range of 12 kilometres. The Flirtey drone has been used to deliver medication with a payload of 2 kilograms and a flight distance of 32.19 kilometres.

Drones enhance Emergency Response Time (EMS). Researchers have suggested a system of 500 UAVs to service cardiovascular patients with a defibrillator (AED) more quickly, and the studies indicate that the UAV might lower the EMS by 5 minutes, from 7 minutes and 42 seconds to 2 minutes and 42 seconds (Bogle et al., 2019). In Canada, simulation tests utilising UAVs and ambulances were conducted to investigate the variation in EMS in rural areas. Six simulations were run with distances ranging from 6 to 20 kilometres from the station to the victim. In every experiment, the UAV reached the victim before the ambulance. In the slower EMS, the UAV arrived 1 minute and 48 seconds before the ambulance, whereas in the quicker response, the UAV reached the victim 8 minutes before the ambulance (Cheskes et al., 2020). Another research found that 100 drones might decrease EMS by six minutes in urban areas and ten minutes in rural areas (Boutilier et al., 2020).

A literature study revealed a considerable disparity between the distance and time required to transport blood samples from hospitals to laboratories in three Swiss towns. Irrespective of the distance between the medical centre and the lab, all three experiments indicate that UAVs are faster than conventional distribution systems. For instance, in the first experiment, conducted in Lugano, the trip length from the hospital to the laboratory was 3.6 kilometres by vehicle and 1 kilometre by UAV, the UAV arrived within 3 minutes, but the automobile delivery time was over 30 minutes. In the next experiment in Zurich, the trip length by automobile and drone was nearly identical. The trip length from the hospital to the laboratory was 6 kilometres by vehicle and 5.8 kilometres by drone. The UAV arrived within 7 minutes, while the automobile delivery time was over 20 minutes. The third experiment was conducted in the same city, where the distance covered by a UAV was nearly double that of a car. The UAV arrived in 7 minutes, compared to 10 minutes by automobile (Roca-Riu & Menendez, 2018).

Nowadays, drone applications in logistics and delivery have become more popular, with many leading companies, such as Amazon, have started shipping by drones. The main challenge is that most studies have focused on a single drone or a few drones with no obstacles. The second challenge is the delivery application because the drone must fly at a lower altitude, increasing the risk (Chung et al., 2017). Trains also play an important role in delivery. Recent research integrated trains with drones to accelerate the process of delivery, where the drones will be placed on the train's roof to deliver a parcel to customers and then return to the train's roof to charge their batteries (Huang et al., 2017).

2.3 Internet of Things (IoT)

Internet of Things (IoT) was expected to exceed 28 billion connected things in 2021, and its market value was about 1.9 trillion US dollars in 2020, as estimated by Ericsson (Ericsson, 2016). The Internet of Things was founded by Kevin Ashton in 1999. He inserted RFID on all lipsticks to allow them to communicate. Today, businesses and service providers compete to deliver IoT solutions to consumers and businesses. Students, researchers, and businesspeople are investigating the difficulties and possibilities of developing new creative goods and solutions. Researchers evaluated IoT applications for intelligent houses, industries, health, farming, the weather, and mobility (Dudhe et al., 2017). It is expected that IoT mobile applications can provide support, ease data exchange, and manage procedures and tasks (Monte et al., 2021). In recent years, research has focused on building intelligent drones using IoT sensors. UAVs integrated with IoT could be more advantageous and efficient by utilising a collection of devices like sensors, transceivers, and vision sensors for a variety of cutting-edge applications (Aldaej et al., 2022). Most smartphones and smartwatches monitor pulse rates using different technologies, and most gadgets are connected to the Internet. At the same time, most of these gadgets are not designed for medical purposes of medical diagnosis or monitoring (Baker et al., 2017).

The accessibility of simple-to-use IoT modules, several online sites for IoT, and Internet access raise the global demand for IoT technology. The Narrow Band IoT (NB-IoT) and eMTC technologies extend the battery's lifespan to more than 10 years (Jörke et al., 2022). UAVs utilise IoT applications for remotely sensed and Internet-based data transmission. 5G, the fifth generation of communication for mobile phones, also supports IoT applications with improved characteristics. 5G offers 100 times faster data transmission than older generations, a downloading bandwidth of up to 20 Gbps, and a latency as low as 1 millisecond, which is advantageous for UAVs (Saif et al., 2020) (GSMA, 2019).

Tracking the vital signs of the body is necessary for the healthcare industry, which could save lives, improve patient diagnostics, and enhance patient care. The IoT enables healthcare practitioners to enhance the efficiency of their services, resulting in a healthier population and a lower chance of medical mistakes. In addition, we should not compromise the patient's privacy by storing vital information on cloud servers (Baker et al., 2017). Connecting the IoT module to a sensor to transmit data via the Internet defines the IoT system's fundamental framework. The data acquired by the UAV's sensors are either analysed on-board or transmitted to the ground station over the Internet. The drone's IoT sensors are segmented into flight control, collecting data, and connectivity (Lagkas et al., 2018). For example, a team of students created a Medicine Box and connected it to the Internet via IoT. This smart box sends a reminder to the patient's phone apps to get his medication as scheduled (Alex et al., 2016).

Nowadays, scientists are studying the acquired sensor data on a smartphone. For example, scientists monitor and store the heel forces via the shoe's sensors. The PIC Microcontroller sends the pressure levels via Bluetooth (Mostfa et al., 2022). New research at Taif University in KSA evaluated the weather sensor data collected by the Blynk apps. The BME280 module and a thermal video transmitter are fitted to a UAV to gather pressure, temperature, altitude, and humidity. Blynk is an IoT smartphone apps for iOS and Android tablets and phones (Almalki et al., 2022).

2.4 Facial Recognition

UAVs utilise their cameras for monitoring, face recognition, object identification, and cinematography (Kortli et al., 2020) (Dering et al., 2019). Face recognition technology refers to a branch of computer vision used in many applications like monitoring, identification, and punctuality (Kortli et al., 2020) (Tamilkodi, 2021). Research indicates that the earliest computer-based study in this area was performed in 1964 and concentrated on 20 face characteristics, such as the size of the eyes and mouth, led by centuries of technological innovations in which the majority of the top companies, such as Facebook and Amazon, created face recognition applications for their platforms (Adjabi et al., 2020). The outbreak of COVID-19 required all to wear masks. In Wuhan, China, a scientific group has developed two methods of face recognition. The first one concentrates on identifying correct mask wear, whereas the second type concentrates on face identification with a mask (Wang et al., 2019). Those techniques are gaining popularity due to regulations and restrictions that mandate wearing masks, which limits conventional facial recognition. Face recognition accuracy during UAV flying is related to the angle of depression and the distance between the UAV and the face (Tamilarasu et al., 2019), whereas the accuracy of 2D face identification is impacted by face posture, illuminance, ageing, and cosmetics (Adjabi et al., 2020). 3D face recognition is superior since it is lesser sensitive to posture and illumination variation, but it is required to scan a 3D subject with cameras like Microsoft Kinect or XB3. However, both active and passive technology are necessary (Zhou & Xiao, 2018).

The research team examined the five best popular face recognition algorithms. Firstly, the Principal Component Analysis (PCA) seems to be the simplest to perform but is extremely illuminate and shadow-sensitive. Secondly, Linear Discriminant Analysis (LDA) offers the most effective method for addressing lighting problems. Thirdly, the Local Binary Pattern Histogram (LBPH) is the optimal method for tough environments, although it is slower due to processing time and the effectiveness of LBPH decreases at high brightness. Fourth, Elastic Bunch Graph Matching (EBGM) is the most effective method for the pose difficulty, although it is light-sensitive. Finally, Neural Network is the most reliable face recognition system, although it takes more data than other techniques. According to this study, three of the five algorithms are light-sensitive. There are three stages to the face recognition system's operation. Face detection utilising algorithms like the Viola-Jones detector and PCA is the initial step. The second step is extracting the face's features, including the face's shape, mouth, nose, and eyes, using techniques like LBP. Thirdly, the extracted face's features are compared to the faces database (Shanthi et al., 2019).

A review paper from Ali et al. (2020) stated that the Eigenface, Support Vector Machine and Fisherface could not deal with changes in lighting conditions. Table 2.4 shows the sensitivity of face recognition algorithms to light.

Table 2.4: Light sensitivity to lighting affects the accuracy of facial recognition (Shanthi et al., 2019) (Ali et al., 2020).

	Algorithm	Lighting effect accuracy of facial recognition
1	PCA	Yes
2	LDA	-
3	(LBPH	Yes
4	EBGM	Yes
5	Neural Networks	-
6	Eigenface	Yes
7	Fisherface	Yes
8	SVM	Yes

2.4.1 Drone Facial Recognition Applications

Face recognition by UAVs is utilised for monitoring. Even though the camera on drones can distinguish faces, the accuracy of face recognition during flying is affected by the angle of depression and the distance from the camera to the face (Tamilarasu et al., 2019), as well as the facial positions, light intensity (including poor lighting and weather), individual features, and cosmetics. (Adjabi et al., 2020).

New research for medication delivery drones (Abeygunawaradana et al., 2021) uses face recognition on mobile apps for authentication, and the paper stated that light affects face recognition. In addition, Walambe et al. (2021) stated that even object detection by the camera on a drone is sensitive to light and distance.

2.4.2 Facial Recognition Camera (FRC)

The Huskylens Face Recognition Camera (FRC) is equipped with a Kendryte K210 CPU and a 2-megapixel camera; according to the manufacturer, their system uses the You Look Only Once (YOLO) technique, which operates at up to two frames per second. The Huskylens is 30 times quicker than YOLO. However, the manufacturer has not disclosed any other information (Zhou et al., 2021) (Aufranc, 2019). Kendryte K210 is a system on a chip (SoC) with low power consumption that is effective for face recognition, picture classification, and object detection. For machine vision, CNN is used. It does face recognition at up to 60 frames per second in real-time (Canaan, 2022). Redmon et al. (2016) presented YOLO for object detection. YOLO is typically utilised for object detection. He added, Fast YOLO may operate at as much as 155 fps, whereas the standard YOLO only operates at 45 fps (Redmon et al., 2016).

2.5 Light's Role in Photography and Face Recognition

Drone face recognition is an outdoor process where the source of light is a natural light source during the day and artificial light sources during the night, as well as a combination of the two during improper lighting. Face recognition is a set of image processing for a photo or a video frame taken by a camera. This section covers the basics of lighting in photography and the effect of lighting on FRC. Langford (2010) covers in his book the features of the light that affect the photo, like the light's intensity, direction, and colour. In the studio, the light conditions are fully controlled, unlike the partial control in landscape photography. The white light colour is measured in Kelvin (K). The lowest light colour is a reddish-white like candlelight, and the highest is a bluish-white like the blue sky, while the daylight is in the middle range of 5500K and the Tungsten light of

3200K. The direction of light will determine the direction of the shadow, which will reflect the appearance of facial features. The front side light illuminates the texture and details of the subject, as shown in Figure 2.2 A, while the back-light makes the subject sharper without the appearance of the details which are in the shadow part, as seen in Figure 2.2 B. Both front-light and back-light happen during sunrise and sunset during the day. Light intensity is known as the brightness of the light. The camera's settings are adjusted according to the brightness of the light. Extreme high or low light intensity will affect the quality of a photo. Ang (2008) stated in his book that the colour temperature of light varies during the day. The hardness of the sunlight from one direction on a sunny day will make the object clear from one direction with a very sharp transition of light. On the other hand, the diffused light from the cloud has better lighting around the subject and a smoother light transition.

Figure 2.2 : (A) Light falls on the backside of the head; (B) light falls on the face.

Shanthi et al. (2019) conclude that the PCA algorithm is extremely sensitive to light and shade, the LBPH algorithm drops during extreme brightness, and the EBGM algorithm is the most sensitive to light. According to his research, three of the five algorithms are light-sensitive.

2.6 Summary

The literature review found that most previous studies on medicine delivery were based on the medicine delivery to the patient's location, the drone's payload, and flight distance, regardless of user identity validation (Scott & Scott, 2018). Face recognition solutions are used widely on drones for surveillance applications. Furthermore, the spread of COVID-19 accelerates telemedicine applications and medication delivery, which require user authentication for security and user safety. Some proposed delivery systems use face recognition to authenticate the user, whether by the Face Recognition Camera (FRC) on the drone or mobile phone apps. The literature review shows the effect of light on face recognition techniques and algorithms. In comparison, all the proposed solutions focus on improving software solutions rather than hardware support systems. The proposed system focuses on precise delivery to the authorised user using an upper-mounted contactless FRC to check the patient's identity. Light directly affects the accuracy and distance of FRC detection. Furthermore, the IoT Guidance Landing System (GLS) was developed to enhance face recognition accuracy. In addition, the Sanitising Unit (SU) is designed to spray sanitiser to eliminate the hazard of COVID-19 viral transmission during delivery.

