Master's thesis

# Designing and Implementation of Drone-based Telemonitoring System for an Inaccessible Area

**Yashodha Karunarathna**

Division of Electrical and Electronic Engineering
Graduate School of Engineering
Mie University

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# Chapter 1

# Introduction

## 1.1 Background

Unmanned Aerial Vehicles (UAVs) are growing rapidly across application domains. Including real-time monitoring, providing wireless coverage, remote sensing, search and rescue, delivery of goods, security and surveillance, precision agriculture, and civil infrastructure inspection is the main application for drone usage [1], and. Drone usages in search and rescue in a disaster situation took a significant place among them. Disasters such as earthquakes, tornadoes, hurricanes and floods which may result in building collapse or hazardous materials releases. It is significant challenges to emergency responders, search and rescue of patients. Under that uncontrollable situation, a huge number of people may lose their lives. Finding a victim and rescue him/her is becoming the most difficult part among many search and rescue teams. In such situations, the rescue system must take fast decisions under pressure to get victims to a safe location. The rescue system must collect the location information and status of victims as quickly as possible to save people. All these works are performed mostly in very dangerous and risky situations. Detection by rescue workers becomes time-consuming and due to the vast area, that gets affected it becomes more difficult. Sometimes the rescue team cannot reach the disaster-affected area due to the inability to search for the live person in the debris.

To reach the disaster-affected area there are several types of rescue robots used in this field. Due to the unbalanced ground and time consumption, the aerial robot takes the best place than a ground robot. In the rescue operations, drones can scan affected areas with their thermographic cameras to locate missing persons. Arial robot reduced dimensions allow them to go to places that are hard to reach and find isolated persons. Even though there are several robots for human detections, almost all of them do not consider the situation of the detected alive human. To save the life of detected human it is required further detail to the rescue team. Due to the difficult and unpredictable circumstances of a disaster, communication and coordination among the incident people and the responders in the field may be challenging tasks. Furthermore, according to Salman et al. Telemonitoring systems monitor human vital signs and provide services in different environments and conditions. Because of weight, this kind of telemonitoring systems is not designed for the drone. A pervasive telemonitoring system allows real-time and continuous healthcare monitoring. Users can obtain their vital signals via sensors (e.g., oxygen saturation [SpO2]) and send them to personal gateways (e.g., hand-held devices, personal digital assistants, and laptops) through small area network protocols (e.g., Bluetooth and ZigBee) in the Wireless Body Area Network (WBAN) [1, 2]. As a matter of fact, in the disaster situation communication protocol can' t predict whether work well or not. According to the Anwar et.al distance from approaching a victim and waiting time can be lessened by a fight-or-fight strategy. In disaster situations required efficient, reliable communication technology such as GPRS, LTE, etc. However, transmission losses or delays occur during transmission.

Previous studies [3, 4] proposed a model that can be used to monitor the vital signs of casualties. But casualty' s physiological conditions cannot be used as an input in the system. Therefore, the rescue team cannot collect vital signs. Nevertheless, other systems [5, 6]can be used to track casualties by employing GPS or wireless networks at a disaster scene. However, issues on prioritization have not been addressed. For the disaster situation, an electronic triage system has been proposed [7]. This system comprises two types of electronic triage tags and an electronic triage server. Electronic triage tags can be attached to a casualty to monitor vital signs continuously. Almost all of the proposed triage system for victims who are in the recovery area. But in a disaster situation, isolated persons lost their lives without medical or survival support even though they saved their life from disaster. This is the biggest problem in disaster management operations.

To avoid this kind of limitation we are going to develop a smooth and stable drone with a system which can detect vital signs and send that data with GPS location to the rescue team using radio transmission. That kind of a smart triage drone may increase the number of saving lives in the unreachable area in a disaster situation.

## 1.2 Problem Statement

However, most of Tele monitoring systems do not consider disaster situations but daily use. Some of them are information systems for use in a disaster situation. Even it is considered about the disaster situation, do not addressed about the people who are in unreachable area. Therefore, we mainly focus main three circumstances.

1. Monitor and identify the alive person who are in inaccessible area. On the other hand, the technologies for a drone is getting popular.

2. The drone-based tele monitoring system has a wide range of applications.
3. When communication infrastructures may not be available because electricity is downed.

## 1.3 Goals and Objectives

The objective of this research is to develop a novel drone-based telemonitoring platform to detect victims and measure their health condition in an unreachable area, under a disaster situation. Hence supply the real-time monitoring system, which is designed and implemented with radio communication personal networks can record and transmit biosignals of patients in an inaccessible area. This system is designed considering not only patients monitoring but also acknowledges some vital signals of a patient, e.g. thermal data, to calculate their severity utilizing physiological data successfully. Also, implemented the algorithms for human detection into the module. More specifically experiments using the developed telemonitoring system is conducted to discuss the performance of the proposed method.

To achieve that goal, the developed device was mounted on the self-assembled drone (hexacopter) and evaluated its performance. In the experiments, the relationship among human detection accuracy, camera angle, and distance from a detecting object (human) was investigated. The experimental results showed that 2m ,3m is the horizontal distance ranges and 1.5m ,2m is the altitude range were required to detect humans and measure their body temperature accurately in real-time. Finally, it can conclude that achieved the goals successfully..

## 1.4 Structure of the Dissertation

The second chapter consists of the literature reviews from previously published studies by various researchers in the identified problem domain. Each of the studies has been analyzed according to the above-mentioned goals and objectives. The third chapter includes the Design concept of the drone system. from the initial sketch, the initial construction to the final construction according to the revisions. It also includes the descriptions of the components that make up the internal structure of the telemonitoring system. The fourth chapter include the experimental protocol of the robot. This explains how the robot interacts with the children in the testing environment. The fifth chapter consists of a result that was obtained while executing the experiments explained in the previous chapter. Here, the results are represented in a manner that is easily understandable. The sixth chapter discusses the results shown in the previous chapter and analyzes them. It also discusses the limitations that occurred during the study. The final chapter includes the conclusion of this study and includes future works that are to be carried out.

# Chapter 2

# Related Works

Studying the work previously done by other people in this area is a mandatory task in the steps leading up to achieving the objectives that were identified in the introductory chapter. This chapter comprises of the review of the works related to telemonitoring system in disaster situation in an attempt to get a better understanding of the target domain.

## 2.1 Telemonitoring system in a disaster situation

A disaster situation is a sudden event that disrupts the functioning of a community/society seriously and causes human, material, and economic or environmental losses. In particular, Japan has many experiences of earthquakes like the Hanshin Earthquake in 1995, East Japan Earthquake in 2011. In addition to these big earthquakes, Japan had many other types of disasters like heavy rain, flooding, landslides every year. In such a disaster situation, most of the lifeline, such as electricity, water/gas pipelines, communication systems, and transportation systems may not work well, and the victims in the inaccessible will be isolated. Some of them may be severely injured/diseased, and in such situations, the rescue team must make fast decisions under pressure to get victims to a safe location. To save victims, The system to collect their location and health status as quickly as possible is strongly required. Therefore monitoring patients remotely is one of the promising ways to save a life in disaster situations.

## 2.2 Why Researchers are Motivated to Utilize drone-based Telemonitoring systems?

On the other hand, the technology for drones is getting popular, and the drone-based telemonitoring system has a wide range of applications. For instance, Electricity companies are now inspecting some of their high-voltage lines without expensive power outages and risky climbs. Railway companies are now considering drones based telemonitoring system for inspection of disrupted tracks in areas with limited access . The authors strongly believe that drone technologies have enough possibilities to detect victims (or missing people) and monitor their health condition without risks under disaster situations.

## 2.3 Telemonitoring Platform for disaster situation

#### Container-based system

Ciprian et. all [8] implements the containerized disaster management telemonitoring system for a disaster situation. Using satellite they create an independent network when the internet affected in the case of an emergency. However, their system does not implement for flood, Tsunami or that kind of huge disaster situation. The system implements for railway accident, road accident with victims or industrial accident: explosion, fire or hydrological phenomena. As the pros of this system, it can cover 100 victims using the container-based management system.

#### Mobile health monitor system

Cell phone-based health monitoring systems have been found in the literature. Wan-Young Chung et.al [9] proposed a cell phone-based health monitoring system with self-analysis processor using wireless sensor network technology. But the system is only for heart diseased and when there is an incoming call the transmission is disrupted.

Srdjan Krco et.al also proposed the mSens mobile health monitoring system. The system has an intelligent health -care sensors and is attached to the patient body. Doctors use their mobile control units to receive notifications in an urgent situation. Also, they are able to remotely control settings of the patient' s health sensors in order to modify and adapt their functionality. Personalized mobile telemedicine systems are for continuous monitoring of a customizable number and type of health parameter.

Ziyu Lu et.at al [10] proposed an iCare mobile health monitoring system for the elderly person. Through vital physiological data monitoring, real-time emergency response helps to reduce sudden accident. The system is not only health monitoring but also life assistant system. However, when the connection dropped all transmission will be disrupted.

#### Wearable health monitoring system

Ambulatory monitoring of physiological parameters through the use of wearable or implant biosensors has been an interesting research area during the past years. Alexandros and Nikolaos [11] proposed Prognosis: a wearable health monitoring system for people at risk. They define a novel model based on fuzzy regular formal language to describe the current state of health of the user. Even though the accuracy is good enough to apply for the disaster situation is not worth enough for the data collection.

Rita, Giannicola and Nicola [12] present a wearable healthcare system based on knitted integrated sensors. This paper shows the feasibility of a system based on the fabric sensing element. The textile health monitoring approach is better to monitor long term data monitoring of the patient for the post-disaster situation when caring about the victims physical and mental health.

### Post-disaster situation

Yukata and Hiroshi [13] proposed a health care monitoring service system to care, disaster survivors, using a 3D infrared camera and biosignal monitoring by air mat sensors are described. The system classifies adults, children, and the other object, and then defects human behaviour such as the trajectory of their movements. However, their target situations are not an isolated person in the disaster scenes.

### RFID, Wi-Fi ,Bluetooth for Communication

Some works tend to use emerging wireless transmission solutions like Bluetooth [14–16] and ZigBee technology [13, 17] to improve mobility and minimize the power consumption of the wearable part. Mobile health monitoring system using RFID ring-type pulse sensor proposed by Yu-Chi et .all [15].All physiological measurements are transmitted to the smartphone through Bluetooth. Although there are some other existing health monitoring systems available to collect pulse and temperature data, none of these systems uses the private network for transmission.

### Data security

Researchers are able to enhance the health monitoring system along with technologies such as mobile device, wireless network and cloud computing. Although there is an improvement in the health monitoring system, the use of untrustworthy cloud service provider possesses a serious risk on the privacy of medical data. Abhijeet, Kailas and Narendra address a secure healthcare monitoring system using Oder Preserving Encryption technique to provide confidentiality of health record collection [18].

## 2.4 Drawbacks of Existing systems

Currently, many research papers on health monitoring systems have been reported. For instance, C. Lupu et al. [8] implemented a telemedicine system for optimal on-site medical response under the disaster and emergency situations. In literature, Arpita K. M et al.proposed a health monitoring system for an ambulance. They employed the Arduino Mega Board to develop the system. Chung et al. [9] showed the integrated wireless CDMA-based ubiquitous healthcare monitoring system. However, most of them do not consider disaster situations but daily use. Some of them are information systems for use in a disaster situation. However, these systems use communication networks such as WiFi, GSM, CDMA, etc. Under the disaster situation, these infrastructures may not be available because electricity is downed. In the real situation, another approach that does not depend on these infrastructures will be required.

# Chapter 3

# Experimental Materials

This chapter consists of how the design of the drone-based telemonitoring system came up from the initial sketch to the final design and also the communication protocol and internal structure of the system which includes the hardware and components of the drone.

## 3.1 Basic Concept overview

The drone-based telemonitoring system is the normal First Person View (FPV) drone with attached the telemonitoring system which has able to identify human with their thermography. A workflow of the telemonitoring system shows in figure 3.1 Basically, the system finds the victims and sends the live stream to the main control. By processing image, human detection is conducted. Then check the thermal image and check whether the same image area emits the thermal ray or not. If yes, the detected person is alive. Finally, transmit the details to the rescue team with GPS location. As shown in figure 3.1 whole system carrying by drone. So Basically this system has main two-part. System carrying the drone and establish the link between drone and rescue team. Under system carrying drone we customized the hex copter which is suitable for the weight of telemonitoring system.

