Pilot Study on the Development of a Low Cost Land Observation and Geo-information Retrieval System for Emergency Monitoring of Agricultural Crop and Disaster-Induced Damages

A Thesis
Submitted to the Department of Electrical and Electronics Engineering
Of
BRAC University
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In partial fulfillment of the requirements for the degree of

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Inspiring Excellence

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Declaration

We do here by declare that the thesis titled 'Pilot Study on the Development of a Low Cost Land Observation and Geo-information Retrieval System for Emergency Monitoring of Agricultural Crop and Disaster-Induced Damage' is submitted to the Department of Electrical and Electronic Engineering of BRAC University in partial fulfillment of the Bachelor of Science in Electrical and Electronics Engineering. This is our original work and was not submitted elsewhere for the award of any other degree or any other publication.

Date: 16.08.2016

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Abstract

A pilot study has been performed under this thesis work in view of establishing a Space-based Emergency Geoinformation Support Service System equipped with necessary Remote Sensing (RS), GIS and ICT functionalities and working blocks as an aid to decision making processes at policy level and management level. The work under the thesis includes integrated application of remote sensing sciences, geo-information technology and UAV (locally made quad copter) technology for emergency observation over limited area as a supplement to remote sensing study for correction and validation operation. Surface features like soil, vegetation and water are the major category of surface features over a given area. The UAV actually is a locally made quad copter. The dedicated system has been designed and developed for acquisition of spectral images for emergency observation under major disaster events, environmental problems and agricultural crop monitoring to acquire emergency information over specific area at specific height and location.

The designed system includes a moving flying platform in the present case it is a quad copter for holding necessary remote sensing device with special arrangement for carrying out measurements. The quad copter is guided through a GPS-guided mission plan covering a disaster affected given area with arrangement for mounting of sensing device with a mechanism to minimize tilting and axial movement during data acquisition. The purpose is to facilitate the emergency information retrieval process in the remote area where monitoring through land vehicle is time consuming and difficult.

Using the software, we can perform mission planning by specifying giving the way point of the area to be monitored and the quadcopter will be instructed to cover that area and acquire images using a high resolution digital camera mounted in the quadcopter. After acquisition of a series of images as specified in the mission plan, all the individual images are geometrically corrected, geo-referenced and finally mosaicked to produce a single image block. At this stage, software has been prepared through coding of algorithm of SMAC (Simplified Method of Atmospheric Correction) to perform necessary atmospheric correction of the acquired images. The developed software performs necessary atmospheric correction of acquired images which are affected by external factors like atmospheric aerosol and other gaseous constituents in the atmosphere. Subsequently the corrected image will be geo-referenced using ERDAS Imagine software. The remaining operation of information retrieval has been made carried out through a model-based approach using spatial modeler language available in the professional Image Processing Software "ERDAS Imagine". Information on surface features particularly agricultural crop, damaged areas, exposed soil etc. are obtained based on the acquired images and damaged areas are also identified.

The whole system seems to be supportive to food security, disaster induced damage assessment, environmental disturbances analysis etc.

Table of Contents

Chapter-1

Introduction

1.1 Objective

The main objectives of this thesis is to design a system which will perform in Geo-information retrieval operations for monitoring crops and disaster induced places using a low budget UAV which can be made using locally available equipment. Bangladesh quite frequently suffers in natural disasters like flood, cyclone, hurricanes etc. which naturally affects in the environment and human lives. Estimating the aftermath of the natural disasters helps the Government and the people to take necessary steps to overcome the damages. The amount of damages is still monitored through on filed visit which is time consuming and sometimes it is not possible to reach the disaster affected area on time due to unavailability of communication and transportation. Aerial monitoring using aerial vehicle can be useful sometimes but landing the vehicle is often a major problem experienced by the pilot. Therefore, one of the most efficient methods of those monitoring system is remote sensing using Land Observation Satellites. As the country does not own its own satellite the UAV based land monitoring and Geo-information retrieval system opens the door of a new method of land observation technique.

The UAV is a perfect choice because the system is solely made using the locally available electrical equipment and appliances. Therefore, any sort of technical difficulties can be easily overcome and repaired by the local technician. Another very important tool for remote sensing operations is the camera sensors. There are wide ranges of cameras present in the market which can receive multiple bands of electromagnetic spectrum. These frequency bands are received by the Land Observation Satellites (Landsat) for remote sensing for Geo-information retrieval operations. The cameras that are mounted in the UAV can also perform these operations for comparatively shorter area which is adequate for fulfilling the needs for UAV based monitoring systems. Moreover, the mission planning software operations is integrated with the UAV which allows the UAV to take high definition aerial image of any given area which does not require human control. During mission plan, the camera is triggered automatically through flight controller board and a series of aerial images are taken. All the images are mosaicked together to get the overall image of the covered area. After completing the mission, it returns back to its home location and the whole process is automatic.