CHAPTER 3: METHODOLOGY

3.1 Introduction

The Methodology chapter focuses on the methodology of the developed system. This chapter covers the methodology of the design, development, and testing of the systems according to our three objectives. The flowchart in Figure 3.1 shows the procedure steps to achieve and validate the three objectives. Chapter three covers the hardware, software, landing and delivery criteria, face recognition, GLS, and performance measurement.

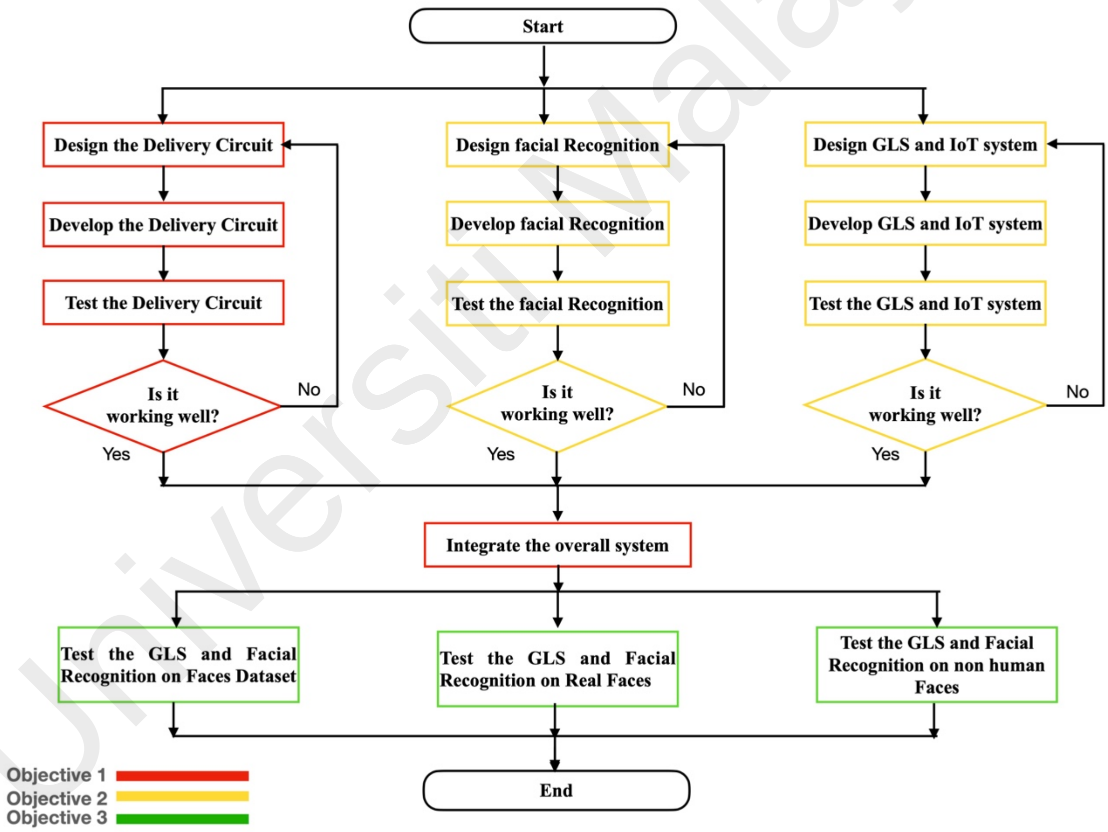

Figure 3.1: Blocks diagram of the overall design.

3.2 Develop a Drone-Based Solution for Medication Delivery.

This section covers the methodology of Objective 1 of this research, which includes hardware and software, as shown in Figure 3.2. This section covers the development and implementation of the drone's delivery units. The subsections cover the Motion Detection Unit (MDU), Sanitising Unit (SU), Voice Commands Guiding Unit (VCGU), and

Delivery Box (DB), as seen in Figure 3.3. The FRC is a part of the medication delivery system, but it will be covered in the next section. The developed circuit is assembled on the DJI Phantom 3, which is able to fly up to 25 minutes and the remote control works in a range of 500 – 1000 metres. The drone's weight is 1.216 Kg, and the payload is about 0.5 Kg.

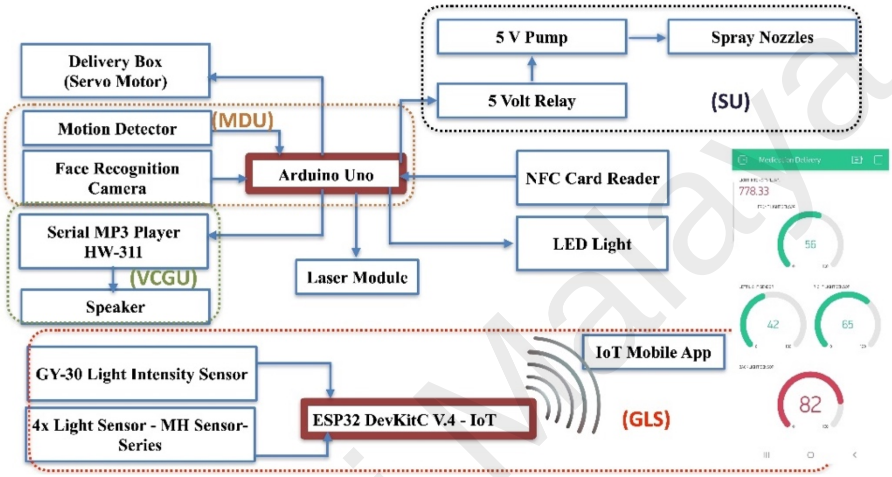

Figure 3.2: Blocks diagram of circuit hardware.

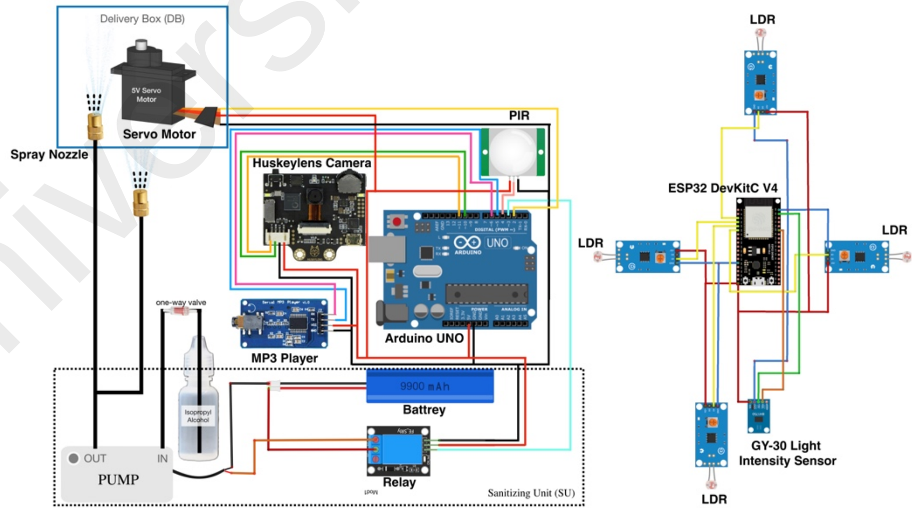

Figure 3.3: Circuit of the hardware.

The drone's hardware and software were developed, assembled, and tested in this study. The hardware for the drone consists of two development boards. The first development board is the Arduino Uno, which controls the FRC, DB, SU, MDU, and VCGU. The second development board is ESP32 DevKitC V4, which controls the GLS.

It is an IoT microcontroller board connected via the Internet to IoT apps, as illustrated in Figure 3.4.

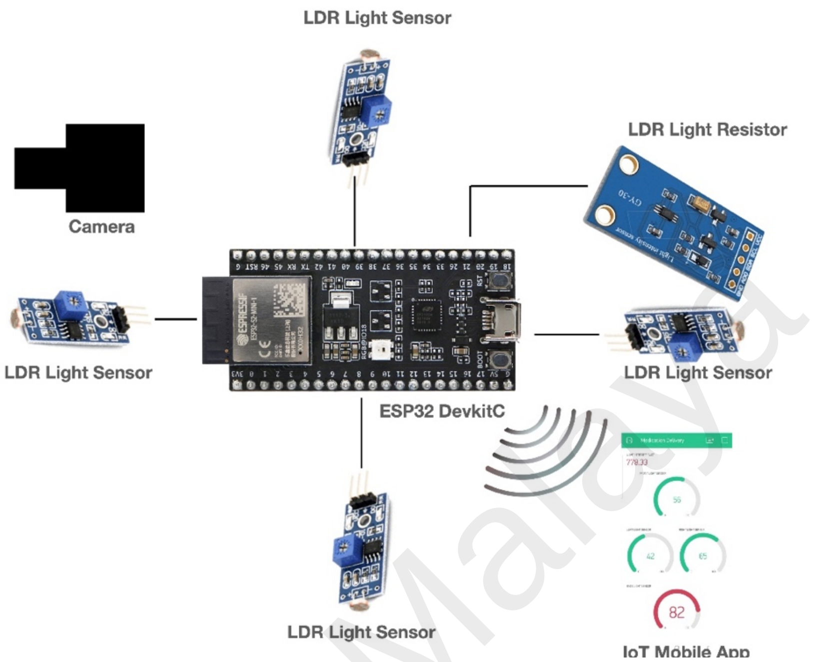

Figure 3.4: Components of the second development board.

3.2.1 Development of the Motion Detection Unit (MDU)

The Motion Detection Unit (MDU) has also been integrated with the drone system in order to preserve the drone's battery and protect the safety of its users (Figure 3.5). The medicine delivery UAV is programmed to remain in standby mode if no movement is detected around it, to enable the DB process when human motion is detected next to it, and to return to standby mode when the person goes away. When no human or animal is within close proximity to the UAV, the take-off mode will activate. The MDU incorporates both the Huskylens FRC and Passive Infrared (PIR) motion detection sensors. The face detection of an undefined user in the Huskylens FRC is a part of the face detection of the MDU.

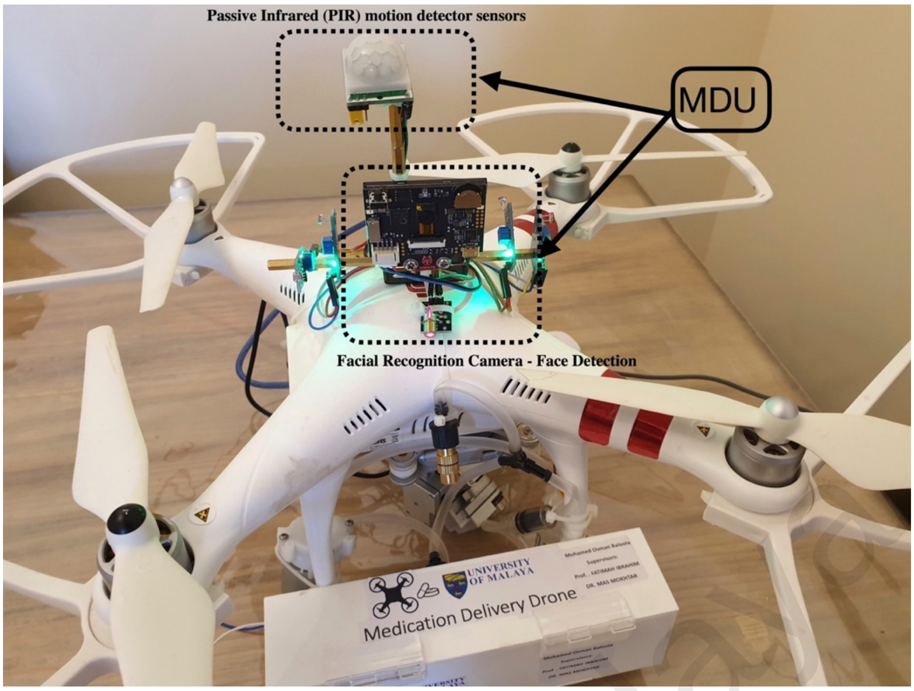

Figure 3.5: Components of Motion Detection Unit (MDU).

PIR sensors are connected to the digital pins of the Arduino Uno. The PIR sensor detects the presence of a human body, animal or moving object beside the drone. At the same time, the Huskylens is connected to the digital pins of the Arduino to communicate via the Universal Asynchronous Receiver Transmitter (UART) serial communication with the Arduino Uno, as shown in Figure 3.6.