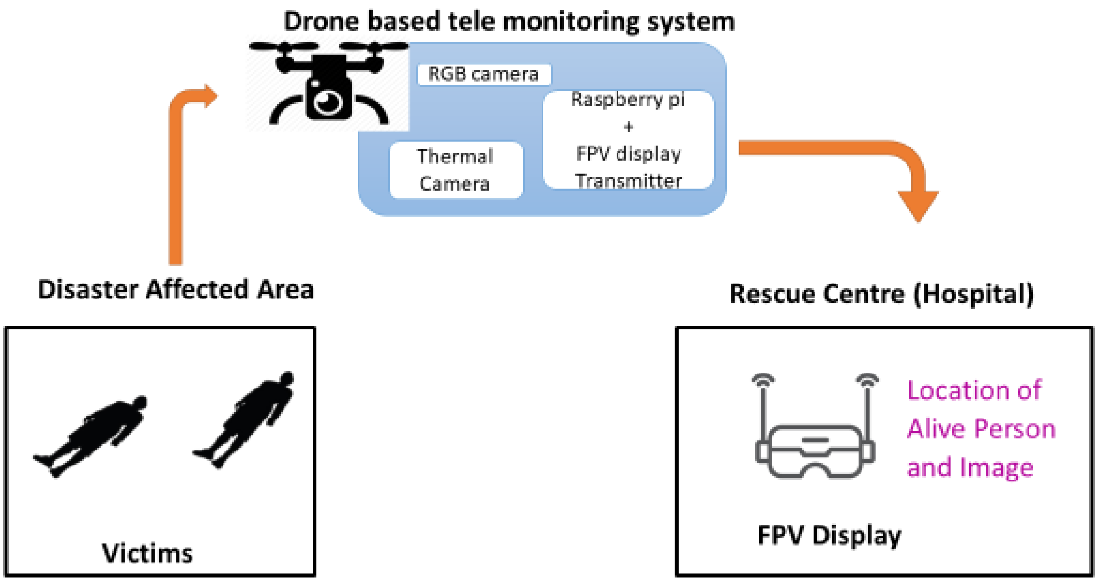


Figure 3.1: Basic concept overview

## 3.2 Hardware Requirement for System Carrying Drone

Here we used several hardware part such as S550 chassis, flight controller, Electronic speed controllers, Battery, propellers, FPV monitor, GPS and compass module as the shown in below figure.

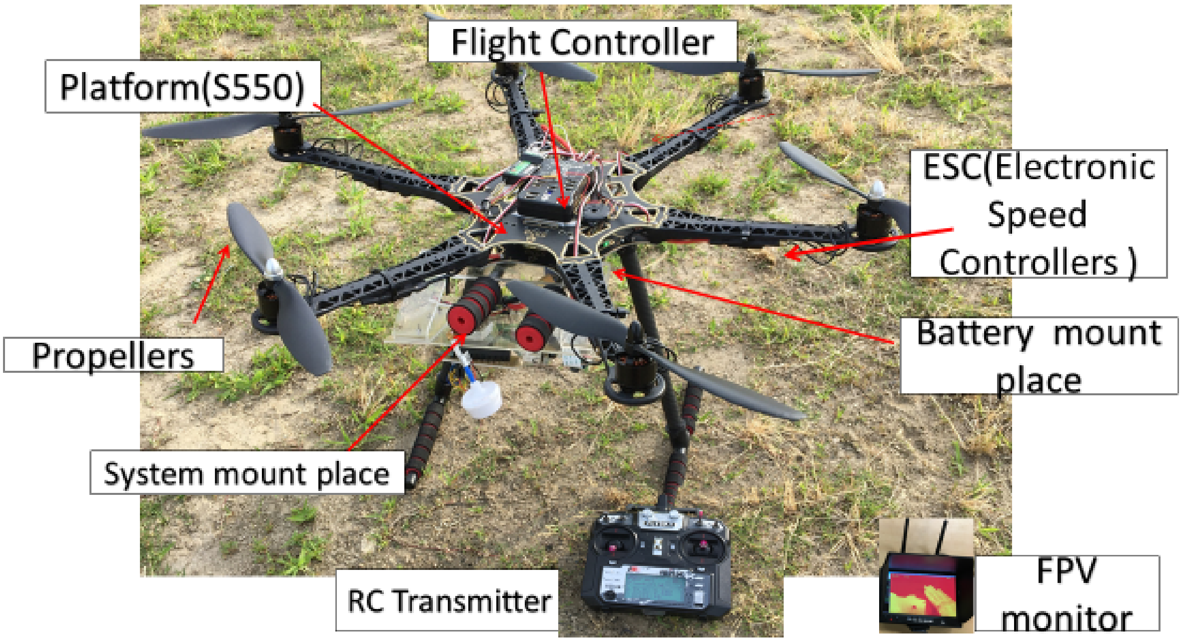


Figure 3.2: System Carrying Drone

The system carrying drone is designed based on open source hardware and software. The system design was defined for redundancy in case of one motor or propeller failure, data collecting payload weight up to 2000 g, vertical take-off and landing. For hardware configuration, this assumption is determined. In the case of one motor or propeller failure, is guaranteed by 6 motors multi-rotor configuration (hex copter). Hex copter uses six motors that will rotate six propellers. This hex copter lifting movement utilizes the thrust that is generated by the propeller combination of hex copter frame. The frame configuration is generally recognized as two type: The Plus (+) and X configurations .Hexacopter has 6 degrees of freedom (DOF), where the six degrees of freedom are affected by the rotational speed of each rotor, thus both frames will have different motion dynamics models. In this research, the X configuration frame is used.

### 3.2.1 Why hexacopter selected

A quadcopter (four motors) is not good enough when one engine failure. Quadcopter will not be able to continue with high payload. Moreover, an additional two motors enable to increase thrust. The motor type in accordance with technical specification generates around 1070 g thrust using APC Propeller (Advanced Precision Composites). It means that maximum thrust generated by 6 motors used in the project is around 6420 g during a design phase it is important to take into account many different technical specifications [19].

In case of components for the custom drone, the market offer is very wide and every product has a different parameter, price, weight and quality. In order to precisely calculate and Six-axis (Hexa X) UAV motion system. Select all necessary components is kind of important parameter when designing the custom drone. Hexa x type motion system and basic components are aerial platform hex copter frame with a built-in printed circuit board (PCB), 30 amps electronic speed controllers (ESC) for brushless motor control, brushless motors (X2212 950KV) with propellers (size 10/45), flight battery lithium polymer (11.1 v 5000mAh 60 c), Flight control- Pixhawk flight controller (FC) with integrated orientation and navigation modules.

### 3.2.2 Trust and Motors

As the propulsion element for the hex copter, the motor is the most important component. However, before determining the capacity of the motor applied in the design, it is necessary to know the total weight that will be lifted and the thrust which is required to lift the heavy load of hex copter. The calculation to determine the thrust per motor as in the following equation:

$$T = (\pi \setminus 4)D^2 \rho v \Delta v \tag{3.1}$$

where
T= thrust[N]
D= propeller diameter[m]
v= velocity of air at the propeller [m/s]
$\Delta v = velocityofairacceleratedbypropellers[m/s]$
$\rho = densityofair[1.225kg/m^3]$

Moreover, static thrust can be calculated by the following equation [20]:

$$T^3 = (\pi \setminus 2)D^2 \rho P^2$$

(3.2)

This calculation will be combined with the following calculations were [20]:

$$Power = Kp \times D_4 \times Pitch \times \omega^3$$

(3.3)

Where Kp is the propeller constant, D is the diameter and RPM is the motor rotational speed. The value of this RPM is calculated from the KV constant and the voltage that is used by the motor. As the main driving force in the Hexacopter system is used BLDC(Brushless) motor that has an advantage, where its structure does not use brush and commutator so that this type of motor will be more efficient than usual DC motor. BLDC motor can produce high RPM (Revolutions per minute). The main parameter of concern of BLDC motor is KV (rpm/volt), where this KV is a parameter that states the magnitude of rpm increase for each unit of voltage that is used.


Figure 3.3: Brushless motors

### 3.2.3 Propellers Performance

The distance streamed by the fluid due to one rotation of propeller' s blade is defined as the pitch parameter that is often noticed in the selection of propellers. Thus, if the pitch and diameter of the propeller are larger, so the motor rotation will be slower and the lifting force that is produced is large. So, if the hexacopter can lift the heavy load, it required large diameter propellers and large pitch. The thrust style equation of this propeller is [21].

$$F_{TH} = \rho C_t n^2 D^4 \tag{3.4}$$

Where () is the air density, n is the rotational speed of the propeller, Ct is the thrust propeller coefficient, and D in meters is the diameter of the propeller. For each speed, this Ct value varies with a small value so it can be ignored. While the power that is generated from the propeller can be calculated [21].

$$P_p = \rho C_p n^3 D^5 \tag{3.5}$$

Cp is the power coefficient of the propeller that is obtained from the rotation. This Cp value changes with speed. For the torque on the propeller is generated based on the following equation:

$$T_q = \frac{P_p}{\omega} \tag{3.6}$$

Where is the propeller' s angular speed. According to the calculation in this research we used 1045 propellers which is enrich with 10 inch and 45 blade angle.

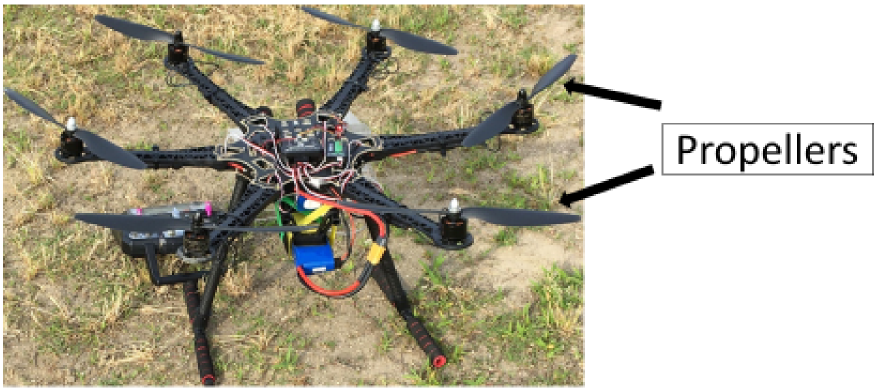


Figure 3.4: 1045 Propellers

### 3.2.4 The capacity of the battery

Batteries are the power source to run all the components on the hexacopter. The battery also affects the flight time so that proper calculations are required to produce optimal results. Therefore, to get the proper power and load combinations, the batteries that are used must have more current than motor currents. The parameter to be considered in the selection of the battery is the number of cells, discharge, and capacity. The number of cells determines the voltage of the battery in an empty state. Then the discharge shows how much current rating / current velocity can be released, and the capacity shows how long the battery can work on certain amperes as shown in figure below. As shown in figure 3.5below we used LIPO 3 cell battery with 11.1v and 5000mhA.


Figure 3.5: LiPo Battery

### 3.2.5 Chassis

S550 hex copter as shown in figure 3.6used to depend on the payload. Each arm is connected to a brushless DC motor and has a propeller (fixed-pitch) so the rotor can force the airflow downward to generate the lift force. The direction of rotor rotation has two directions, i.e. three counter clockwise rotors (Counter Clock Wise; CCW) and three other rotors clockwise (Clock Wise; CW). So, it is clearly seen that the dynamic motion of hex copter is simply influenced only by the speed of motor rotation.

Figure 3.6: Heavy-lift hex copter frame design

The frame should be constructed from the lightweight material but strong enough to support its operational weight and structural load. Hence, it is necessary to analyse the flexibility and strength of the composting material of the frame.

### 3.2.6 Electronic speed controllers (ESC)

30 amps electronic speed controllers (ESC) for brushless motor control, brushless motors (X2212 950KV) with propellers (size 10/45), Flight control- Pixhawk flight controller (FC) with integrated orientation and navigation modules.

Figure 3.7: Electronic speed controllers

### 3.2.7 Flight controller(FC)

The drone FC must be designed to provide smooth and stable flight performance. Therefore, we used Pixhawk flight controller (FC) which can run an open-source Arducopter firmware (Ardupilot 2016). As shown in figure Mainly, FC is designed to automatic control of angular stabilization, angular position and trajectory during flight phases (operation modes) from take-off to landing [22].The Pixhawk belongs to the APM flight controller. The APM flight controller has an 8-bit processor and the original Pixhawk uses Pixhawk Flight Controller 32- bit processor. The Pixhawk can be used with both of the main open-source drone projects, ArduPilot and PX4, and also is completely open-source hardware. This means that many independent manufacturers can build and sell the boards, but the architecture is the same. There are plenty of IO ports on the pixhawk, making it easy to communicate with an onboard computer, like a raspberry pi. It is an easy product to find and buy. Most pixhawk kits come with all the required supplementary hardware, like GPS, magnetometer, buzzer, Lipo power module etc [23].

The hexacopter stabilization is controlled in a loop feedback mechanism, used in control systems, named PID controller (proportional-integral-derivative controller). In this particular system, the PID controller receives data measured by the sensors on the FC (gyros and accelerometers) and comparing that against expected values to alter the speed of the motors to compensate for any differences and maintain balance [24]. The PID controller calculation algorithm involves three separate constant parameters, the proportional, the integral and derivative values that are to be tuned for a specified construction.

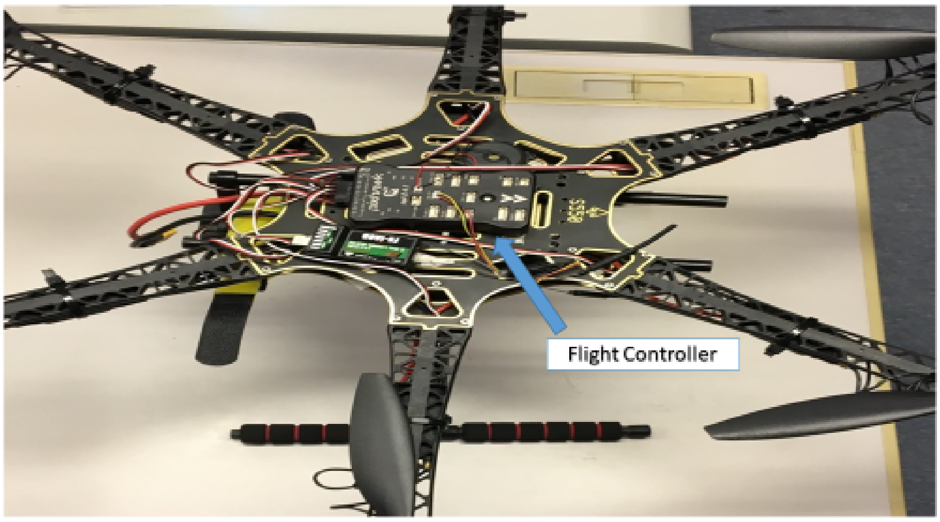


Figure 3.8: Pixhawk flight controller with other parts

### 3.2.8 Remote controller

To control the drone , as the remote controller used to fs-is fly sky with 6 channel. Offering superior protection against interference while maintaining lower power consumption and high reliable receiver sensitivity.It has bidirectional Communication Capable of sending and receiving data, each transmitter is capable of receiving data from temperature, altitude and many other types of sensors, servo calibration and i-BUS Support.Each transmitter and receiver has it's own unique ID. Once the transmitter and receiver have been paired, they will only communicate with each other, preventing other systems accidentally connecting to or interfering with the systems operation.The high efficiency Omni-directional high gain antenna cuts down o interference, while using less power and maintaining a strong reliable connection.The system is built using highly sensitive low power consumption components, maintaining high receiver sensitivity, while consuming as little as one tenth the power of a standard FM system, dramatically extending battery life. Specification as below.

| Name | Specification |
|---|---|
| Channels | 6 |
| Model type | Quadcopter |
| RF range | 2.408 - 2.475GHz |
| Bandwidth | 500 KHz |
| Bands | 135 |
| RF power | Less than 20 dBm |
| Protocol | AFHDS 2A |
| Modulation type | GFSK |
| Stick resolution | 4096 |
| Low voltage alarm | Yes (lower than 4.2V) |
| PS2/USB Port | Yes (Micro-USB) |
| Power input | 6V DC 1.4AA*4 |
| Weight | 392g |
| Size | 174*89*190 mm |
| Color | Black |
| Certificate | CE, FCC: N4ZFLYSKYI6 |

Table 3.1: specification of the Remote Controller

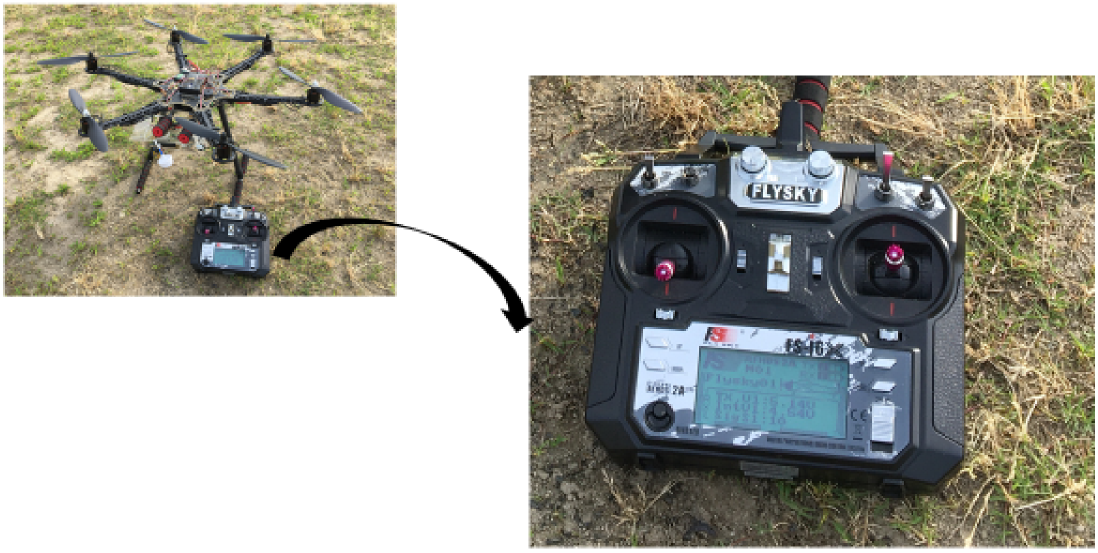


Figure 3.9: Fly sky FS-iS remote controller

## 3.3 Hardware Requirement for the Telemonitoring System

Data acquisition module is a Raspberry pi camera for RGB image and Seek compact pro thermal camera with Raspberry Pi 3 model B as a main processor.Primary concern was reduction the system weight as much as possible.Therefore here we selected the all hardware as their miniature size such as Raspbery Pi camera,Thermal camera and altitude sensor.Apart from that to communication system it included that FPV transitter and power distributor for entire telemonitoring system .

### 3.3.1 Seek Compact Pro Thermal Camera

SEEK Compact Pro thermal camera is a thermal night vision camera. “Temperature” that is invisible to human eyes is clearly coloured, and not only the discovery of the target but also the traces are not missed. The SEEK Thermal Compact Pro is equipped with a high resolution 320 x 240-pixel thermal sensor and can detect up to 550m.It can record still images and videos. In addition, the FF (Fast Flame) model is a special model that can render smoother images.

| Name | Specification |
|---|---|
| model | Seek Compact Pro Fast Frame |
| Detection element | 320 × 240 pixels |
| Detection distance | 0.15m 550m |

| | |
|---|---|
| Update rate | 15Hz |
| Measurement viewing angle (° ) | 32 ° |
| Temperature range | -40 550 ° C |
| focus | Adjustable |
| Lens material | Chalcogen glass |
| Micro bolometer | Vanadium pentoxide |
| Temperature sensitivity | ¡70mK |
| Measurement wavelength | 7.5 14 $\mu$ m |
| User interface | Seek Thermal Mobile APP for iOS / Android |
| Temperature display | ℃ / ° F / Kelvin |
| Color palette | 9 options |
| recoding media | Record directly on your smartphone |
| Power supply | Power-saving smartphone power supply (280mW) |
| weight | 14 g |
| Size (L × W × H) | 2.5 × 4.5 × 2.5 cm |

Table 3.2: specification of remote Controller

Main Applications

- Wildlife Surveys
- Electrical construction
- Leakage surveys
- Rescue in disaster areas

### Images from seek compact pro

Using Seek Thermal Pro camera we can take the image as temperature profile as shown in below figures 3.11 The corner margin shows that the temperature ranges corresponding to the colour bar.

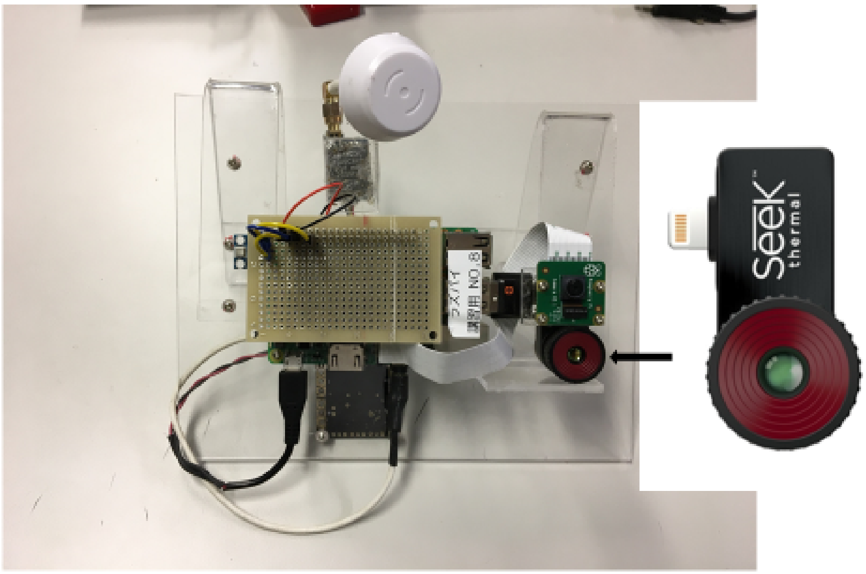


Figure 3.10: Thermal Camera:Seek Compact Pro

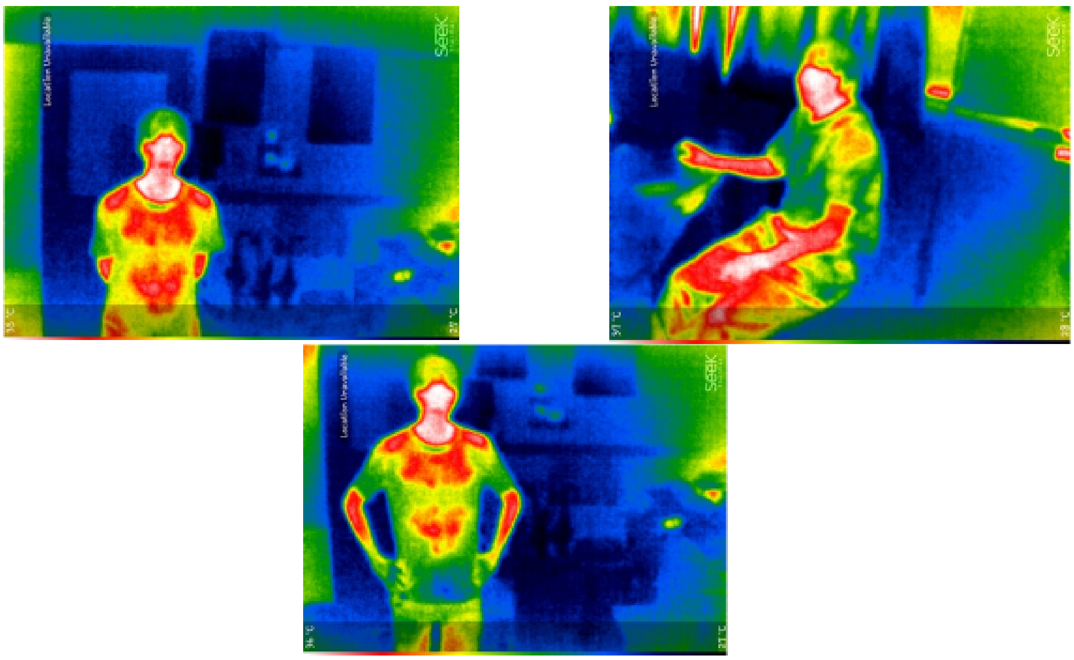

Figure 3.11: Thermal images from Seek camera

### 3.3.2 Raspberry pi camera

To take the RGB image and conduct the human detection , here we used the Raspberry pi camera as the one of data acquisitions.The Camera v2 is the new official camera board released by the Raspberry Pi foundation. The Raspberry Pi Camera Module v2 is a high quality 8 megapixel Sony IMX219 image sensor custom designed add-on board for Raspberry Pi, featuring a fixed focus lens. It's capable of 3280 x 2464-pixel static images, and also supports 1080p30, 720p60 and 640x480p60/90 video. It attaches to Pi by way of one of the small sockets on the board upper surface and uses the dedicated CSi interface, designed especially for interfacing to cameras. 8-megapixel native resolution sensor-capable of 3280 x 2464 pixel static images, supports 1080p30720p60 and 640x480p90 video and camera is supported in the latest version of Raspbian, Raspberry Pi's preferred operating system. The board itself is tiny, at around 25mm x 23mm x 9mm. It also weighs just over 3g, making it perfect for mobile or other applications where size and weight are important. It connects to Raspberry Pi by way of a short ribbon cable. The high quality Sony IMX219 image sensor itself has a native resolution of 8 megapixel, and has a fixed focus lens on-board. In terms of still images, the camera is capable of 3280 x 2464-pixel static images, and also supports 1080p30, 720p60 and 640x480p90 video reference [25].