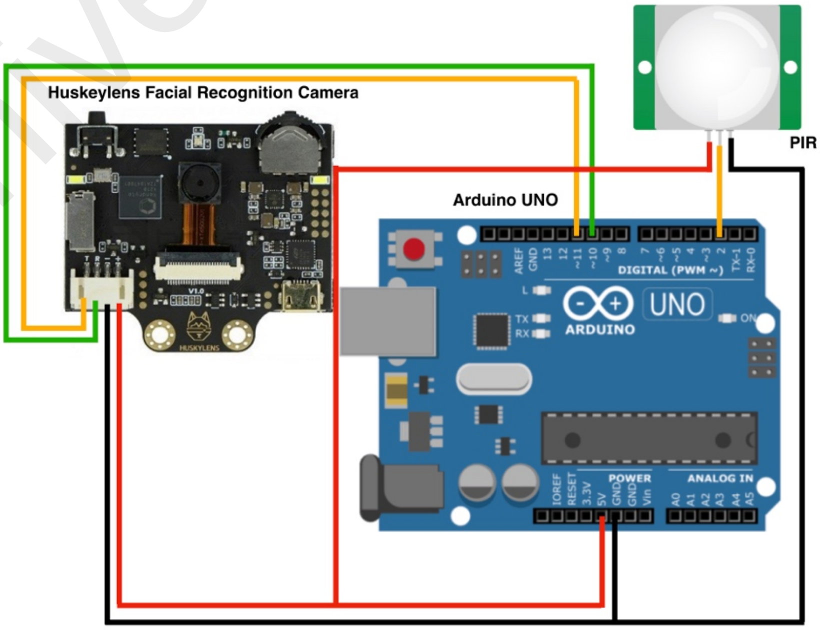

Figure 3.6: Circuit connection of the Motion Detection Unit (MDU).

3.2.2 Development of the Sanitising Unit (SU)

The Sanitising Unit (SU) sprays sanitiser liquid composed of 70 % Isopropyl Alcohol (IPA) using a 15 ml reservoir tank, which is sufficient for the pre and post-sanitising process delivery to the patient. A 3.7 Lithium-Ion battery operates the SU. Two adjustable spray nozzles are used to sanitise the most exposed surfaces that may be touched by the patient, as shown in Figure 3.7. The first spray nozzle inside the delivery box sanitises the sealed medicine package and the inner surface of the box, while the second nozzle outside the box sanitises the external surface of the box and the drone's external surface. The relay of SU is an active high relay, and it is connected to the digital pin of the Arduino. A 9900 mAh 3.7 Lithium-Ion battery provides sufficient current to run the liquid pump, which is controlled by the relay, as shown in Figure 3.8.

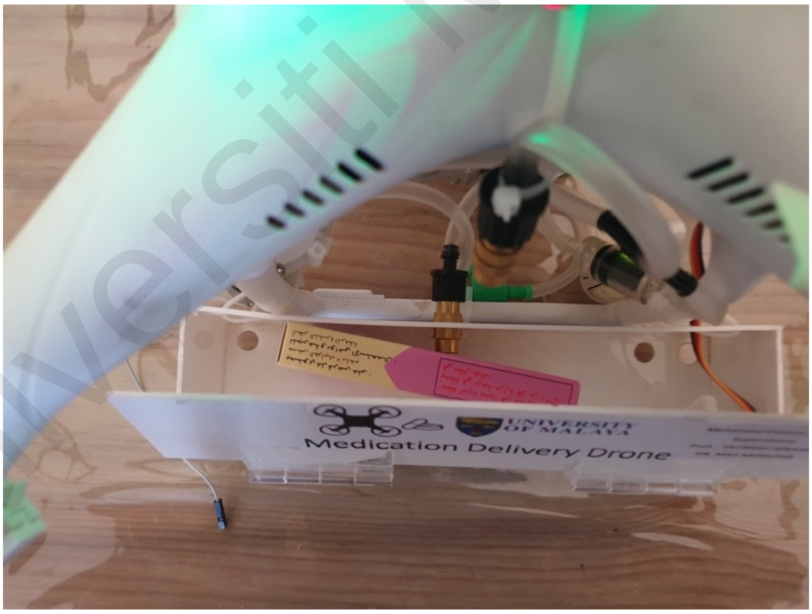

Figure 3.7: Sanitising Unit (SU) and Delivery Box (DB).

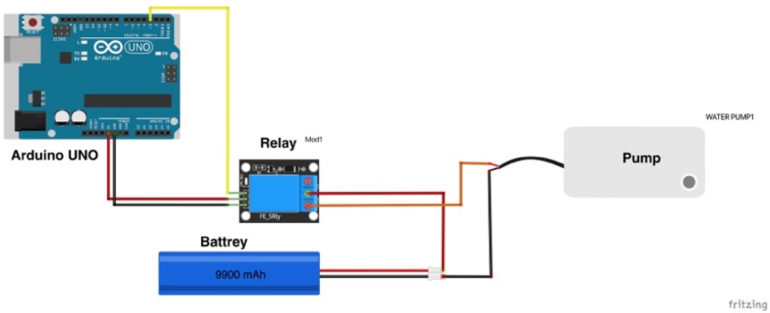

Figure 3.8: Sanitising Unit (SU)

An air valve is used to control the amount of air in the system to ensure the easy flow of IPA sanitiser, reduce the percentage of IPA evaporation, and avoid shrinking of the tank due to the limitations of the air inlet flow, as shown in Figure 3.9. In addition, to avoid leakage during the flight or any incident, a one-way valve is used to ensure the non-return of the IPA sanitiser.

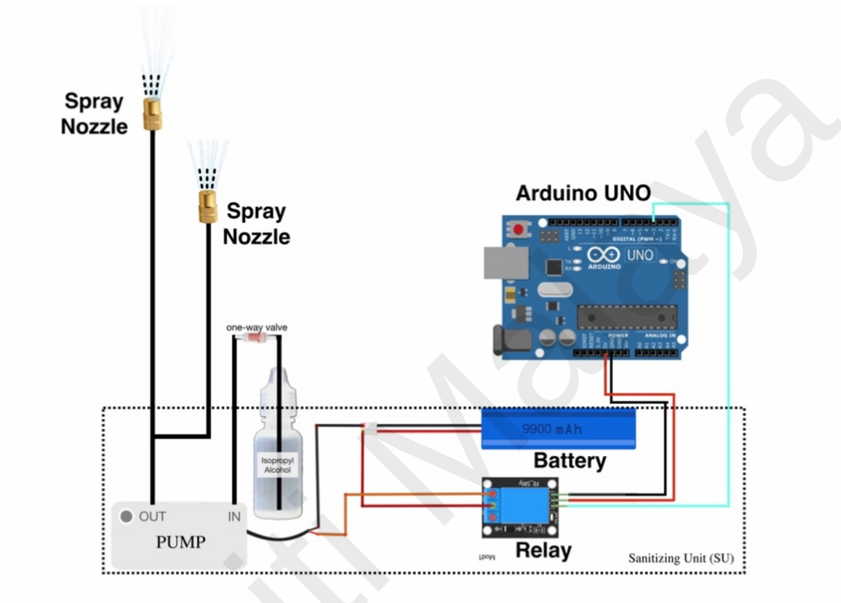

Figure 3.9: Sanitising Unit (SU).

3.2.3 Development of the Delivery Box (DB)

The mechanical Delivery Box (DB) is designed to open and close by a 5-volt servo motor operated by a Pulse Width Modulation (PWM) from the Arduino, as illustrated in Figure 3.10.

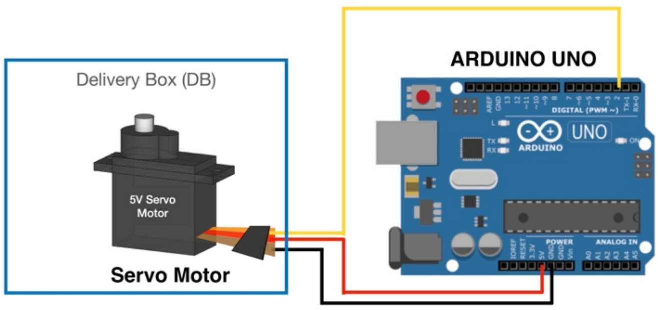

Figure 3.10: Circuit of the Delivery Box (DB).

3.2.4 Development of Voice Commands Guiding Unit (VCGU)

As indicated in Figure 3.11, the UAV is integrated with the Voice Commands Guiding Unit (VCGU), which is an interactive system with the client. The MP3 player mode (HW-311) is utilised to play voice instruction. Serial communication transmits an array of eight bytes in order to play a particular audio file. Each array consists of two bytes of data, beginning and ending bytes, version, array size, two bytes of data, command, feedback enable and disable flags, and array size. For example, the first audio clip will be used to greet the user, while the second will ask the client to stand facing FRC's lens. The MP3 player is controlled via the digital pins of the Arduino for serial communication, as illustrated in Figure 3.11.

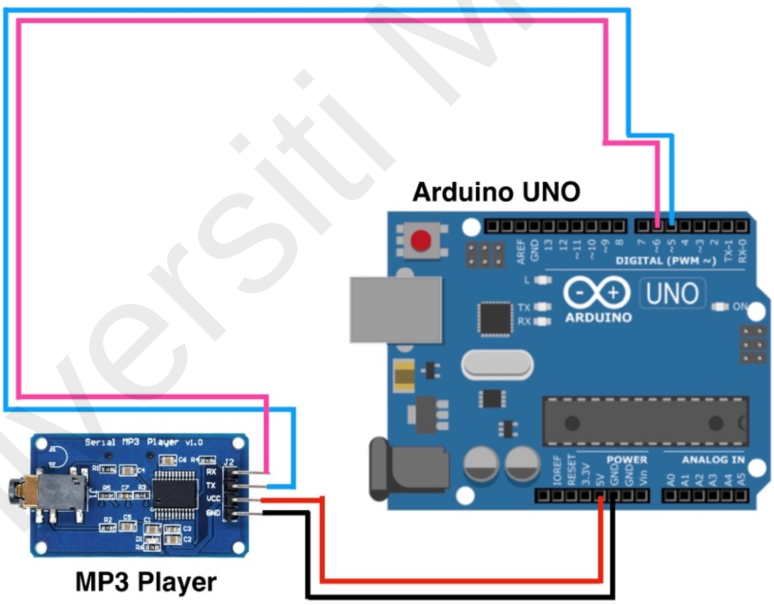

Figure 3.11: Circuit of the Voice Commands Guiding Unit (VCGU).

3.2.5 Testing the Drone Delivery

Testing the stability of the drone during flight with circuits on the drone. Select the best locations of the circuits, delivery box, facial recognition camera, GLS, and batteries on the drone. Compare the delivery times by drone, walking, and motorcycle.

3.3 Develop Guidance Landing System (GLS), Internet of Things (IoT) and Facial Recognition on the Drone.

This section covers the methodology of Objective 2 of this research, which consists of designing, developing and testing the face recognition system, Guidance Landing System (GLS) and Internet of Things (IoT). This section covers hardware and software development.

3.3.1 Design and Implement the Face Recognition System

The Huskylens FRC for face recognition (DFRobot Electronics, Shanghai, China) is equipped with a Kendryte K210 Chipset. It is an extremely lightweight FRC with face recognition that does not need Internet access. It is connected to the Arduino (Arduino S.R.L., Via Andrea Appiani, 25, 20900 Monza MB, Italy) by the Universal Asynchronous Receiver Transmitter (UART) or Inter-Integrated Circuit (I2C). As illustrated in Figure 3.12. The first microcontroller reads from the Huskylens FRC through the UART at 9600 baud rates. The controller board reads from the Huskeylens the user ID and checks it with a predefined user's identification. It is powered by 5 volts. Digital pins 10 and 11 are wired to the Huskylens FRC's Rx and Tx, respectively. Huskylens is built with a Multiple Faces Learning feature. Volunteers provided us with thirty pictures. Faces were assigned to IDs 1 to 3. ID = 0 is assigned to undefined faces. The ID = 0 helps in detecting the existence of any face. Consequently, a certain action was programmed into the Arduino Uno to respond to the user ID. The DB will open for the defined ID 1, 2, and 3 to give the medication, whereas the VCGU will sound a welcoming recorded message by the user name for ID 1, 2, and 3 and a voice alarm message to walk away from the UAV for ID 0.

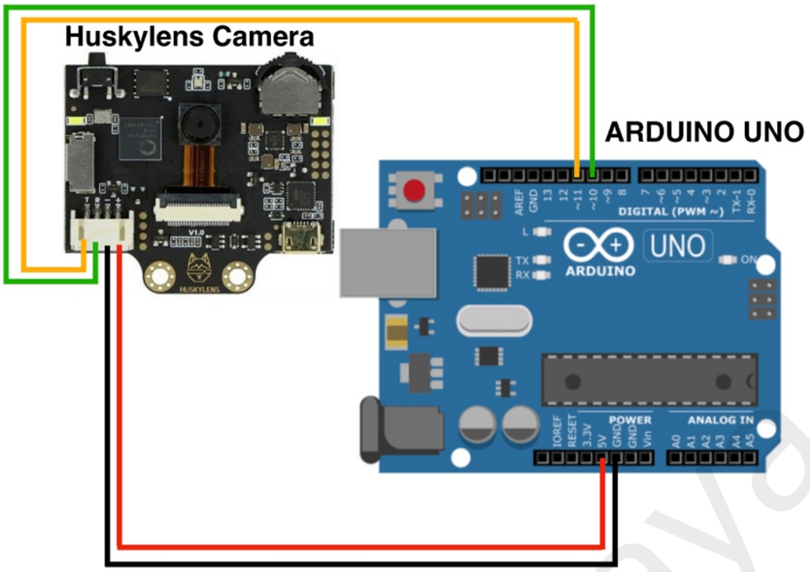

Figure 3.12: Circuit diagram of the Facial Recognition System.

3.3.1.1 Performance Testing of the Facial Recognition Camera

To ensure the accuracy, sensitivity, and specificity of the face recognition by using the Huskeylens FRC. The Huskylens FRC has been tested using three (3) reference standard faces photos and thirty collected faces photos. The accuracy is measured by the number of detected and recognised faces. At the same time, the sensitivity was measured according to light direction and intensity for the third objective. Furthermore, the specificity was measured by detecting the three trained faces.

3.3.1.2 Huskeylens Facial Recognition Camera Training Procedure

The Huskylens FRC has multiple training options. After selecting the "Multiple Faces Learning", point the "+" sign toward the face, press the blue square to detect the face and show the face ID starting from Face: ID 1. Then, the Huskylens FRC will ask you if you want to continue the learning process to learn a new face and so on. A new face ID will be given to each face during the learning process. In the case of face detection, a coloured frame will show on the screen with the face ID. The Huskeylens camera sends the ID number via serial communication to the development board.

3.3.1.3 Huskeylens Facial Recognition Camera Testing Procedure

To check the accuracy, sensitivity, and specificity of the Huskeylens FRC, four (4) testing procedures were conducted as follows:

(i) Testing on non-human online faces dataset

(ii) Testing on the reference standard photos

(iii) Testing using online dataset photos

(iv) Testing on real faces

3.3.1.4 Experimental Methods to Study the Facial Recognition Camera on Non-Human Faces

The objectives of the test are to check the face detection and face recognition of non-human faces. First, a series of face recognition tests were conducted on 5001 animal faces from the Animal Faces-HQ (AFHQ) dataset (Choi et al., 2020), as shown in Figure 3.13. The tests on animals are conducted to check the accuracy of facial recognition cameras for animal detection for the future pet-friendly delivery system and to deliver medicine for assistance pets for the disabled.

Figure 3.13: Face detection of non-human faces (animal), A) detect the animal's face, B) the animal face is undetectable.

3.3.1.5 Experimental Methods to Study the Facial Recognition Camera on Human Faces

The following tests are conducted on human faces:

(i) Test the face recognition of the three trained faces with 30 photos of the three volunteers.

(ii) Test the face recognition of three trained faces on a dataset of 5000 undefined faces from the Flickr-Faces-HQ dataset (FFHQ) (Karras et al., 2019).

(iii) Live test of face recognition on 35 volunteers

The results are available in the Results and Discussion chapter. The objectives of this test are to check the face detection and face recognition on a real human face of volunteers. A series of face recognition tests were conducted on real human faces, as shown in Figure 3.14, and human face photos.

Figure 3.14: Live test on the real human face of a defined user

3.3.2 Development of Guidance Landing System (GLS)

The second development board is the ESP32 DevKitC V4, as shown in Figures 3.15 and 3.4. IoT applications could leverage this microcontroller's dual-core processor, 12-bit ADC ports, and Wi-Fi connectivity. Four MH LDR sensors are wired to 12-bit ADC pins. As seen in Figures 3.15 and 3.16, LDR sensors are utilised to assess light intensity from four directions. The GY-30 light sensor outputs a Lux value. To measure the illuminance that falls on the patient's user face, the sensor is pointed in the opposite direction of the FRC. The sensor is connected by I2C to the SDA and SCL of the ESP32 DevKitC V4 development board. A 5-volt laser light module guides the patient to the proper position in front of the FRC.

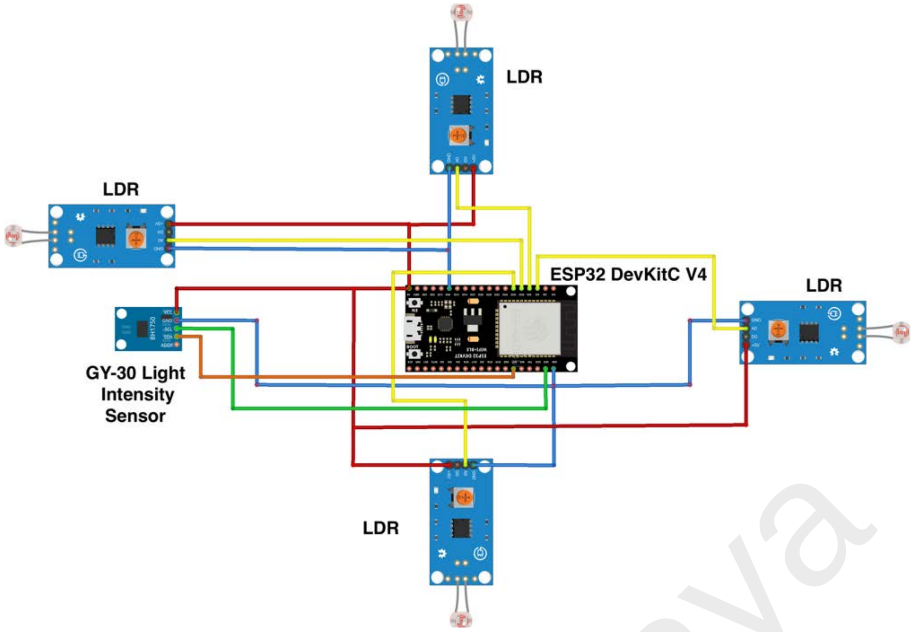

Figure 3.15: Circuit diagram of the Guidance Landing System (GLS).

The Global Positioning System (GPS) is fitted to the UAV to guide it to the landing location near the patient's residence. When scheduling a delivery, the patient receives a notice with the expected delivery time. Prior to the delivery, SMS and email notifications will be issued to the cell phone number and email address of the patient. The delivery depends on the patient's identification. In the situation of a patient who is elderly, ill, or busy, the face database should be updated with face recognition information of the patient's relatives. A text message and an email will be sent to the patient when the UAV arrives at the patient's position.

$$\%\ of\ the\ light = \frac{Analog - to - Digital\ Converter\ (ADC)\ Value\ \times\ 100}{2^{12}\ -\ 1} \tag{1}$$

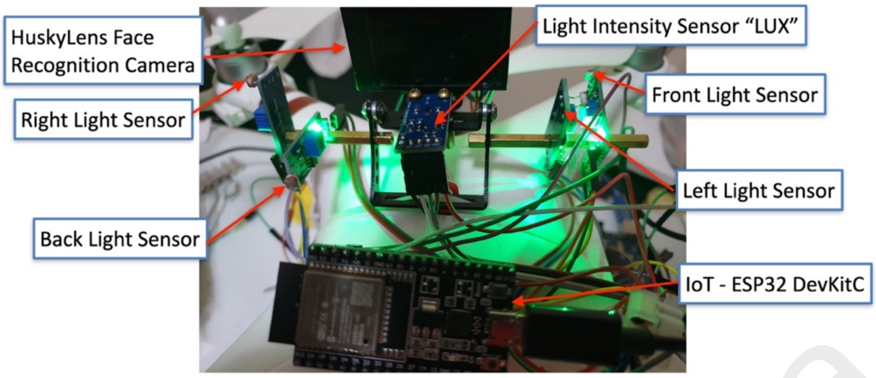

Figure 3.16: Components of the Guidance Landing System GLS).

As seen in Figure 3.15, the IoT board retrieves sensor data and transmits it to the IoT apps. The IoT board is connected to Wi-Fi. As seen in Figure 3.17, it reads data from five sensors. The illuminance sensor gives the value in Lux. Four photoresistors detect the proportion of light from four different directions. The light percentage is then sent to a smartphone apps to compare the illuminance from all angles. The percentage of light is calculated by Equation (1). The drone uses a 4G portable modem on the drone for internet connectivity.

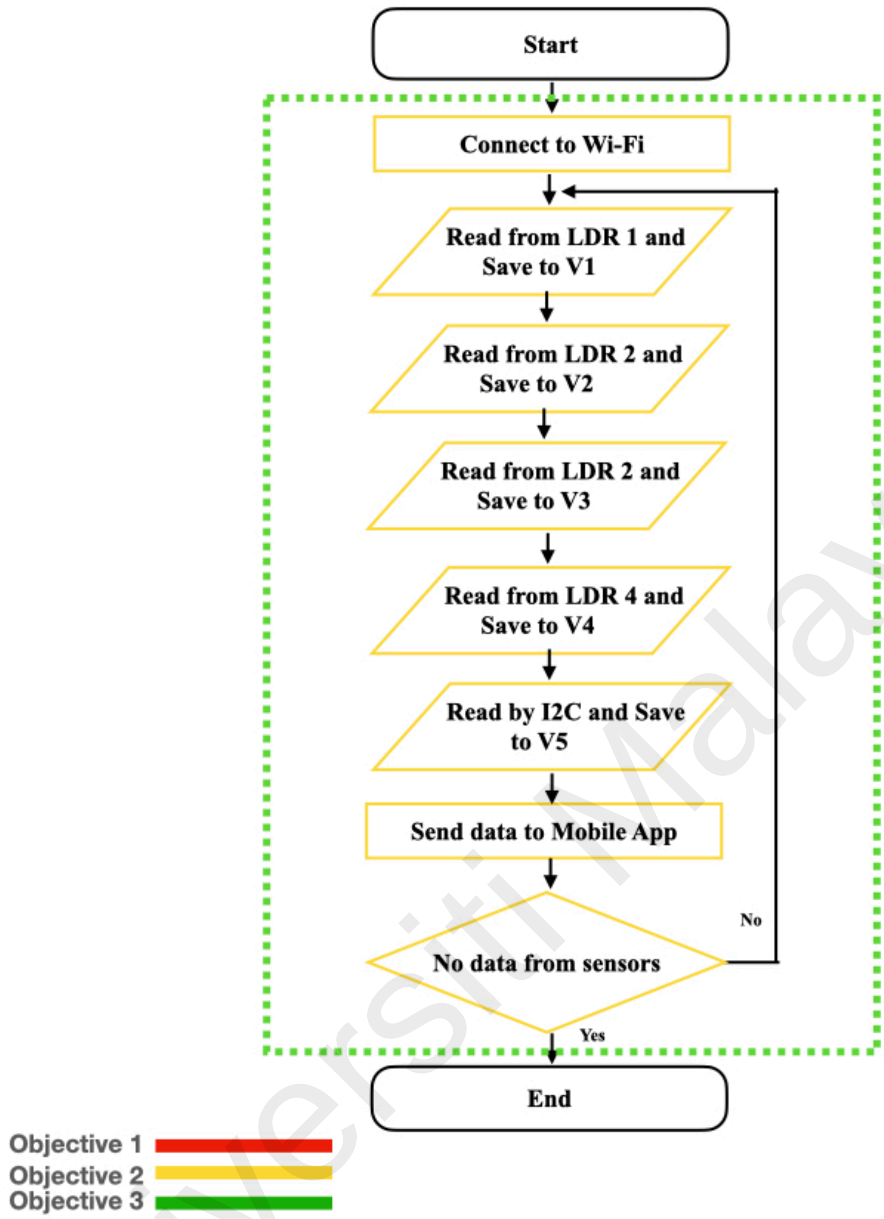

Figure 3.17: Flowchart of GLS. Notes: LDR connect to virtual pins (V1 -V5) in the IoT smartphone application.

3.3.3 Delivery Procedure

The flowchart in Figure 3.18 shows the procedure of the medication delivery starting from pre-sanitising before the take-off, followed by the take-off to the patient location. Then, the GLS helps select the optimum angle for delivery, as shown in the flowchart in Figure 3.17.