Applications

- CCTV security camera
- motion detection
- time lapse photography

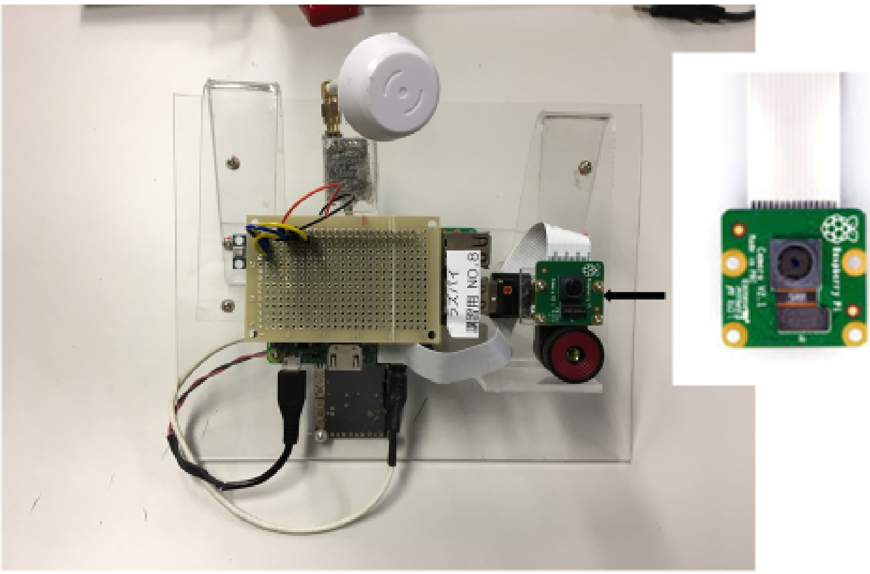

Figure 3.12: Raspberry Pi camera Module

### 3.3.3 BMP180 the Air Pressure Sensor

To measure the altitude from the ground to the drone here we interface the BMP180 air pressure sensor via the $I^2C$ bus of the Raspberry Pi. The easiest way to address the sensor is to take an existing library that already has all the functions when there is the communication system. The pin connection as shown in the table below.

| Sensor | Raspberry Pi |
|---|---|
| VCC 3V3 | (Pin 1) |
| GND GND | (Pin 6) |
| SCL SCL | (pin 5) |
| SDA SDA | (Pin 3) |

Table 3.3: The pin connection

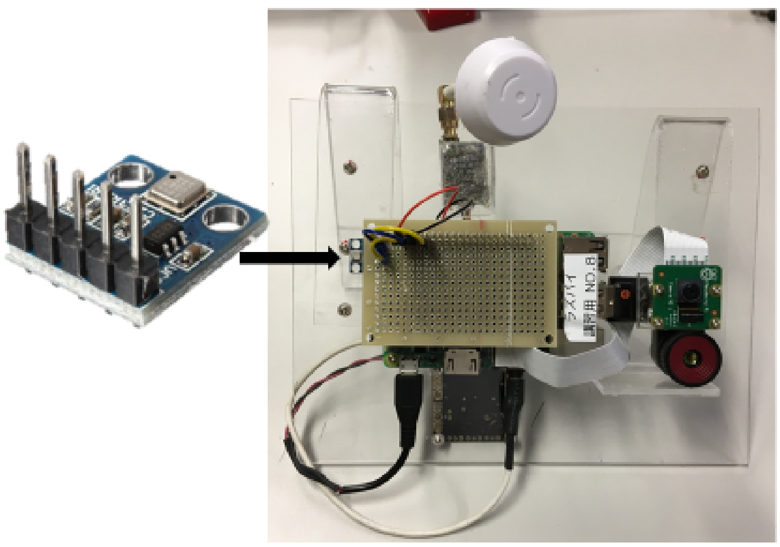

Figure 3.13: BMP180 the air pressure Sensor

### 3.3.4 Power distributor

In the tele monitoring system required the basically power for raspberry pi, Altitude module and antenna. Therefore, to distribute the power from the battery here we used CC3D NAZE32 F3 Power Distribution Board.

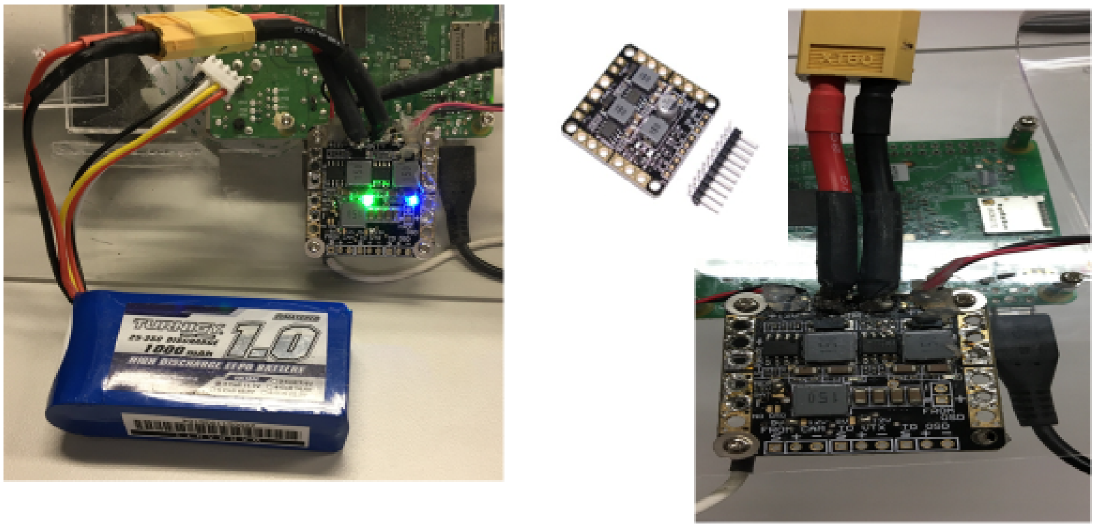

Figure 3.14: Power distribution module

## 3.4 FPV (First person view) Communication system

To receive the data from drone, to transmit the raspberry pi display here we used FPV display as receiver and 5.8Ghz transmitter which is mount on the tele monitoring system. First Person View provides a true pilot's eye view while flying by placing a video camera and transmitter on drone paired with a receiver and either an LCD on the ground. An optional OSD (On Screen Display) helps maintain orientation by providing aircraft instrument overlay on FPV monitor.

5.8Ghz 25mw to 200mw video transmitter/receiver pair. Supply voltage tolerances accommodate 2s-4s Lipo batteries normally used. Many autopilots integrate this function directly. If not, external OSDs like MinimOSD can be used. However, being able to see the battery status, flight data, etc. makes a much more enjoyable flight. Separate batteries for powering the above are rarely needed now, since most now accommodate the flight pack's voltage range from full to empty.

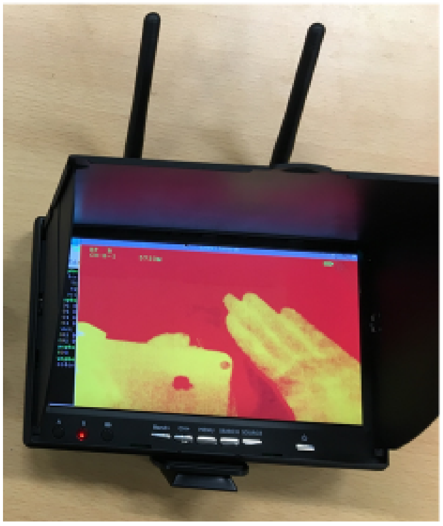

Figure 3.15: FPV display

## 3.5 Software configuration

To programming the Raspberry Pi, it used the python programming language in the Rasbian OS to human detection and thermal image processing. All python code attached as an Appendix.

### 3.5.1 Mission Planner

The flight controller is able to operate with the ground station based on different architecture. The basic GCS configuration consist of Windows PC with installed Mission Planer Software A Linux users are provided with APM Planner 2 software. The GCS communication channels can be established via radio modem for a long range, via WiFi module for a short range or Bluetooth for very short range, all using MAVLink protocol.

In order to perform photogrammetry and remote sensing tasks, the presented GCS software will play a major role. The software is divided on 5 main screens, able to control and configure UAV. Flight Data screen provides information about current flight parameters and system status and messaged. Flight Plan screen delivers basic and advance tools to prepare flight plans (missions). Initial Setup section is for initial set up and configuration of FC to prepare it for particular vehicle. Configuration Tuning part is to configure the parameters how FC is control hex copter. The simulation tool is designed to perform Software in The Loop (SITL) simulation. It can simulate particular vehicle behaviour without the need for any vehicle hardware.

# Chapter 4

# Methods

## 4.1 Development of Drone Based Tele monitoring System

### 4.1.1 Motivation

A disaster situation is the effect of a natural hazard such as flood, tornado, earthquake, heatwave, or landslide on human beings. Under that uncontrollable situation a huge number of people losing their lives. Finding a victim is a prime concern. In such situations, the rescue system must take fast decisions under pressure, and try to get victims to a safe location at their own risk. The rescue system must collect the location information and status of victims as quickly as possible to save people. All these works are performed mostly in very dangerous and risky situations. Detection by rescue workers becomes time-consuming and due to the vast area, that gets affected it becomes more difficult. There are several types of rescue robots used in this field. Due to the unbalance ground and time consumption an Arial robot with a human detection system takes the best place than a ground robot.

### 4.1.2 System Requirements

Drones are becoming more popular among emerging technologies and expected to be ubiquitous soon. Even though drones were used only in the military domain in earlier decades, with the recent advancements of UAV (Unmanned Aerial Vehicles) technology, drones have started to appear in civil domain in a rapid manner. But until recently drones were not considered as a social entity that humans would socially interact with. In order for drones to approach humans, the acceptance level of the drone as a social entity and the proxemics ranges for a comfortable interaction need to be better understood.

Even though there are several robots for human detections almost all of them do not consider the situation of the detected alive human. According to the disaster management criteria, there is a method to categorize the person depend on their situation such as emergent, urgent, non-urgent, and none. Therefore, monitor the situation is one of the best solution to control the situation and identify the health condition of the person and inform it to the rescue team to increase the number of saving lives. Therefor we are going to design, implement and find best the drone based tele monitoring system for alive.

### 4.1.3 System Architecture

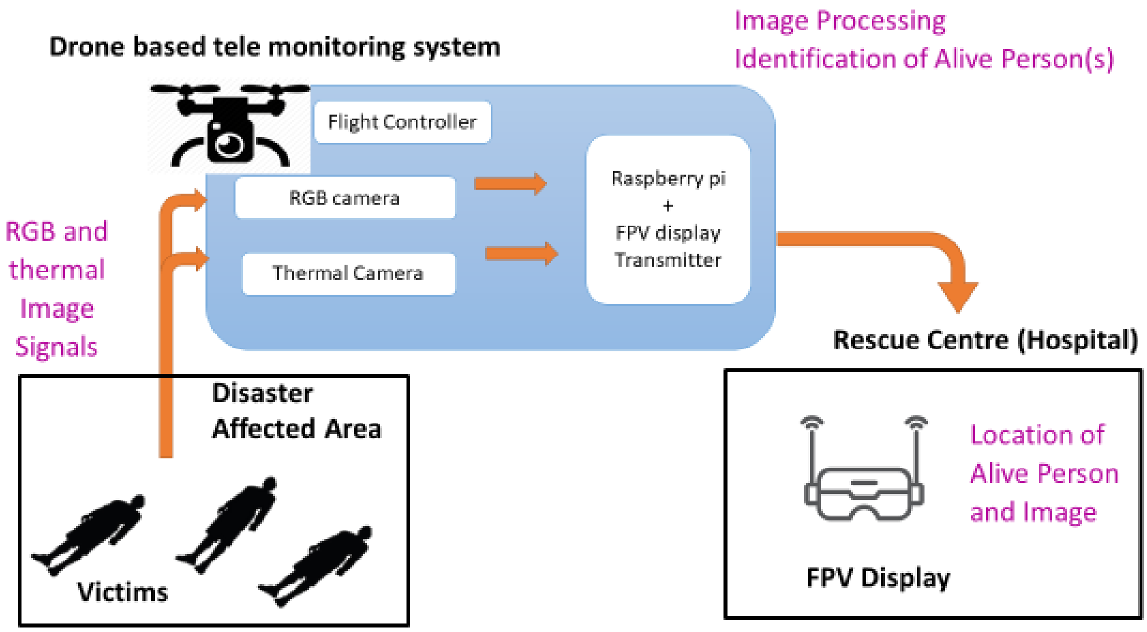


Figure 4.1: System Architecture

System carrying drone fly to disaster affected area and then check the victims using collect RGB image which is connected to the Raspberry pi as data acquisition system. Then real time image processing regarding the Thermal image processing then identify the person whether live a not. Then using personal communication system transfer the data for rescue team with thermal image data for further evacuation.

### 4.1.4 Processing Flow

Basically the system has main three sub system. Data collection system, Data processing system and Data transmission system as shown in figure 4.2 .

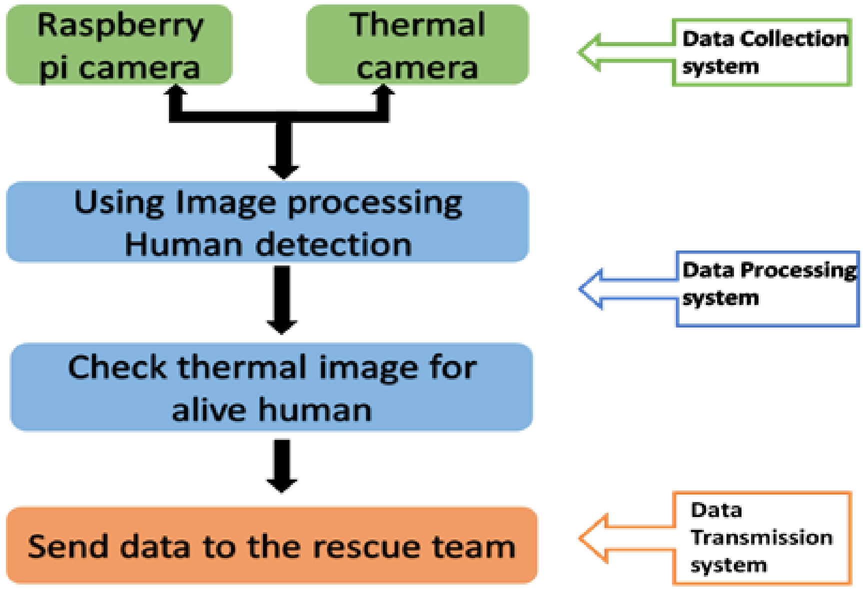


Figure 4.2: Processing Flow

### 4.1.5 Assemble the Hardware Environment

Assemble the hardware environment according to the as shown in figure 4.3. Hexacopter frame with a built-in printed circuit board (PCB) connect to the30 amps of electronic speed controllers (ESC). Attached the brushless motor motors (X2212 950KV) with propellers (size 10/45) and two stands. Then calibrate the Pixhawk flight controller and attached it to the drone with integrated orientation and navigation modules. FPV camera mount with proper power distribution module and FPV video transmitter. In hexacopter frame it has inbuilt PCB, therefore, we must be careful when soldering connection. Then connect all hardware part and connect the flight battery lithium polymer (11.1 v 5000mAh 60 c). The flight controller has the ability to operate with the ground station based on a different architecture. The basic configuration consists of Windows PC with installed Mission Planer software.