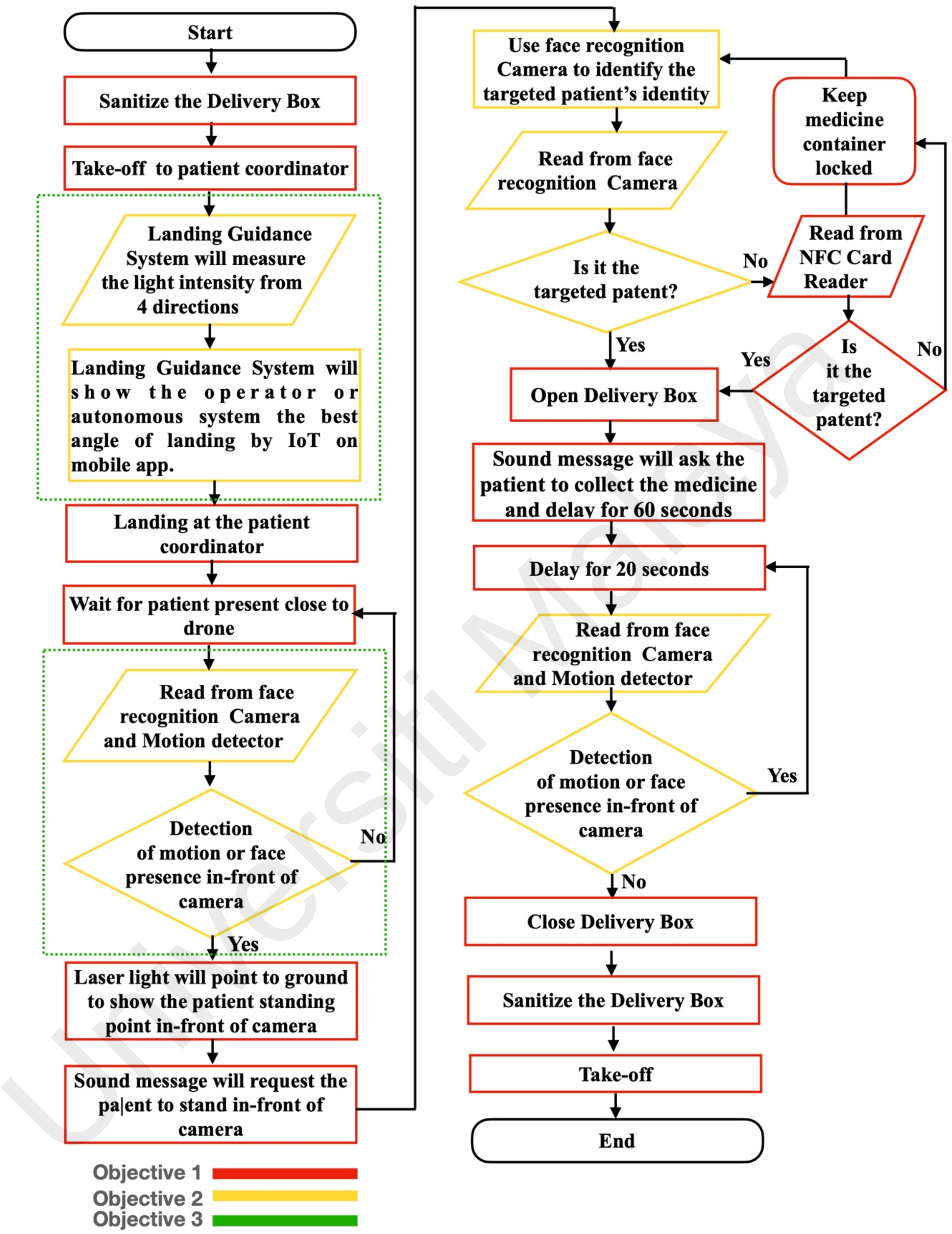

Figure 3.18: Flowchart of drone's delivery procedure.

To enhance the effectiveness of face recognition, the pilot or autopilot system of the UAV will choose the best landing angle depending on the illuminance using the IoT guiding system. Depending on the GPS coordinates, the UAV will land and turn off all rotors at the client's location. Then, using the motion sensor and FRC, the drone will request the client to step in front of the FRC to verify the patient's identification if a person is detected near the landing place. A red laser is pointed to the floor directly in front of the lens to assist the client in finding the right spot ahead of the lens, which is near the delivery box, for a more convenient user experience. Then, based on the client's recognition, the drone will greet the client. After that, the client will be able to receive the medicine by opening the DB. The box will then close, and the sanitisation process will begin to prevent the transmission of viruses and germs to clients and operators. If an unauthorised user is detected in the view of the lens, the UAV will sound a warning message requesting the individual to move away. The alarm will sound in case the violator doesn't respond to the request, and a photo will be forwarded to the operating centre.

3.3.4 Delivery Protocol

The delivery protocol will start to sanitise the delivery box before and after putting the medicine inside the box. Then, the drone will fly to the patient's GPS coordinates. Before landing, the GLS will show the pilot or autopilot the most efficient landing angle depending on the reading of the four light sensors and light intensity sensor on the mobile application by IoT, as shown in Figure 3.15 and Figure 4.9. The MDU detects the person's presence around the drone. The red laser points to the floor to show the preferred standing point in front of the FRC. A sound message requests the client to stand in front of the lens. The FRC detects the identity of the person. One of two scenarios can happen. In the first scenario, the alarm sound message will request the person to move away from the drone when the unknown face is detected. In case of a violation against the request, the alarm sound will operate, and a photo of the violator will be sent to the operation centre. In the second scenario, when the patient's identity is recognised, the delivery box will open, and a sound message will ask the patient to collect the medicine, as shown in Figure 3.7. Then, a delay of 60 seconds is given for the patient to collect the medicine. The sound message will ask the patient to move away from the box before closing it. If any motion is detected, the MDU delays the closing process for 20 seconds. If no motion is detected for a while, the delivery box will close, and the sanitising process will start. Finally, the drone is ready for take-off.

3.4 Investigate the Effect of the Direction and Intensity of Light on Facial Recognition and GLS

This section covers the methodology of Objective 3 of this research, which includes the methodology of studying the effect of light intensity and direction on the accuracy and sensitivity of the FRC and the GLS systems. The tests were conducted under controlled and non-controlled light at 3200K and 5500K. A light with a diffuser mimics a cloudy day, and light without a diffuser for a sunny day.

3.4.1 Study the Effect of Light Direction Using Uncontrolled Light

Different scenarios were tested to investigate the relationship and impact of light directly on the efficiency of face recognition utilising uncontrolled light. Lux (lx) represents the amount of light in lumens per square metre.

The length between the LED light and the UAV was set to 1.11 metres, and the LED source's intensity was also fixed at 580 Lux.

Scenario A:

In a dark room with one LED light source lighting the back of the face, as seen in Figure 3.19A and Figure 2.2A.

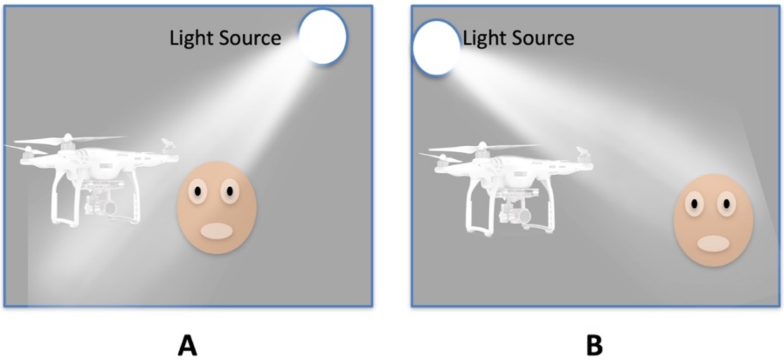

Figure 3.19: GLS and light direction, (A) light fall on the back of the head; (B) light falls on the face.

Scenario B:

The light falls on the back of the face in a room with an illuminance of 27.5 Lux and one LED light source, as seen in Figure 3.19A and Figure 2.2A.

Scenario C:

A dark room with one LED light illuminates the face, as seen in Figures 3.19B and 2.1B.

Scenario D:

In a room with an illuminance of 27.5 Lux and one LED light, as seen in Figure 3.19B and Figure 2.2B, the light falls on the face. For all four scenarios, the recognition distance of the subject's face by using FRC on the UAV was measured.

3.4.2 Study the Effect of Light Intensity and Colour Using Controlled Light

In this test, light intensity and colour were adjusted using a controlled light. The adjusted light colours were 3200K and 5500K. Figure 3.20 illustrates two different types of light sources; one with a diffuser and one without. The Kelvin (K) represents the temperature of light colours. The lower the light temperature, the redder the colour, whereas the higher the light temperature, the bluer the colour.

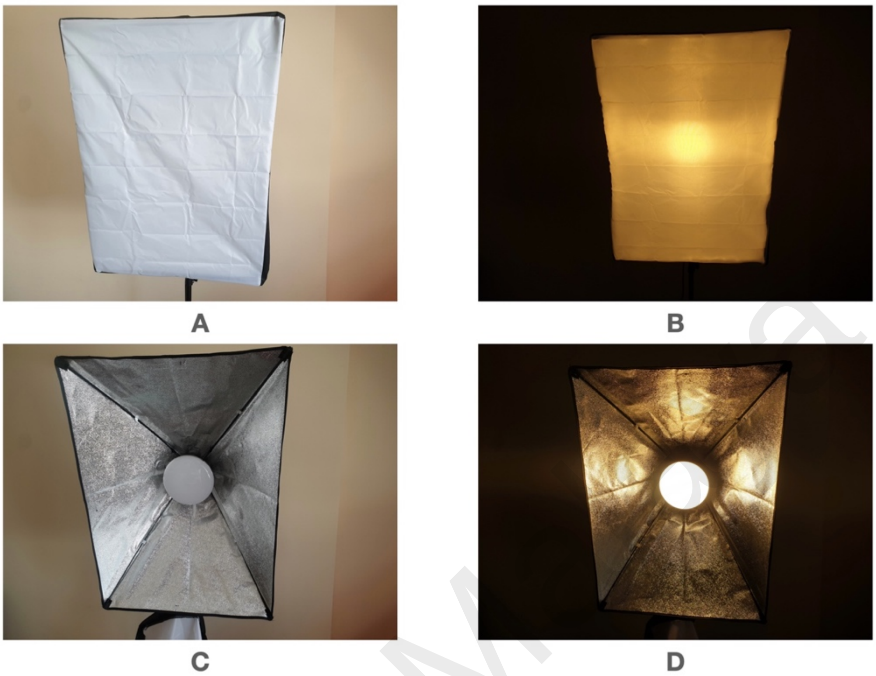

Figure 3.20: Light with/without a diffuser.

As seen in Figure 3.21, the illuminance sensor that gives the value in Lux was relocated to the rear of the UAV after the controllable light direction was directed to the FRC's rear.

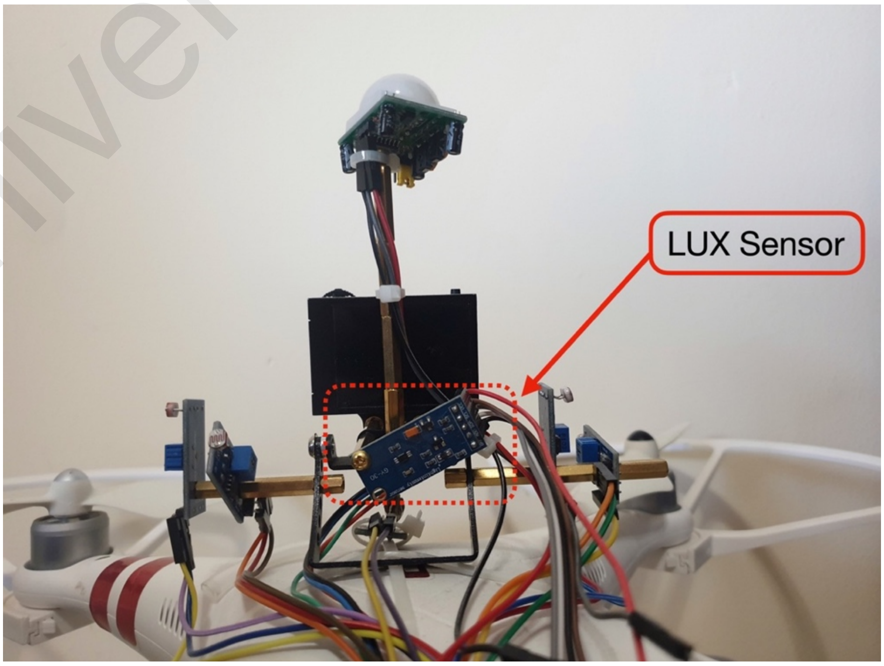

Figure 3.21: The illuminance sensor that gives the value in Lux is relocated to the rear of the UAV.

As seen in Figures 3.20 A and B, the first set of testing was done utilising a controllable source of light with a diffuser. At each of the five lighting levels, the illuminance and face recognition length were measured. The five-lighting levels were conducted again at 3200K and 5500K.

For the second set of experiments, a controllable light without a diffuser was utilised, as seen in Figures 3.20 C, D, and the illuminance and length were recorded when the subject's face was recognised at five levels.

The Pearson correlation coefficient (Pearson, 1896) was calculated to determine the relationship between detection length and illuminance in various conditions.

$$r = \frac{\sum_{i=0}^{n}(x_i - \bar{x})\left((y_i - \bar{y})\right)}{\sqrt{\sum_{i=0}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=0}^{n}(y_i - \bar{y})^2}} \tag{2}$$

3.4.3 Performance Measurement

The delivery accuracy depends on the efficiency of facial recognition, which is determined by the distance of face detection (the length from the lens to the face), and the distance is proportional to the amount of light that falls on the face. The GLS is designed to assist the pilot or autopilot in choosing the most efficient landing angle to solve this issue. Five illuminance sensors are integrated on GLS to measure the illuminance conditions and asses the efficiency of the system.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

The results and discussions in this chapter follow the sequence of the three objectives of this study. The first section is for the results and discussion of developing a medication delivery drone. Secondly, the results and discussion of the IoT–GLS and face recognition. Thirdly, the investigation of the effect of the direction and intensity of light on face recognition and GLS. Finally, the summary of the results and discussion.