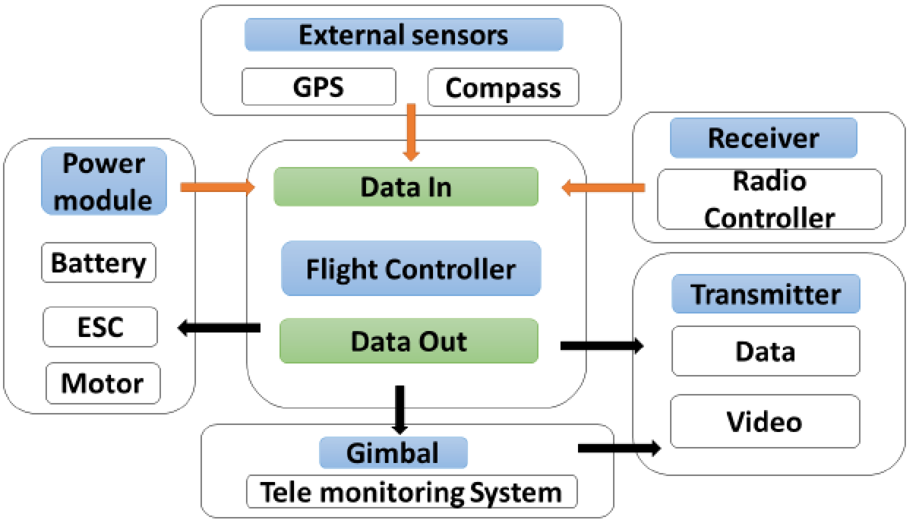


Figure 4.3: Drone internal structure

### 4.1.6 Communication Protocol

Communication protocol is basically radio control (RC), radio modem for ground station data transfer, video down-link with battery and LCD monitor for the live video feed from the platform. For scientific use, it is a need to establish communication in the ISM band. Industrial, scientific and medical (ISM) applications (of radio frequency energy) is an operation of equipment or appliances designed to generate and use locally radio frequency energy for industrial, scientific, medical, domestic or similar purposes. Including ISM bands have been shared with license-free error-tolerant communications applications wireless LAN in the 915 MHz, 2.450 GHz, and 5.800 GHz bands. Unlicensed devices are required to be tolerant of ISM emissions in these bands, unlicensed low power users are able to operate in these bands without causing problems for ISM users (ITU-R Report SM.2180) [26]. Therefore, as shown in the figure 4.4 License-free communication equipment is used to establish the communication protocol for human drone interaction.

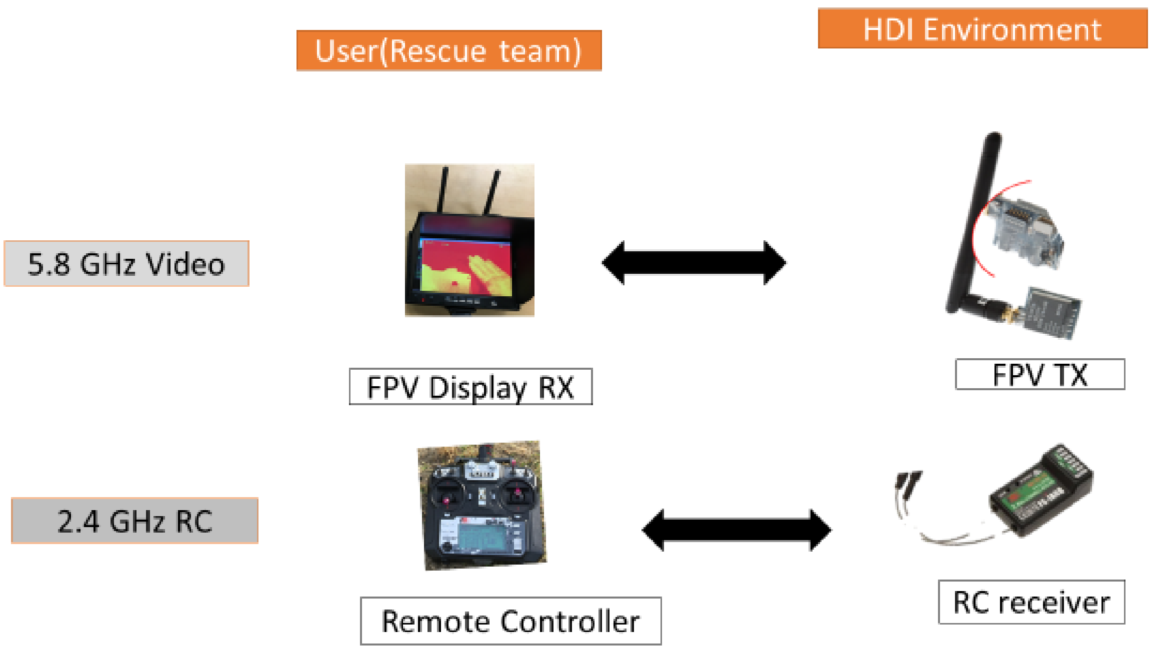


Figure 4.4: Communication protocol for human drone interaction

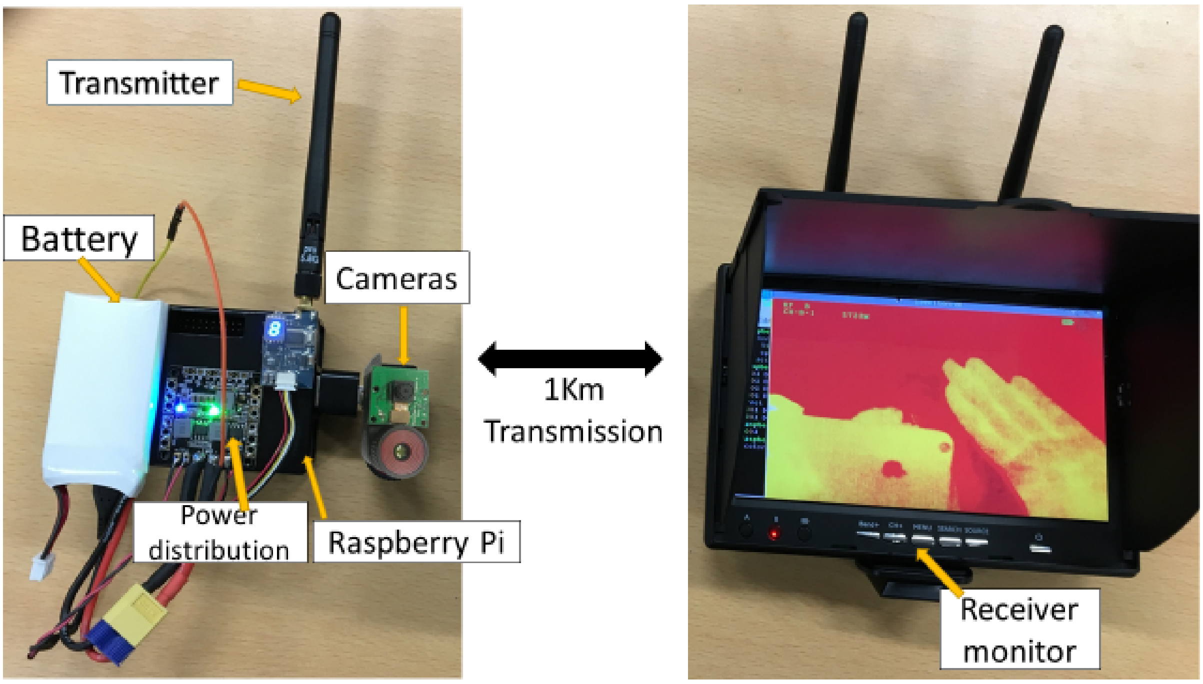


Figure 4.5: Constructed personal communication system which do not depend other infrastructure.

## 4.2 Measurement plan of the Drone based tele monitoring system

When the system mounted to the drone we kept a measured angle as angle $45^{\circ}$ ,$30^{\circ}$ , and $60^{\circ}$ and while doing experiment always person data collect from certain distance. Then according to the Pythagoras law calculated the hypotenuse.Then analysed the best parameters to identify the alive human using developed drone based tele monitoring system

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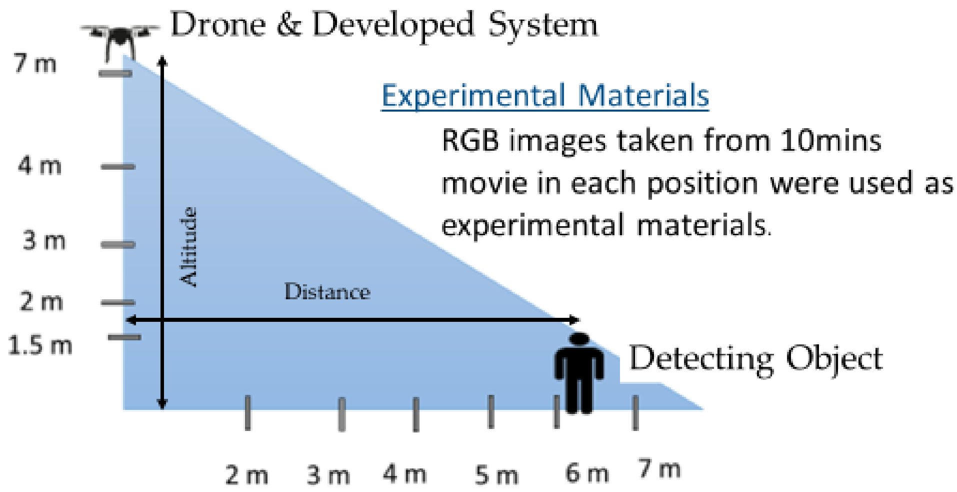


Figure 4.6: Measurement plan of the Drone based tele monitoring system

### 4.2.1 Human Detection with Thermal image

As shown in the figure 4.7below conducting the tele monitoring until find the person and then check the thermal image. Then send the data to the rescue team as real time data transmission.

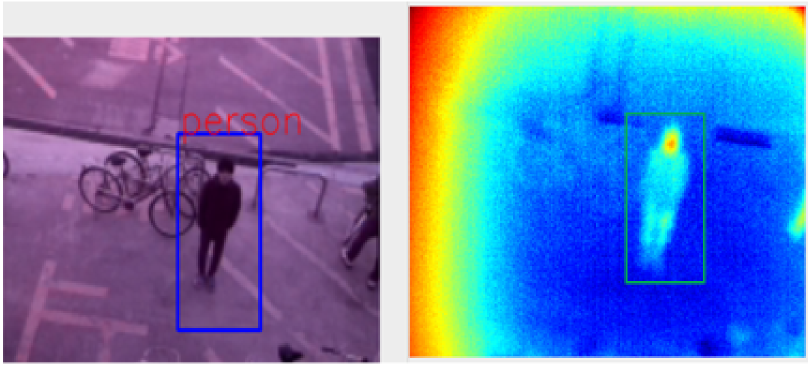


Figure 4.7: Human detection with thermal image from the system

### 4.2.2 Detection the Altitude

To identify the altitude, the system there is running air pressure sensor in the background with reference to the ground value from the satellite. From using that value calculate the altitude as shown in the figure. 4.8.

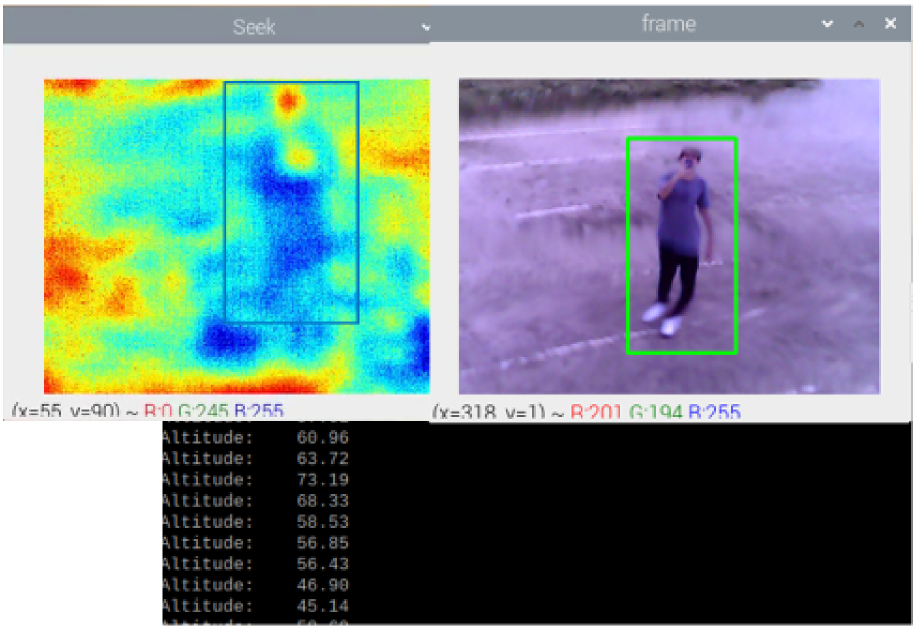


Figure 4.8: Reading Altitude from the Sensor

### 4.2.3 Data Collection Procedure

Data was collected in several time with laboratory students as victim sample in the university ground which is in front of the faculty building. All flight time take as a video and then separate it as number of images.