4.2 Drone for Medication Delivery

This section covers the results and discussion of Objective 1 of this research, including the results and discussion of the drone medication delivery system and components.

4.2.1 Results of Drone for Medication Delivery

As seen in Figure 4.1, a medical delivery UAV with face recognition capability has been designed and implemented. It's designed with a mechanically secure DB, the SU, which sprays sanitiser during delivery to prevent the transmission of COVID-19 viruses. Using vision recognition technology to identify the client, the designed UAV could safely deliver medication (Figure 4.2). The UAV was developed to interact with the client and communicate using voice commands. The UAV is integrated with a Huskylens artificial intelligence (AI) FRC, which is utilised to identify patients and conduct the delivery procedure based on the client's identification profile.

Figure 4.1: UAV with face recognition, Guidance Landing System (GLS) and Delivery Box (DB).

Figure 4.2: Face Recognition on the drone.

Three tests have been conducted to check the to check the delivery time by drone walking and motorcycle as shown in table 4.1

Table 4.1: Medicine delivery time taking by drone, walking and motorcycle

Starting Point	Destination	Drone Time (MM:SS)	*Motorbike Time (MM:SS)	Walking Time (MM:SS)	Distance Drone (Metres)	Distance Motorbike (Metres)	Distance Walking (Metres)
BME Department	**Library 24 Hours**	01:02	01:16	05:31	270	600	350
Library 24 Hours	**BME Department**	01:02	02:52	05:31	270	2200	350
BME Department	**Chancellor Building**	00:35	01:52	04:20	201	900	247
Chancellor Building	**BME Department**	00:35	02:27	04:20	201	1600	247
2nd Residential College	**Examination Hall**	00:47	04:31	07:18	297	2400	500
Examination Hall	**2nd Residential College**	00:47	01:48	07:18	297	750	500

4.2.2 Discussion of the Results of Drone for Medication Delivery

Our design has four constraints. The first constraint occurs once the sun has an acute angle during sunrise and sunset. The second limitation occurs in poorly lit environments with a single source of light emitting from 20 to 50 Lux. The third constraint is in a dark environment where there is no lighting source or if the illuminance is below 20 Lux. The fourth constraint occurs when the user is wearing a face mask, and our FRC cannot recognise a face.

The offered approaches to solving limitations number one and two consisted of implementing the GLS, which offers the optimal landing angle to maximise the effectiveness of face recognition. Regarding the third constraint, a mini-LED may be fitted and mounted to the drone so that the light flashes when the drone senses a dark area. For the fourth restriction, the VCGU was incorporated into the system; the VCGU would require a client to step directly in front of the lens and off their masks. As illustrated in Figure 3.1, we recommend installing an NFC card reader (RC-522) on the UAV in the event of subsequent detection failure, plus a keypad. To enhance a secure experience, the UAV's camera will report a photo of the violator user and a recording of the delivery procedure to the operations centre.

Three test locations have been successfully conducted to deliver medicine at Universiti Malaya, as shown in Table 4.1. The compression between delivery by drone, walking and motorbike proved that the drone has the fastest delivery time compared to all traditional delivery methods. The delivery tests were conducted back and forth for the three locations. The first test was conducted from the Biomedical Engineering department to UM 24 library, which is close to the Students Clinic. The drone was delivered within 01:02, while the motorbike back and forth timing between 01:16 to 02:52, and the walking delivery took 05:31. The Second experiment from the Chancellor building to BME, the drone was delivered within 00:35 while the motorbike back and forth timing between 01:52 to 02:27 and walking delivery took 04:20. The third experiment from 2nd Residential College to Examination Hall, the drone deliver within 00:47 while motorbike back and forth timing between 01:48 to 04:31 and walking delivery took 07:18.

The majority of published research on the development and improvement of face recognition algorithms concentrates on the design of software to address illumination concerns. Our proposed approach is designed to help face recognition algorithms, particularly in an outside environment where conditions are difficult to control. The great majority of scientific papers focus on controlled indoor conditions.

The gap found in the literature review is that all the studies and research focus on the development of face recognition algorithms.

4.3 Guidance Landing System (GLS) and Facial Recognition on the Drone

This section covers the results and discussion of Objective 2 of this research, including the results and discussion of the FRC and the Guidance Landing System (GLS).

4.3.1 Results of the Guidance Landing System (GLS) and Facial Recognition on the Drone

By developing the IoT-GLS, the pilot or autopilot system of the delivery drone will be able to determine the appropriate landing angle depending on illuminance and direction of light to ensure maximum face recognition efficiency. Depending on the GPS coordinates, the UAV was able to land at the patient's location and turn off all rotors. By the motion detector and FRC, the drone was able to recognise any human near the landing place and request the client to step in front of the lens to verify the patient's identification. A controlled laser was utilised to point a red laser at the floor ahead of the lens and assist the client to the right spot, which would be near the delivery box, in order to enhance the user experience. Then, based on the patient's identity, the drone used a voice to communicate with the client. The DB was then unlocked for the client to take the medication. Finally, the DB closed, and the sanitisation procedure was initiated to prevent the transmission of viruses and germs to the clients and the operators. If an unauthorised person is detected, the UAV will sound a warning message requesting the individual to move away. The alert will sound, and a photo will be reported to the control centre if the violator doesn't respond within 10 seconds.

4.3.1.1 Results of the Facial Recognition of Animal Faces

A series of tests were conducted on non-human faces. The tests were conducted on 5001 animal faces from the Animal Faces-HQ (AFHQ) dataset. The majority of faces were not detected, as shown in Figure 3.13B; 86.76% of the animal faces were not detected by the FRC, as shown in Figure 4.3. However, the FRC was able to detect animal faces; 13.24% of the animal faces were detected, as shown in Figure 4.4.

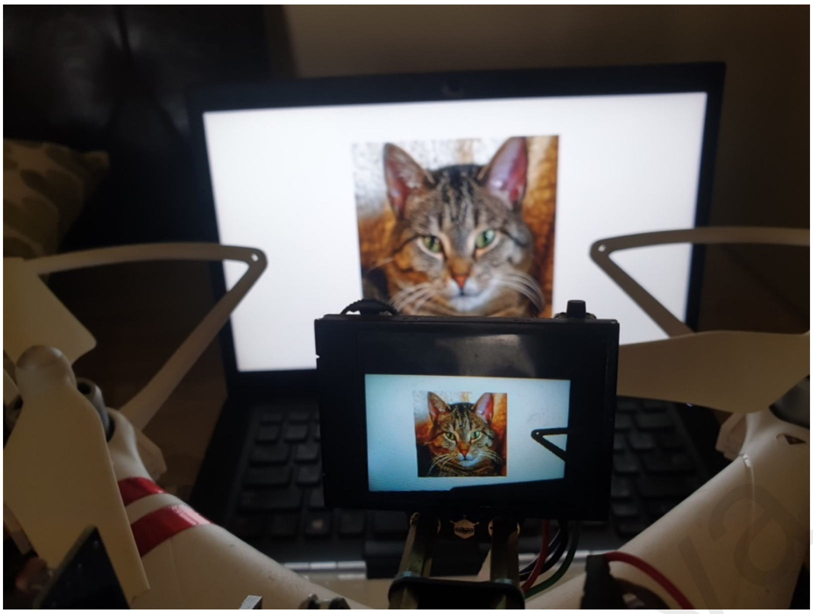

Figure 4.3: Face detection test of the non-human face of animal

A randomly selected face photo of cats, dogs and wild animals. The Huskeylens FRC did not recognise any animal faces, as shown in Table 4.2.

Table 4.2: Animals' faces detection

	No.	No. of face detected	Percentage from the same Species %	Overall percentage %	Face Recognized	Percentage of Recognized Faces %
Cats	1667	63	3.78	1.26	0	0
Dogs	1667	538	32.27	10.76	0	0
Wild animals	1667	61	3.66	1.22	0	0
Total	5001	662		13.24	0	0

The Huskylens FRC detected 13.24% of the animal faces. 10.76% of dogs' faces were detected, while only 1.26% of cats' faces and 1.22% of wild animals' faces were detected, as shown in Figure 4.4.

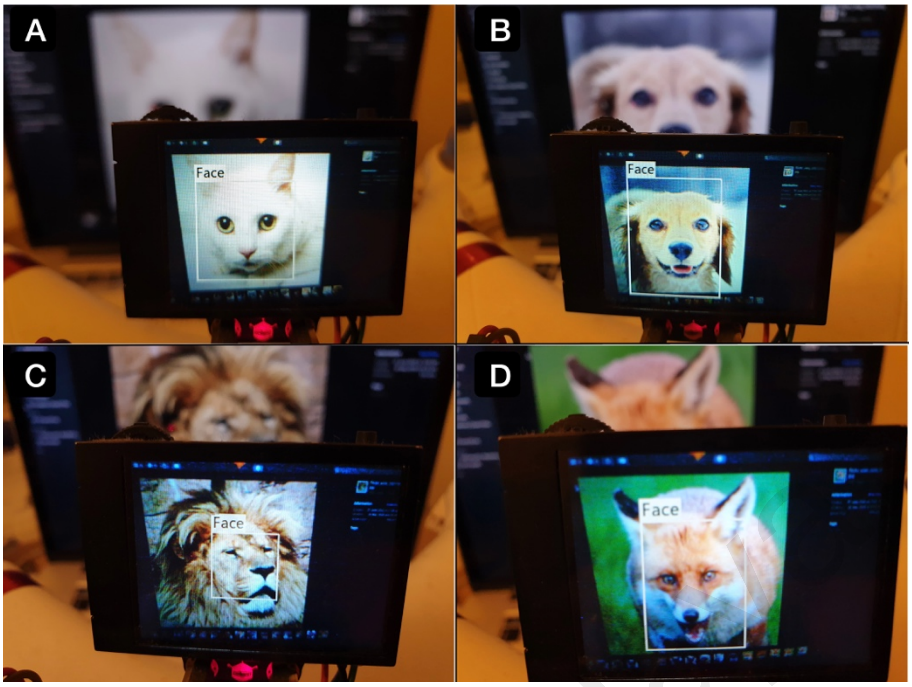

Figure 4.4: Animal detection of non-human faces of animals' faces, A) Cat face, B) Dog face, C) Wild Animals detection - Lion face, D) Wild Animals detection - Fox face detection

4.3.1.2 Results of the Facial Recognition from Photos Dataset

Three volunteers were utilised to evaluate the reliability of the Huskylens FRC, and 5000 face images from the Flickr-Faces-HQ dataset (FFHQ) have been used to assess the system's accuracy. To calculate face detection accuracy, the majority of faces were undefined. The images of the three participants were recognised and represented 0.596% of the overall 5030 pictures.

The Huskylens FRC includes two features; firstly, it detects the existence of a person's face; and secondly, it identifies the face's identity. The first test utilised 5000 images from the FFHQ dataset to detect human faces using the Huskylens FRC. The FRC accurately detects the existence of 4,997 faces with an accuracy rate of 99.94%. Only three images were not identified. Two faces weren't detected due to their hair partly covering them, and the third face was hidden by a hat. Face detection has a 0.06% per cent false positive rate.

4.3.1.3 Results of the Facial Recognition of Trained Faces

In the second test, 30 images of the three participants' faces were utilised to evaluate the system's accuracy. The FRC recognised 29 faces. However, the unrecognised face image was due to poor quality. As an outcome, the error rate reached 3.33 per cent. The Huskylens FRC trained and tested for the three standard faces, ID 1, ID 2 and ID 3, which are given to the three faces as shown in Figures 4.5, 4.6 and 4.7.

Figure 4.5: Train and test the Face ID 1

Figure 4.6: Train and test the Face ID 2

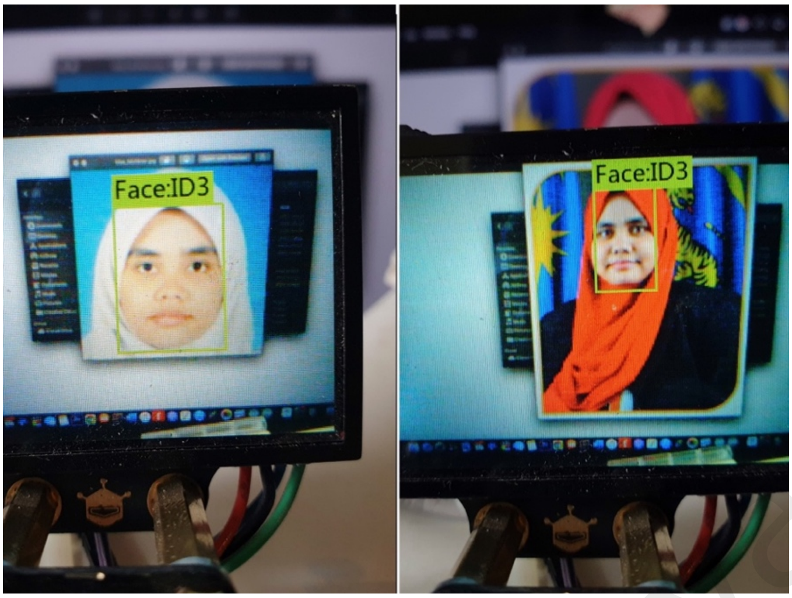

Figure 4.7: Train and test the Face ID 3

4.3.1.4 Results of the Facial Recognition of Real Human Faces of 35 Volunteers

A series of face recognition tests were conducted on real human faces of 35 volunteers' real faces. All three defined faces are detected and recognised perfectly, as shown in Figures 3.14 & 4.8A. All 35 faces are detected, as shown in Figure 4.8. One volunteer's face is recognised wrongly. The face detection of the Huskeylens FRC is 100%, and the face recognition accuracy of the test on real faces is 97.14%.