## 4.3 Experiment Environment

To evaluate the system, we collect the huge data from the system with difference altitude, difference distance and difference angle. Then analysis the all data as shown in results in the next chapter and finally conclude the best position for the best data from the tele monitoring system.

# Chapter 5

# Results and Discussions

This chapter includes the observations that were made during the execution of the test plans described in the previous chapter and also the results gathered from the experimental sessions.

## 5.1 Experimental Results

Basically there are main two situations when we obtained the result to explore the optimal distance and attitude.

1. Altitude changes with same distance

2. Distance changes with same altitude

Success Data :In the graph representation success data mean ,the image which can identify all data (RGB image,Human Detection,Thermal Image )clearly and the images which does not include one of them consider as fall image,which are not taken for system evaluation.

### 5.1.1 Results analysis when Altitude changes with same Distance

When altitude changes distance 2 m and 3m was the best for when altitude 1.5 m and 2m. Altitude 1.5m means it is almost same as the person height. Therefore, altitude 2m will be a better height for this system. As shown in below figures there is capability to the best image when the distance is 4m,5m,6m and 7m is good enough with altitude 2m,2m,2m and 3m respectively.

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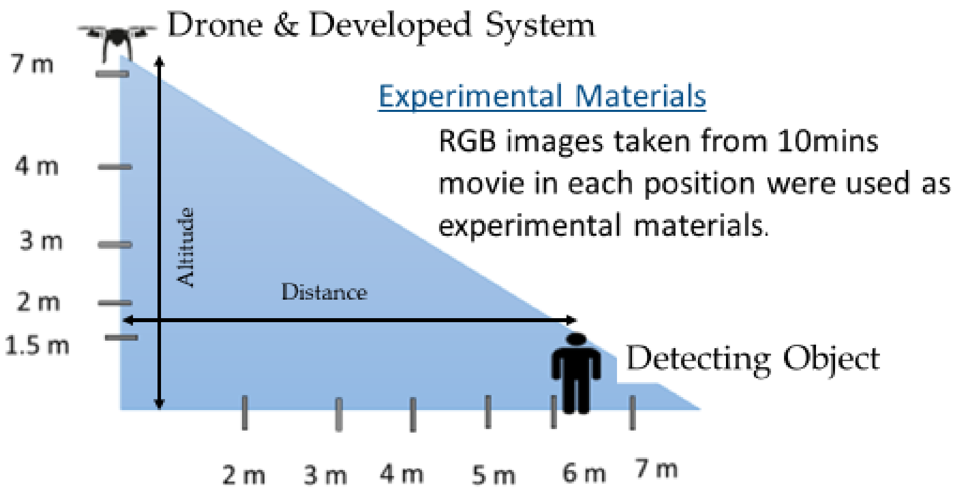


Figure 5.1: Experimental procedure situation

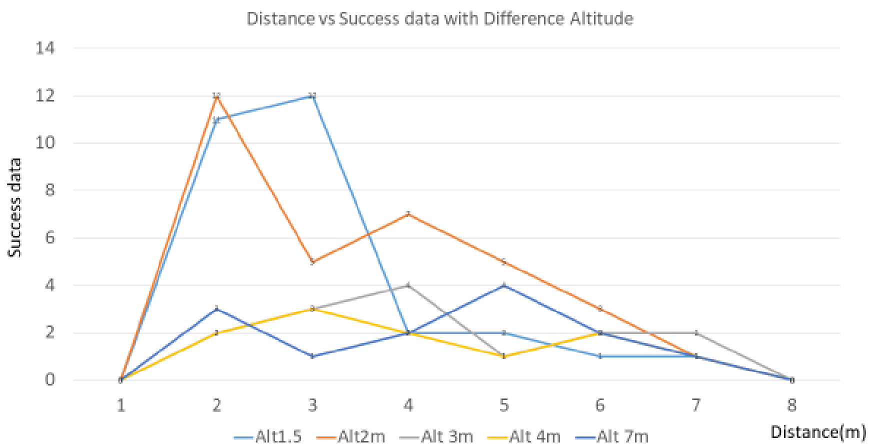


Figure 5.2: The graph representing the Distance Vs Success data with difference Altitude

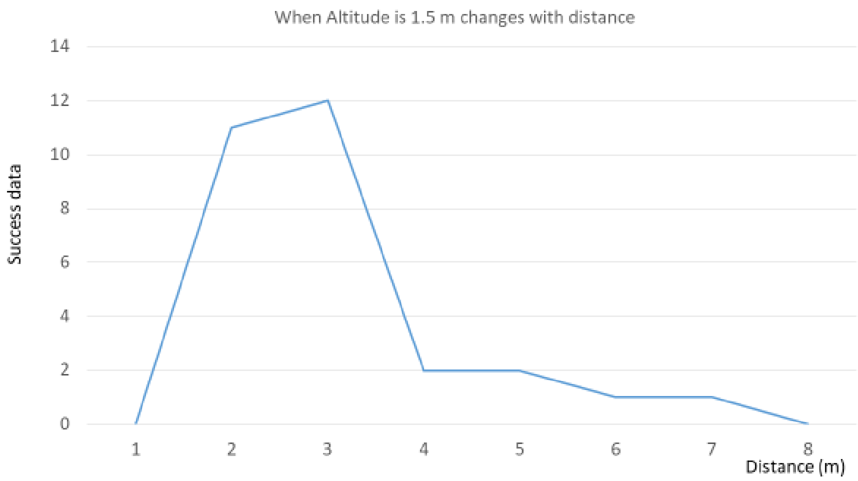


Figure 5.3: The graph representing the when altitude is 1.5 m changes with distance

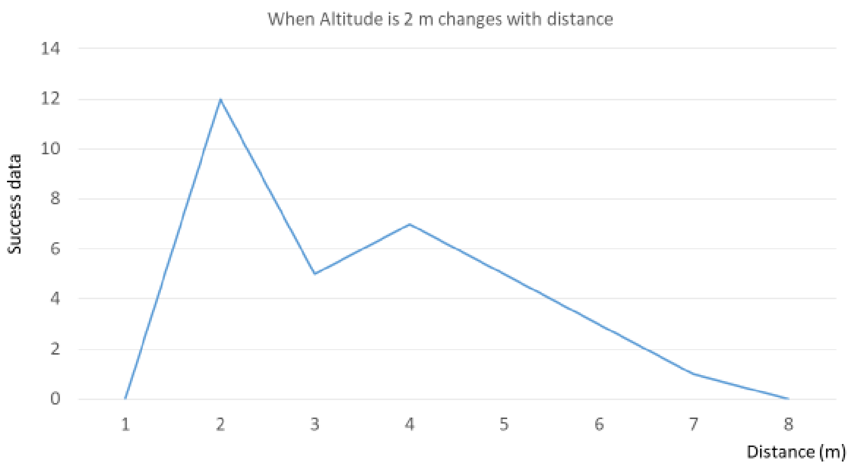


Figure 5.4: The graph representing the when altitude is 2 m changes with distance

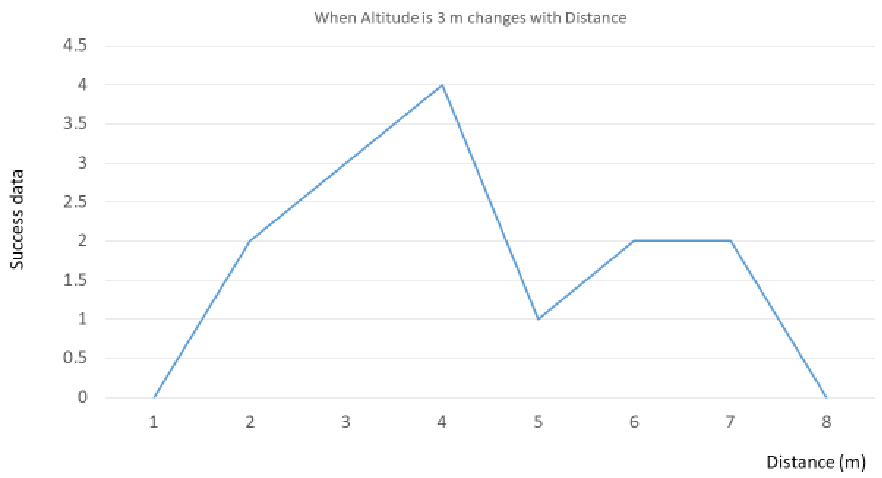


Figure 5.5: The graph representing the when altitude is 3 m changes with distance

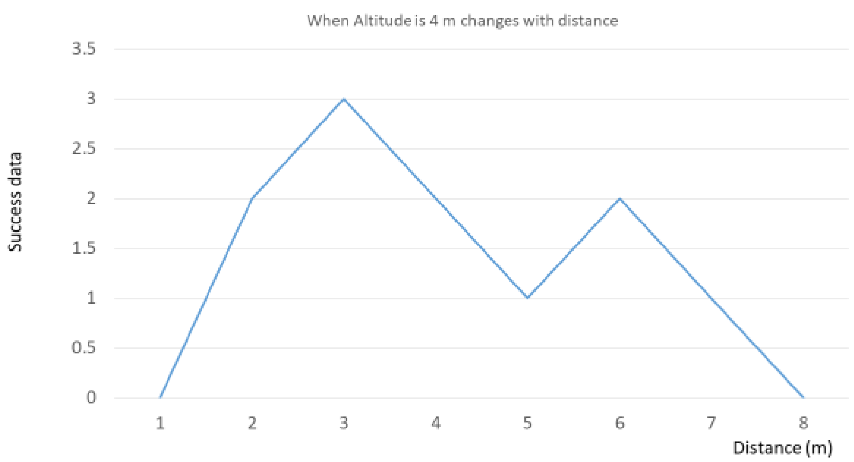


Figure 5.6: The graph representing the when altitude is 4m changes with distance

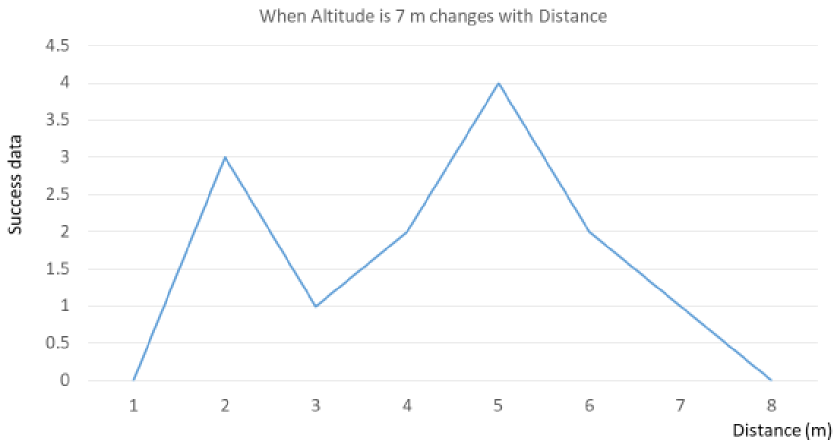


Figure 5.7: The graph representing the when altitude is 7m changes with distance

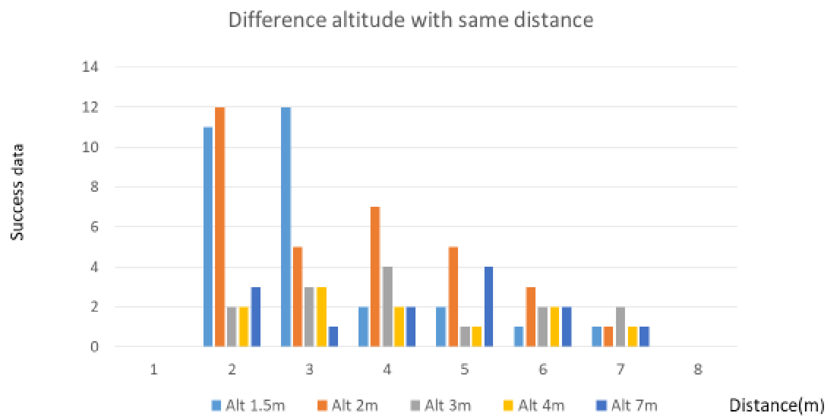


Figure 5.8: The graph representing the when difference altitudes with same distance

### 5.1.2 Results analysis when distance change with same altitude

When distance changes altitude 3 m and 2m was the best for when distance 3 m and 2m. Therefore, altitude 3m will be a better height for this system. As shown in below figures there is the capability to the best image when altitude is 4m,5m and 6m is good enough with distance 4m,3m and 5m respectively.

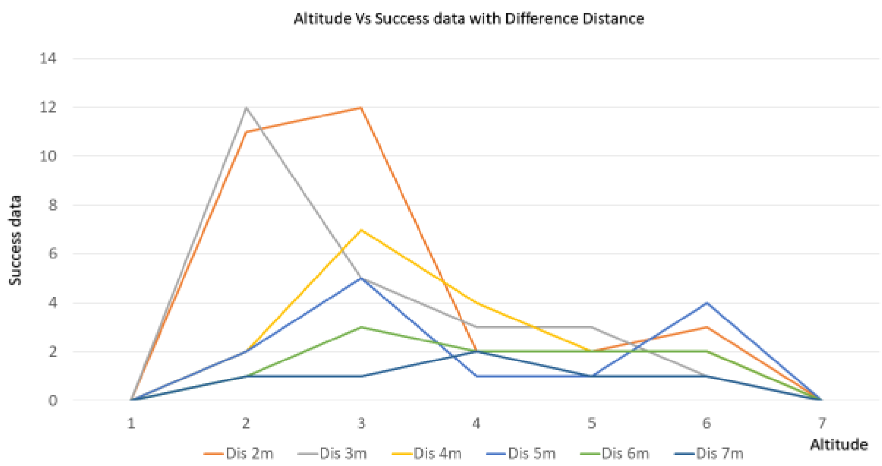


Figure 5.9: The graph representing the Altitude Vs Success data with difference distance

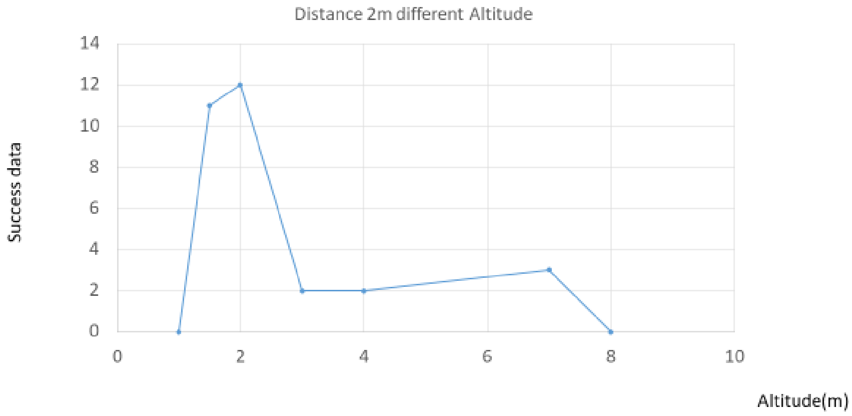


Figure 5.10: The graph representing the when distance 2m with difference Altitude

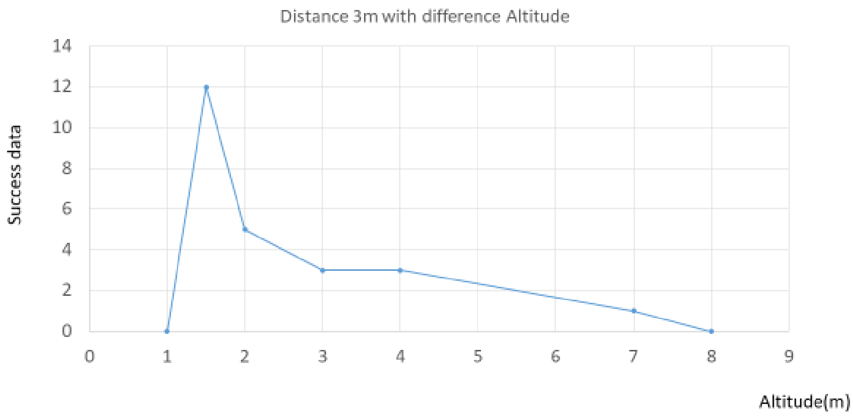


Figure 5.11: The graph representing the when distance 3m with difference Altitude

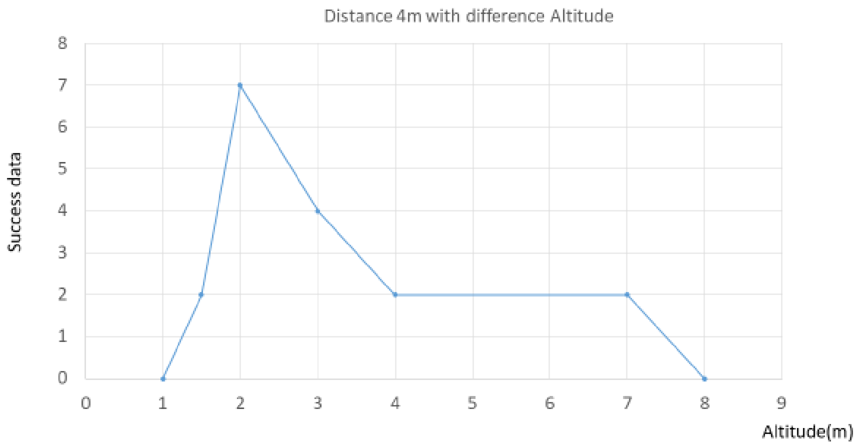


Figure 5.12: The graph representing the when distance 4m with difference Altitude

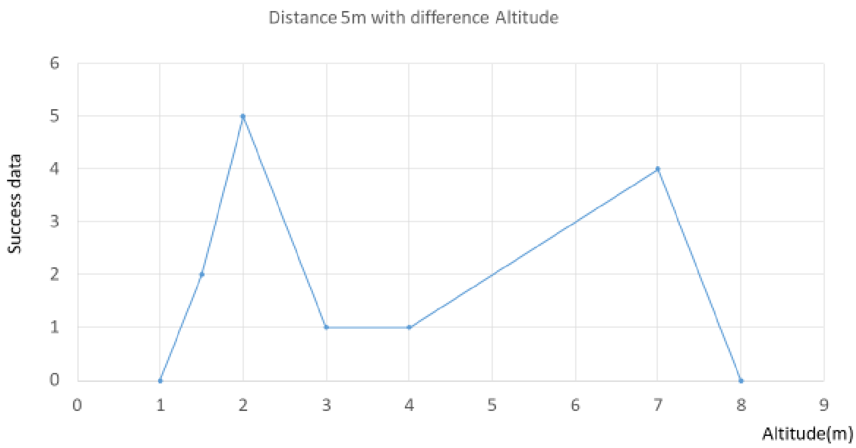


Figure 5.13: The graph representing the when altitude is 5m changes with distance

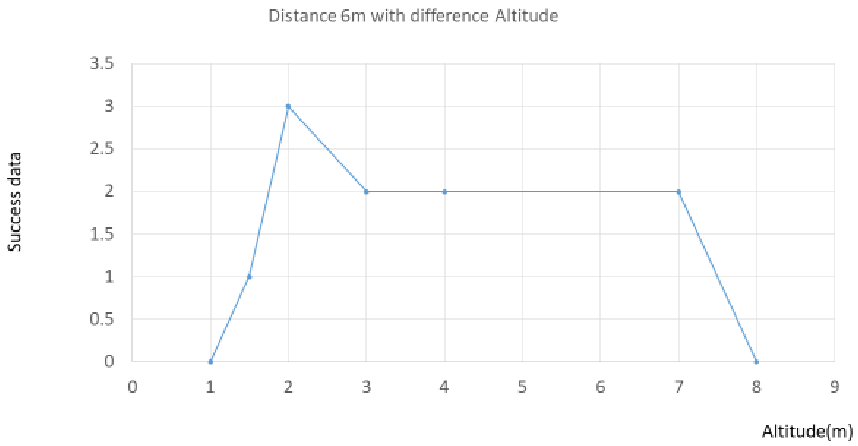


Figure 5.14: The graph representing the when altitude is 6m changes with distance

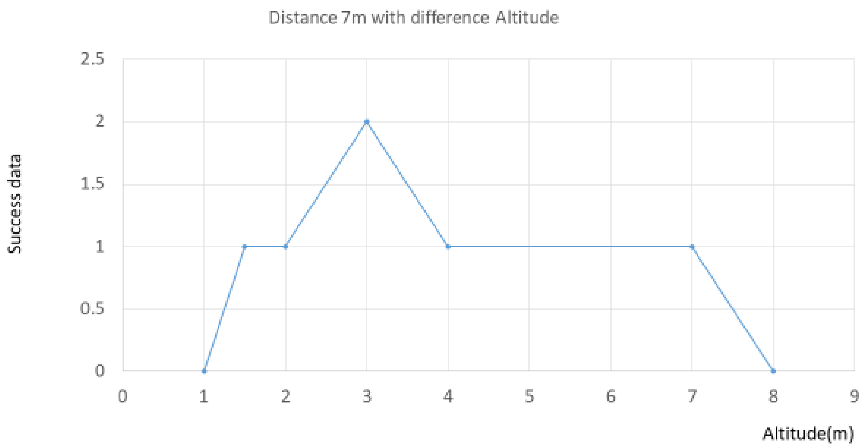


Figure 5.15: The graph representing the when altitude is 7m changes with distance

## 5.2 Discussion and Future work

The designed telemonitoring system provides the RGB image and corresponding thermal image in real-time smoothly with including human detection techniques. Basically here raspberry pi display transmits by using radio transmission. Design custom drone which flies with smooth and stable flight performance. Due to the hardware specification, this system has the ability to carry around 1 kg smart triage system. Hence there is no weight limit for the development of the enhance this system to acquire other sensor data from the person. Not only the telemonitoring system but also this it is good enough for other application like agriculture, photography and so on.

As shown in the figure 5.16 below we have raised some problem with while collecting the data. When the background environment is too hot more than the human temperature it is difficult to identify the person for the naked eye. Therefore to avoid that issue in it is better to use a black body as a reference for person body temperature near to the thermal camera.

Sometimes human detection is basically depending on the feature from the front view of the human. Therefore, when the victim not faced to the telemonitoring system it will be some misdetection. To avoid the issue, we are going to train our own model using collected data from the system as future work.

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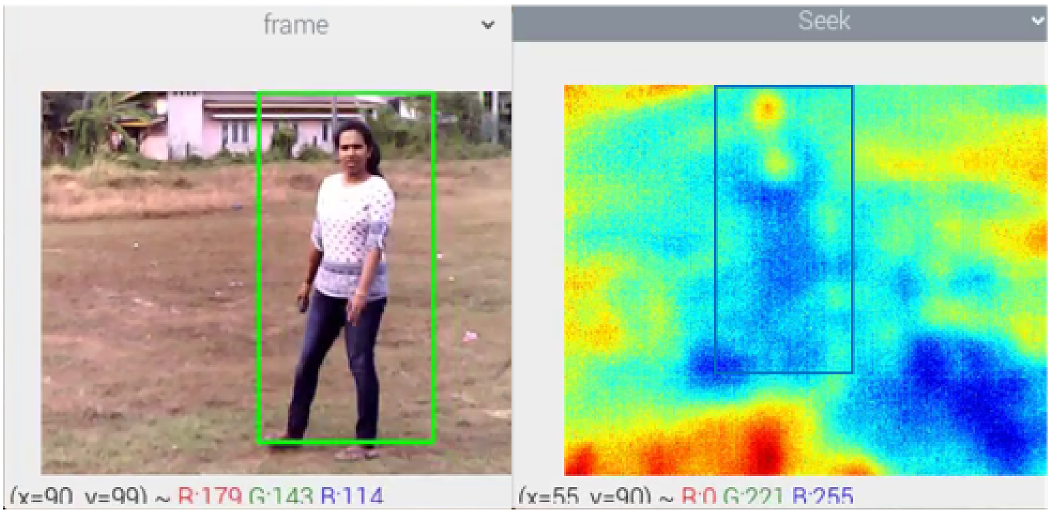