Figure 4.8: Results of the test of the real human faces of 35 volunteers, A) detect and recognize face ID 3 with an acute angle of female, B) detect and unrecognize male face with glasses from a close distance of male, C) detect and unrecognize face of an undefined male user, D) detect and unrecognize face of undefined female user.

The FRC can detect the face even when volunteers wear a face mask. The FRC is detecting faces at the same level as in Figures 4.8B, 4.8C, and 4.8D and with an acute angle, as shown in Figure 4.8A. In addition, the FRC detects female users in Figures 4.8A and 4.8D and male users in Figures 4.8B and 4.8C.

4.3.2 Discussion

Due to the UAV's payload, the significant challenge is utilising an incredibly light FRC without Internet access. In studies conducted under ideal settings, the Huskylens FRC offers an on-chip face recognition capability that satisfies the requirement and shows a high level of reliability in identifying the client, surpassing 98%. In addition, our proposed GLS system improves face recognition efficiency. The controlled laser light assists the client in finding the accurate place in front of the FRC.

The initial two tests were done with the images of three volunteers and 5,000 images from the FFHQ. The overall accuracy of our two tests in a controlled setting with ideal lighting conditions was 99.92%.

The percentage of light from 4 directions was then transmitted to the IoT smartphone apps in order to analyse the illuminance from all angles and determine the optimal landing angle. Figure 4.9 illustrates the IoT smartphone apps that was designed. The topmost value represents the rear side illumination as seen in Figure 4.9A; the illumination percentage on the front sensor as seen in Figure 4.9B; the illumination on the right-side sensor as seen in Figure 4.9C; the illumination on the left-side sensor as seen in Figure 4.9D; and the backside light intensity per cent as seen in Figure 4.9E.

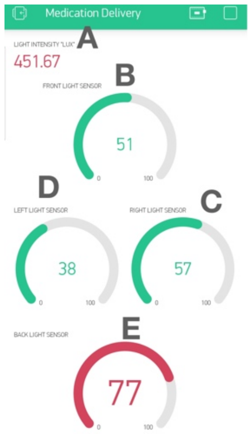

Figure 4.9: Smartphone application for GLS-IoT (A) The top numerical number indicates the illumination on the backside of the UAV toward the face. (B) The illuminance percentage is measured by the front-facing sensor. (C) The percentage of illuminance is measured by the appropriate sensor. (D) Illuminance percentage as measured by the left sensor (E) percentage of the rear sensor's luminance.

4.4 The Effect of the Direction and Intensity of Light on Facial Recognition and GLS

This section covers the results and discussion of Objective 3 of this research, which includes the results and discussion of the effect of the illumination and light direction on the face recognition and GLS system.

4.4.1 Results of the Direction and Intensity of Light on the Facial Recognition and GLS

In the research of the influence of illumination direction utilising uncontrolled light testing, in scenario A, when face recognition accuracy was evaluated in a dark room with one LED light where the light direction fell on the back of the head, the FRC didn't even detect the face at all. However, in scenario C, where face recognition accuracy was evaluated in a dark room with one LED light source, the FRC was able to recognise the subject's face from 1.92 metres away when the illumination direction fell on the subject's face.

In scenarios B and D, the accuracy of face recognition was evaluated in a room with an illuminance of 27.5 Lux and the LED light in the same location. When the light fell on the subject's head from behind, the FRC recognised the face from 0.6 metres (scenario B). In scenario D, however, the FRC recognised the subject's face when the light fell from a distance of 2.07 metres on the subject's face.

The findings of the research on the influence of illumination direction utilising uncontrollable light source scenarios indicate that the IoT-GLS enhanced the range of recognition by 192% in a dark place with one light source when it selected the optimal angle when the light fell on the subject's face. In addition, the test was performed in a low-light room (27.5 Lux) using one LED light. Using the IoT-GLS, the measurement increased the face detection range to 1.47 metres. To optimise the assessment of the intensity of light that falls on the face, the sensor was redirected from the top of the drone to the rear (Figure 3.21).

By changing the brightness of light, the second experiment examined the impact of illuminance and colour. The first round of controllable light source testing was done with a diffuser-equipped controlled light source. Five light intensity levels were measured. The five experiments were repeated at light colours of 3200K and 5500K. Table 4.3 shows the distance at which the subject's face was detected and assessed in each test.

Table 4.3: Examine the relationship between light colour (Kelvin), illuminance (Lux) and recognition range (metre) for a diffused light source.

3200K		**5500K**	
Distance * (metre)	**Illuminance ^ (Lux)**	**Distance * (metre)**	**Illuminance ^ (Lux)**
0.95	90.83	1.08	91.67
1.46	206.67	1.45	234.17
1.63	335.83	1.70	314.17
1.72	451.67	1.81	435
1.81	494.17	1.84	500.83

* Recognition distance between face and FRC. ^ The medical delivery drone's sensors measure the light intensity.

Table 4.3 represents the data gathered for the illumination testing with diffusers. At 5500K direct light, the light intensity was 500.83 Lux, and also the detection range reached 1.84 metres.

The acquired data for the illumination testing without a diffuser is shown in Table 4.4. At 5500K, the illuminance was 778.33 Lux, and also the detection range reached 1.99 metres.

Table 4.4: Examine the relationship between light colour (Kelvin), illuminance (Lux) and recognition range (metre) for light source without a diffuser.

3200K		5500K	
Distance * (metre)	Illuminance ^ (Lux)	Distance * (metre)	Illuminance ^ (Lux)
1.34	152.5	1.07	140.83
1.61	359.17	1.50	362.5
1.73	555	1.80	524.17
1.81	731.67	1.88	707.5
1.87	761.67	1.99	778.33

* Recognition distance between face and FRC. ^ The medical delivery drone's sensors measure the light intensity.

Next, four studies were done to determine the effect of altering the light direction from the right to the left of the UAV and face. The third round of controllable light source experiments was done utilising a controllable light with a diffuser from the right side of the face of the UAV. Five illumination levels were tested. The five experiments were repeated in the light colours of 3200K and 5500K. At each test, the distance was recorded when the subject's face was identified.

Table 4.5 displays the distance at which the subject's face was detected and measured in each test. Real and side-light intensities were recorded with the sensor of the UAV facing the source of light and turned 90 degrees to the right.

Table 4.5: Examine the relationship between light colour (Kelvin), illuminance (Lux), and detection length (metres) for a diffused light on the right.

3200K			5500K		
Illuminance ^ (Lux)	**Illuminance ^ Right (Lux)**	**Distance * (metre)**	**Illuminance ^ (Lux)**	**Illuminance ^ Right (Lux)**	**Distance * (metre)**
60.83	10	0.69	56.67	9.17	0.76
129.17	22.5	1.20	113.33	18.33	0.97
193.33	36.67	1.40	183.33	27.5	1.23
241.67	46.67	1.51	231.67	37.5	1.44
307.5	53.33	1.83	315	50	1.74

* Recognition distance between face and FRC. ^ The medical delivery drone's sensors measure the light intensity.

The fourth round of controllable light-source experiments was done utilising light without a diffuser on the right side of the face and the UAV. Five light intensity levels were recorded. The five experiments were repeated at light-colour of 3200K and 5500K. Table 4.6 represents the distance at which the subject's face was identified and detected in each test. Actual and side-light intensities were measured with the sensor of the UAV toward the light source and turned 90 degrees to the right.

Table 4.6: Examine the relationship between light colour (Kelvin), illuminance (Lux), and detection length (metres) for light without a diffuser on the right.

3200K			5500K		
Illuminance ^ (Lux)	**Illuminance ^ Right (Lux)**	**Distance * (metre)**	**Illuminance ^ (Lux)**	**Illuminance ^ Right (Lux)**	**Distance * (metre)**
98.33	10.83	0.87	91.67	10.83	0.90
208.33	21.67	1.27	210	25	1.28
335.83	31.67	1.44	339.17	40	1.53
415.67	41.67	1.56	462.5	54.17	1.59
495.83	58.33	1.64	503.33	59.17	1.66

* Recognition distance between face and FRC. ^ The medical delivery drone's sensors measure the light intensity.

The fifth set of controllable light source testing included light with a diffuser from the left-side of the UAV and the face. Five light intensity levels were measured. The five experiments were repeated at light-colour of 3200K and 5500K. Table 4.7 shows the distance at which the subject's face was detected in each test. Actual and side-light intensities were recorded with the sensor of the UAV facing the light source and turned 90 degrees to the left.

Table 4.7: Examine the relationship between light colour (Kelvin), illuminance (Lux), and detection length (metres) for a diffused light on the left.

3200K			5500K		
Illuminance ^ (Lux)	**Illuminance ^ Left (Lux)**	**Distance * (metre)**	**Illuminance ^ (Lux)**	**Illuminance ^ Left (Lux)**	**Distance * (metre)**
60.83	10.83	0.70	56.67	9.17	0.75
129.17	24.17	1.21	113.33	19.17	0.99
193.33	35.83	1.41	183.33	34.17	1.31
241.67	49.17	1.56	231.67	42.5	1.47
307.5	51.67	1.72	315	53.33	1.77

* Recognition distance between face and FRC. ^ The medical delivery drone's sensors measure the light intensity.

The sixth round of controllable light source tests were done utilising a light without a diffuser from the left-side of the face and the UAV. Five light intensity levels were observed. The five experiments were repeated at light-colour of 3200K and 5500K. Table 4.8 represents the range at which the subject's face was detected in each test; the actual and side-light intensities were recorded while the sensor was facing the light and when turned 90 degrees to the left.

Table 4.8: Examine the relationship between light colour (Kelvin), illuminance (Lux), and detection length (metres) for light without a diffuser on the left.

3200K			5500K		
Light Intensity ^ (Lux)	**Light Intensity ^ Left (Lux)**	**Distance * (metre)**	**Light Intensity ^ (Lux)**	**Light Intensity ^ Left (Lux)**	**Distance * (metre)**
98.33	12.5	0.90	91.67	11.67	0.92
208.33	25	1.37	210	24.17	1.24
335.83	35.83	1.52	339.17	41.67	1.50
415.67	47.5	1.58	462.5	51.67	1.53
495.83	66.67	1.80	503.33	57.5	1.62

* Recognition distance between face and FRC. ^ The medical delivery drone's sensors measure the light intensity.

Two studies were performed to determine the effect of moving the light directly from the front, right, and left of the UAV and face at a constant distance. From three different orientations, the illumination was recorded. With/without a diffuser, the experiments were performed at 3200K and 5500K. As indicated in Tables 4.9 and 4.10, the distance was set at 1.30 metres after the subject's face was identified. The real and side-light intensities were measured while the light sensors were facing the light and when the sensor of the drone was turned 90 degrees to the right and left. The real and side-light intensities were measured while the light sensors were facing the light and when the sensor of the drone was turned 90 degrees to the right and left.

Table 4.9: Results of the illuminance (Lux) and light colour (Kelvin) at a fixed detection length of 1.30 metres for the light without a diffuser from the front and two sides.

	3200K			5500K		
Direction	**Illuminance ^ (Lux)**	**Illuminance ^ Sides (Lux)**	**Distance * (metre)**	**Illuminance ^ (Lux)**	**Illuminance ^ Sides (Lux)**	**Distance * (metre)**
Front	99.17	99.17	1.30	95	95	1.30
Right	185	25.83	1.30	154.17	20.83	1.30
Left	185	25	1.30	154.17	20	1.30

* Recognition distance between face and FRC. ^ The medical delivery drone's sensors measure the light intensity.

Table 4.10: Results of the illuminance (Lux) and light colour (Kelvin) at a fixed detection length of 1.30 metres for the light with a diffuser from the front and two sides.

	3200K			5500K		
Direction	**Illuminance ^ (Lux)**	**Illuminance ^ Sides (Lux)**	**Distance * (metre)**	**Illuminance ^ (Lux)**	**Illuminance ^ Sides (Lux)**	**Distance * (metre)**
Front	114.17	114.17	1.30	97.5	95	1.30
Right	150	26.67	1.30	133.33	26.67	1.30
Left	150	27.5	1.30	133.33	26.67	1.30

* Recognition distance between face and FRC. ^ The medical delivery drone's sensors measure the light intensity.

The efficiency of delivery relies on the precision of face recognition, which would be influenced by the range of face detection (distance from the face to FRC). There is a positive correlation between light intensity and recognition distance; as the light intensity increases, so does the detection distance, and vice versa. This study discussed the examine the GLS to assist the pilot or autopilot in determining the optimal landing spot. Five light sensors were installed on the GLS in order to measure the light's intensity and direction and evaluate the system's precision.

As demonstrated in Figure 4.10, a multirotor drone may land at the same spot with 360° of rotation (yaw) flexibility along the vertical axis. Facial detection in outdoors is extremely difficult due to the varying weather conditions. A series of tests were performed to enhance facial recognition and detection quality.

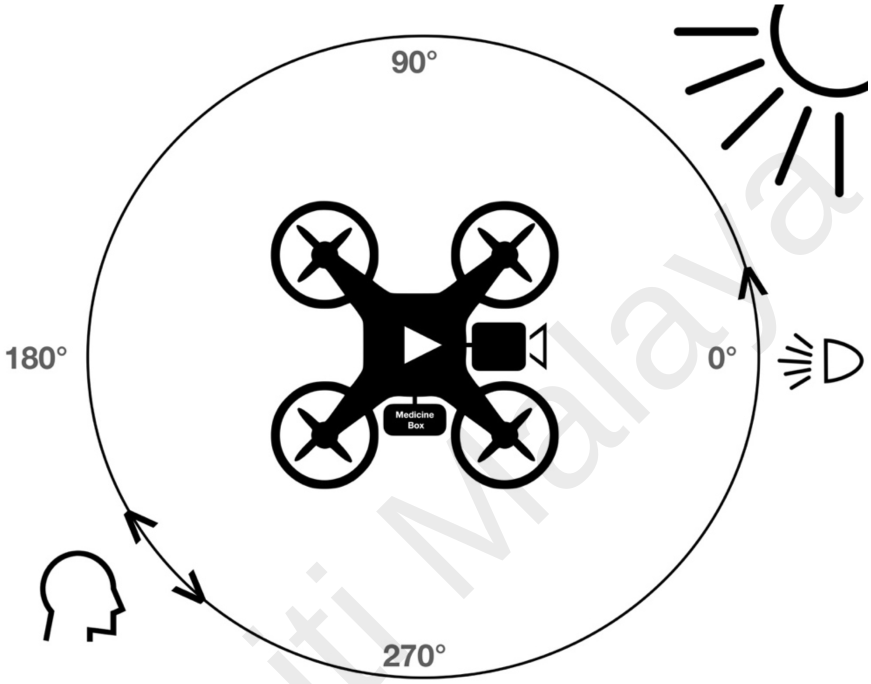

Figure 4.10: The drone has freedom of 360° spins (yaw) around the vertical axis.

4.4.2 Discussion of the Direction and Intensity of Light on Facial Recognition and GLS

The effects of varying the light directly from the front and two sides of the UAV and face at a specific length were measured and compared in the last two sets of tests. The intensity of the light was measured in three directions. The experiments were repeated with/without a diffuser at 3200K and 5500K. As indicated in Tables 4.9 and 4.10, the length was set to 1.30 metres when the subject's face was identified.

The findings clearly demonstrated the impact of moving light from the sides to the front. The illuminance required to identify a face at 1.30 metres when the light source emanated from the left or right, with/without a diffuser, was identical. The 3200 K light tests done without a diffuser showed a significant variation of more than 85 per cent in the needed light intensity for the exact same length when the light direction shifted from the front to the right and left. As indicated in Figure 4.11, the needed light intensity from the front was 99.17 lux, and from the sides, it was 185 lux. For 3200K without a diffuser, the needed light intensity from the front was 95 lux and from the sides was 154.17 lux or roughly 62.3%. Then, the 3200K light tests done with a diffuser showed that the light intensity needed for the same length varied by more than 31.4% when the light direction moved from the front to the right and left. The needed light intensity from the front was 114.17 lux, and from the sides, it was 150 lux. For 3200K with a diffuser, the needed light intensity from the front was 97.5 lux, but from the sides, it was 133.33 lux or approximately 36.7% more. From the results presented above, it is obvious that the differences between the front side and the two sides for light without a diffuser are significant, but the differences are reduced for light with a diffuser.

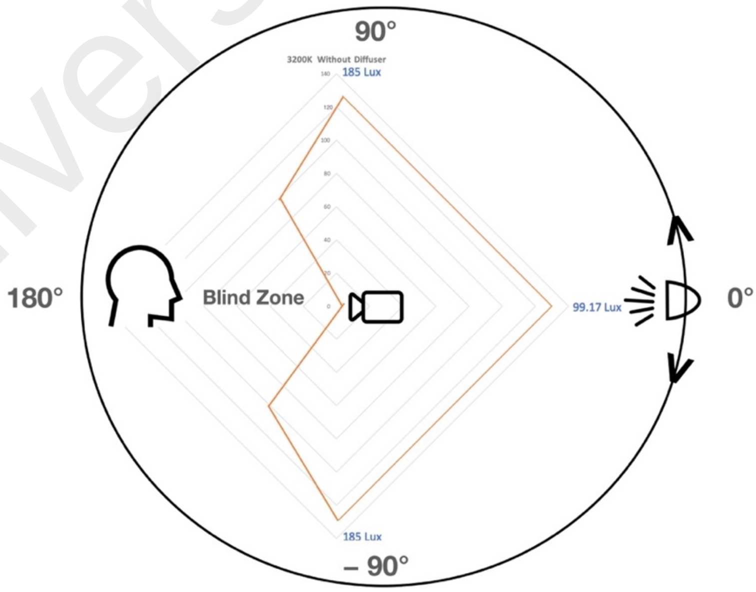

Figure 4.11: Examine the light intensity (Lux) needed for face recognition at a fixed distance of 1.30 metres from the front and two sides of a 3200K light without a diffuser.

A significant correlation was discovered between face recognition, detection distance, light direction, light intensity, and light colour (p 0.05); as seen in Table 4.11, optimal efficiency of face recognition for medication delivery could be achieved using the IoT-GLS, which can assist the operator or autonomous system in determining the optimal angle of landing depending on the light direction and intensity.

Table 4.11: The correlation coefficient of Pearson between 3200K and 5500K with/without a diffuser

	3200K		5500K	
	With Diffuser	**Without Diffuser**	**With Diffuser**	**Without Diffuser**
r	0.9415	0.9782	0.9625	0.9749
p	0.016835	0.003851	0.008668	0.004756

As indicated in Figure 4.12, the strongest correlation was discovered at 5500K when the direct-light had a longer recognition distance. As illustrated in Figure 4.13, the detection distances for 3200K direct light were nearly identical.

Figure 4.12: The graph illustrates the relationship between illuminance (Lux) and detection length (m) for soft 5500K light and direct 5500K without a diffuser.

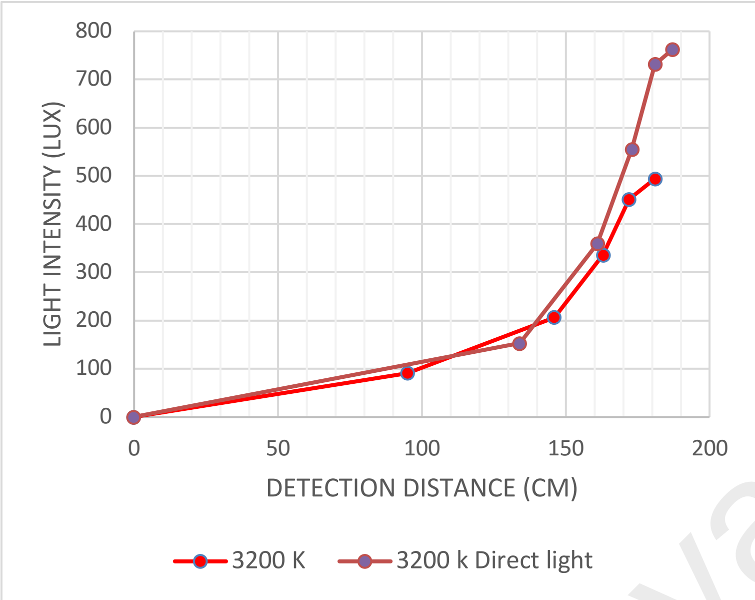

Figure 4.13: The graph illustrates the relationship between illuminance (Lux) and detection length (m) for soft 3200K light and direct 3200K without a diffuser.

4.5 Discussion and Comparison of the Results with Studies in the Same Field

Previous studies and researchers highlighted the illumination issues with face recognition and the sensitivity of the FRC to light, as covered in the Literature Review chapter (Shanthi et al., 2019) (Ali et al., 2020). The outdoor light conditions vary and are uncontrollable due to many possibilities. The proposed systems by researchers focus on improvements to the software of the algorithm (Shanthi et al., 2019). The gab found a lack of assistive hardware systems to overcome the illumination issue and light sensitivity. The results of this study prove that changing the light intensity and direction could significantly enhance facial recognition accuracy. The Literature Review chapter showed that FRCs are used with a drone for user authentication either by the drone's camera or a smartphone's camera (Abeygunawaradana et al., 2021) (Walambe et al., 2021). For both approaches, light sensitivity concerns were raised. Our findings in this study showed that detection distance and face recognition have improved with the IoT-GLS system. The IoT-GLS can support any mobile face recognition system, such as the FRC on a robot, drone, or autonomous car.

4.6 Summary

The drone-based solution medication delivery has been tested successfully at three locations at Universiti Malaya by drone, walking and motorcycle, as shown in Figure 4.14.

Figure 4.14: Flight test for drone

The FRC is used for face detection and face recognition. In the first test done on the 5000 undefined human faces from the FFHQ dataset, the system FRC detected 99.94%. Next, the three trained faces were tested with 30 photos; the accuracy reached 96.67%, and the accuracy of 5030 faces was 99.92%. Then, the FRC was tested on 35 real human faces; the FRC detected 100% and recognised 97.14% of the faces. Furthermore, the FRC tested on non-human faces of animal faces of the AFHQ dataset. The FRC detected 13.24% of the animal faces; the most detected faces were dogs' faces.

For the relationship between face recognition distance, light intensity and light direction, in the first test conducted with the uncontrolled light source in a dark room and a room with a light intensity equal to 27.5 Lux, the IoT-GLS improved the recognition distance up to 1.47 metres. Furthermore, six tests were conducted with a control light source from the front, right, and left sides for 3200K and 5500K with and without a diffuser to simulate sunny and cloudy environments. As a result, the maximum face recognition distance reached 1.99 metres for 5500K light without a diffuser when the light intensity equals 778.33 Lux when the light source is from the front side.

Finally, a couple of tests were conducted to show the light intensity required for a fixed distance of 1.30 metres from the front and two sides, with and without a diffuser, and the result showed that the illumination required for the same detection length might be almost doubled when the light source is from the sides and front. In one experiment without a diffuser, the light intensity required from the front was 99.17 lux, while from the two sides, it was 185 lux.

The highest correlation was found at 5500 K, where the direct light had a longer detection distance. However, for the 3200 K direct light, the detection distances were almost the same.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

5.1 Conclusions

A contactless Drone-Based Solution for Medicine Delivery Using Face Recognition and Guidance Landing System was successfully designed. The drone was equipped with IoT-GLS and face recognition capability to detect users' identities for medication delivery applications. The drone has SU and a secure DB to deliver sanitised medication to the authorised user. The face recognition system has been tested with human and non-human faces for face recognition and detection, reaching 98.53% accuracy. The IoT-GLS improvement was developed and implemented to maximise efficiency. The IoT-GLS enhancement was introduced to optimise the efficiency of face recognition and overcome the current illumination challenge of face recognition on the drone during sunrise, sunset, and at night with a light intensity of around twenty (20) to fifty (50) Lux. The implemented IoT apps can display the percentages of illuminance from four (4) directions in addition to the amount of illuminance from the backside of the camera, representing the illuminance that falls on the patient's face. Moreover, experimental results revealed a strong relationship ($p<0.05$) between light direction, light intensity, and detection distance. The GLS improved the face recognition distance by 192% in a dark environment. The created IoT-GLS shall enable the autopilot system or UAV pilot to choose the optimal landing angle, increasing the face recognition distance to more than two (2) metres. This will enhance hygiene practices to avoid spreading the viruses and bacteria in the contactless solution for medication delivery.

5.2 Recommendations for Future Work

Future work is to implement a real medication delivery test based on the payload and delivery distance to enhance the medication delivery processes. In addition, future work will be to evaluate the GLS for several face recognition algorithms. As well as to research the influence of a broad spectrum of light colours.

Furthermore, since the GLS can overcome the light intensity and direction issues faced in the face recognition algorithm, the assistive GLS can be further implemented in all outdoor face recognition cameras or systems, including mobile phone face recognition cameras and a pre-installation of the face recognition camera.

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