Figure 5.16: Background Environment temperature is a too high situation

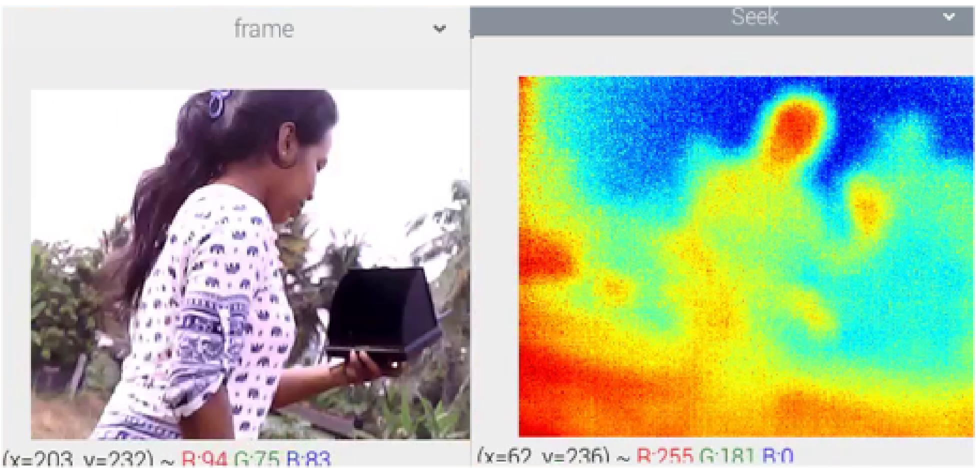


Figure 5.17: Human misdetection situation

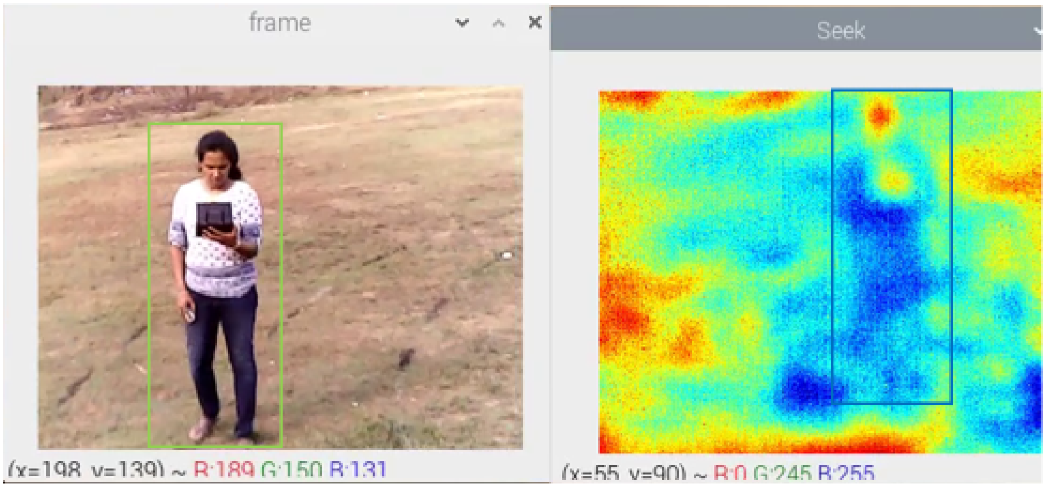


Figure 5.18: Experimental situation

# Chapter 6

# Concluding Remarks

The main objective of this research was to study the of designing, implementation and exploring the optimal distance of drone-based telemonitoring system for an inaccessible area. Hence reliability and accessibility is the imperative determinism for rescue missions, it can conclude that we designed the smooth and stable telemonitoring system and established the communication between the drone and rescue team successfully. This chapter includes the conclusion of this study.

## 6.1 Conclusion

Telemonitoring is one of the promising fields where they can reach everywhere like rural areas, access in emergency situations etc. Inaccessible patient ⊠ s area unit currently able to access their healthcare suppliers through real-time monitoring, conferencing and alternative varieties of technology. This approach is applicable to the emergency situation to establish communication between the patient who is in an isolated area and rescue team. In this study, we present the study of design a drone-based telemonitoring system as a solution of the patient who is in an unreachable area with the inability to established communication protocol like Wi-Fi, GPS, etc. According to the results images, when altitude changes distance 2 m and 3m was the best for when altitude 1.5 m and 2m. Altitude 1.5m means it is almost same as the person height. Therefore, altitude 2m will be a better height for this system. As shown in below figures there is the capability to the best image when the distance is 4m,5m,6m and 7m is good enough with altitude 2m,2m,2m and 3m respectively. When distance changes altitude 3 m and 2m was the best for when distance 3 m and 2m. Therefore, altitude 3m will be a better height for this system. As shown in below figures there is the capability to the best image when altitude is 4m,5m and 6m is good enough with distance 4m,3m and 5m respectively. Hence it can be concluding that for the developed drone-based telemonitoring explore the best result when it is flying with altitude 2m and distance 3m from the victim.

# Acknowledgement

First of all, I really would like to express my deepest gratitude to Prof. Shinji Tsuruoka, who is the Executive Vice-President of Mie University and Associate Prof. Hiroharu Kawanaka at Graduate School of Engineering, Mie University who offered continuing supports and constant encouragements. I am also grateful to Associate Prof. Chinthaka Premachandra at Shibaura Institute of Technology, Tokyo. He provided a lot of technical help and encouragement and accepted me as a short-term study at his laboratory in Shibaura Institute of Technology. Thanks to his help and encouragement, I was able to make good progress in my project. And finally, I would like to appreciate other members who helped my research project.

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# Publication List

## International Conferences

[1]Yashodha Karunarathna, Hiroharu Kawanaka, Chinthaka Premachandra,Shinji Tsuruoka. "Eagle Eye for ER Doctor: Basic Study of Drone based Tele Monitoring System for an Inaccessible Area", International Conference on Image Processing and Robotics(ICIPRoB2020) pp 63,IEEE.(2020)

[2]Yashodha Karunarathna, Hiroharu Kawanaka, Chinthaka Premachandra,Shinji Tsuruoka, "Alive Human Detection for Smart Triage Drone in Disaster situation" in the 9th International Symposium for Sustainability by Engineering at Mie University (Research Area C), pp. 3-4, 2019.

[3]MWYC. Karunarthhna W. Wijesinghe, H. Kawanaka "Development of a Home Automation Systems for Sri Lanka Using ARM Cortex M4", In 2019 IEEE 8th Global Conference on Consumer Electronics (GCCE) (pp. 598-600). 2019, IEEE.

[4]MWYC. Karunarthhna W. Wijesinghe, H. Kawanaka "A Low-Cost Home Energy Saving System Based on ARM Cortex M4 ", The 26th Tri-U International Joint Seminar and Symposium, China, 2019.

M. Karunarthhna and W. Wijesinghe, "Development of a low-cost home automation system using arm cortex m4", Annual Symposium on Research and Industrial Training in Department of Electronics, Wayamba University(ASRITE) 2018, pp. 201-206.

[6]Manawadu, U. A., Karunarathna, M. W. Y. C., Gunawardana, H. D. C. N., Premachandra, C., De Silva, P. R. S., Wijesinghe, W. A. S. (2018, October). A Study of automated image capturing HDI environment using NAVIO 2. In 2018 IEEE 7th

Global Conference on Consumer Electronics (GCCE) (pp. 308-311). IEEE.

# AppendixA

# Python Code for the system

import usb.core
import usb.util
import numpy as np
import cv2
from PIL import Image

Address enum READ$_{C}HIP_{I}D = 540x36$
$START_{G}ET_{I}MAGE_{T}RANSFER = 830x53$

GET$_{O}PERATION_{M}ODE = 610x3D$
$GET_{I}MAGE_{P}ROCESSING_{M}ODE = 630x3F$
$GET_{F}IRMWARE_{I}NFO = 780x4E$
$GET_{F}ACTORY_{S}ETTINGS = 880x58$

SET$_{O}PERATION_{M}ODE = 600x3C$
$SET_{I}MAGE_{P}ROCESSING_{M}ODE = 620x3E$
$SET_{F}IRMWARE_{I}NFO_{F}EATURES = 850x55$
$SET_{F}ACTORY_{S}ETTINGS_{F}EATURES = 860x56$

WIDTH = 320
HEIGHT = 240
RAW$_{W}IDTH = 342$
$RAW_{H}EIGHT = 260$

face$_{c}ascade = cv2.CascadeClassifier('haarcascade_{f}ullbody_{d}efault.xml')$

class SeekPro():
""" Seekpro class:
Can read images from the Seek Thermal pro camera

def $_{init_{(self):self.dev=usb.core.find(idVendor=0x289d,idProduct=0x0011)ifnotself.dev:raiseIOError('Devicenotfound')self.dev.set_configura}}$
def get$_dead_pixl_ist(self, data):$
$"""Getthedeadpixelsimageandstoreallthecoordinatesofthepixelstobecorrected"""img =$
$self.crop(np.frombuffer(data, dtype = np.uint16).reshape(RAW_HEIGHT, RAW_WIDTH))$
$returnlist(zip(*np.where(img < 100))$
$)$

def correct$_dead_pix(self, img):$
$"""Foreachdeadpix, takethemedianofthesurroundingpixels"""fori, jinself.dead_pixels:$

$img[i, j] = np.median(img[max(0, i-1) : i+2, max(0, j-1) : j+2])$
$returnimg$

def crop(self,raw$_img):$
$"""Gettheactualimagefromtherawimage"""$
$returnraw_img[4 : 4 + HEIGHT, 1 : 1 + WIDTH]$

def send$_msg(self, bRequest, data_or_wLength,$
$wValue = 0, wIndex = 0, bmRequestType = 0x41, timeout = None):$
$"""Wrappertocallctrl_transferwithdefaultargstoenhancereadability$
$"""assert(self.dev.ctrl_transfer(bmRequestType, bRequest, wValue, wIndex,$
$data_or_wLength, timeout) == len(data_or_wLength))$

def receive$_msg(self, bRequest, data, wValue = 0,$
$wIndex = 0, bmRequestType = 0xC1,$
$timeout = None):$
$"""Wrappertocallctrl_transferwithdefaultargstoenhancereadability$
$"""returnself.dev.ctrl_transfer(bmRequestType, bRequest, wValue, wIndex, data, timeout)$

def deinit(self):
"""
""" for i in range(3):
self.send$_msg(0x3C, b'0000')$

def init(self):
""" Sends all the necessary data to init the camera
""" self.send$_msg(SET_OPERATION_MODE, b'0000')$
$r = receive_msg(GET_FIRMWARE_INFO, 4)$
$print(r)$

$r = receive_msg(READ_CHIP_ID, 12)$
$print(r)$
$self.send_msg(SET_FACTORY_SETTINGS_FEATURES,$
$b'060008000000')$
$r = receive_msg(GET_FACTORY_SETTINGS, 12)$
$print(r)$
$self.send_msg(SET_FIRMWARE_INFO_FEATURES, b'1700')$
$r = receive_msg(GET_FIRMWARE_INFO, 64)$
$print(r)$
$self.send_msg(SET_FACTORY_SETTINGS_FEATURES,$
$b$"010000060000")
$r = receive_msg(GET_FACTORY_SETTINGS, 2)$
$print(r)$
$foriinrange(10):$
$forjinrange(0, 256, 32):$
$self.send_msg(SET_FACTORY_SETTINGS_FEATURES, b$"2000" $+$ $bytes([j, i])$ $+$
$b$"0000")
$r = receive_msg(GET_FACTORY_SETTINGS, 64)$
$print(r)$
$self.send_msg(SET_FIRMWARE_INFO_FEATURES, b$"1500")
$r = receive_msg(GET_FIRMWARE_INFO, 64)$
$print(r)$
$self.send_msg(SET_IMAGE_PROCESSING_MODE, b$"0800")
$r = receive_msg(GET_IMAGE_PROCESSING_MODE, 2)$
$print(r)$
$self.send_msg(SET_OPERATION_MODE, b$"0100")
$r = receive_msg(GET_OPERATION_MODE, 2)$
$print(r)$

def grab(self):
""" Asks the device for an image and reads it """ Send read frame request
self.send$_msg(START_GET_IMAGE_TRANSFER, b'585b0100')$
$toread = 2 * RAW_WIDTH * RAW_HEIGHT$
$ret = self.dev.read(0x81, 13680, 1000)$
$remaining = toread - len(ret)$
$512insteadof0, toavoidcrasheswhenthereisanunexpectedoffset$
$Itoftenhappensonthefirstframe$
$whileremaining > 512:$

$print(remaining, "remaining")$
$ret+ = self.dev.read(0x81, 13680, 1000)$
$remaining = toread - len(ret)$
$status = ret[4]$
$iflen(ret) == RAW_HEIGHT * RAW_WIDTH * 2 :$
$returnstatus, np.frombuffer(ret, dtype = np.uint16).reshape(RAW_HEIGHT, RAW_WIDTH)$
$else :$
$returnstatus, None$

def get$_image(self) :$
$"""MethodtogetanactualIRimage"""whileTrue :$
$status, img = self.grab()$
$print("Status = ", status)$
$ifstatus == 1 : Calibrationframe$
$self.calib = self.crop(img) - 1600$
$elifstatus == 3 : Normalframe$
$ifself.calibisnotNone :$
$returnself.correct_dead_pix(self.crop(img) - self.calib)$

if $_{name}{}_{=='}{}_{main'}{}_{:importcv2fromtimeimporttime}$
def rescale(img):
""" To adapt the range of values to the actual min and max and cast it into an 8 bits image """ if img is None:
return np.array([0])
mini = img.min()
maxi = img.max()
return (np.clip(img-mini,0,maxi-mini)/(maxi-mini)*255.).astype(np.uint8)

cam = SeekPro()

cv2.namedWindow("Seek",cv2.WINDOW$_NORMAL)$
$t0 = time()$
$whileTrue :$
$t = time()$
$print("fps : ", 1/(t - t0))$
$t0 = time()$
$r = cam.get_image()$
$w, h = 512, 512$

Draw the rectangle around each person
for (x, y, w, h) in faces:
cv2.rectangle(r, (x, y), (x+w, y+h), (255, 0, 0), 2)
imgt=rescale(r) scaling image
imgt=cv2.applyColorMap(imgt, cv2.COLORMAP$_{J}ET)applyingcolormap$
$https://docs.opencv.org/master/d3/d50/group_{imgproc_{colormap.htmlcv2.imshow("Seek",imgt)showfinalimage}}$
cv2.imwrite("im3.png",imgt)
cv2.waitKey(1)