The image processing is done using specially designed software named ERDAS Imagine. It is professional image processing software mainly used to retrieve data from satellite images. The camera used in this thesis can receive three bands, RGB. The software can separate all the three bands and distinguish colors. Mainly soil, vegetation and water are separated and the area covered in each of those separated regions can be calculated. Thus we can estimate amount of gross production in any area and can compare the harvest of crops with respect to time. If government wishes to estimate the amount of rice production this method can be used.

1.2 Background information

1.2.1 History of Remote Sensing

The term remote sensing was first introduce in 1958 by Everyln Pruitt of the U.S Office of Naval Research [9]. To survey soil and crop scientists use to use aerial photography in various agriculture areas. During World War 2 infrared photography was developed, by using infrared technology scientists was able to understand the crop status, water management and crop-soil condition.

In 1960 new laboratories was established for crop identification and the Crop Identification Technology Assessment for Remote Sensing (CITARS) program.

In the early 1970, NASA became more concern about remote sensing and provide funding in selected universities to develop remote sensing technologies. NASA wanted to improve their future sensor systems, so the spectral bands was very important as those band works under different principal and have different characteristics.

The first of the Landsat sensor configuration was launched in 1972, was able to estimate the wheat yield over wide area. NASA, NOAA and USDA was being jointed in the LACIE program. Between 1974 and 1975 the Great Plains of the US concentrate on the development of both yield estimation model and spectral ‘signatures’. Subsequently various country became more concern about remote sensing including Canada and Soviet Union. LACIE program became more successful and they expand the program including various types of crop monitoring such as barley, corn, cotton rice, soybeans and wheat.

1.2.2 History of UAV

From an article by Cam Tetrault we have found the big history behind Unmanned Arial Vehicles

In 1782 the Montgolfier brothers in France done the first experiment with balloons. In 1861-1865 during the American Civil War, Northern Union use to put flaming object to start fire in battle lines. Japan used high altitude balloon in 1944 to start forest fires in North America.

In 1848 steam powered propeller driven model was designed by John String fellow and William Henson, which is a 10 feet wingspan known as ‘aerial steam carriage’. The model was successful to cover 60 yards but the landing was a disaster, Samuel Langley successfully flew a steam model in 1896 also knows as' aerodrome number 5'.

In 1918 the Charles Kettering Aerial also known as Kettering Bug was a big success in American Army. The object had gasoline fueled and was able to fly 50 miles and the concept of composed of a gyroscope was introduced. But the first major UAV was designed by the German also knows as 'Buzz Bomb' or 'Doodle Bug' of 1944 having a speed of 400 mph. It was the fastest of them all and for its high speed the German was able to strike London from launch Sites in France.

In World War 2 the remote controlled flying bombs was developed by the United States. In 1944 they was able to hit 18 times successfully in on target. One of the good feature was having a TV Camera mounted in the nose for steering.

Between 1950-1970 more development and improvement was done in US UAV programs like "Global Hawk" which was capable of gathering such information that was retrieved by satellite only.

1.2.3 History of UAV on Remote Sensing

Unlike success on military operations, scientists were interested on UAV for doing "dull, dirty and dangerous" work. End of the cold war UAV has been improved on control and navigation system area which thrive scientists to use this technology for their research. Between 1970 to 1980 NASA ran UAV based mission named "Mini Sniffer" but in 1990s "ERAST" mission was the major step for remote sensing using UAV. After the age of minimization of sensors and electronics many "Do it yourself" community evolved for UAV construction for many research purpose on early 2000. Which also help to cut down the price of UAV system. Although, many countries have regulation issues which is inversely affecting the research process based on UAV, now-a-days researchers have many options of UAV's regarding their research purpose.

1.3 Literature Review

Studying the literature from various journals helped us in understanding the basic concept of remote sensing and the use of UAV for geo-information retrieval operations for monitoring of crops and disaster induced damages. To understand the term remote sensing, we had studied "Remote Sensing and Image Interpretation" by LILLESAND, T.M & KIEFER, R. W. from where we understood that this is a part of scientific study where the geo-information is retrieved using a device which is not in contact with the object [5]. The information can be acquired from a various electronic device, which can be various sensors, camera etc. All the objects of the earth emits electromagnetic radiations but the amount of wave radiated may vary for different objects and thus due to this variation of electromagnetic radiated waves the objects can be identified. The range of electromagnetic waves are separated into different bands of frequency, called electromagnetic spectrum. The main purpose of these sensors is to receive the electromagnetic waves and these sensors have been categorized for receiving different spectral bands which we studied from "Spectral Imaging for Remote Sensing" written by Gray A. Shaw and Hsiao-hua K. Burke [8]. Mainly soil, vegetation and water are separated from the sensor output.

There are a various methods of remote sensing, one of the most popular way for doing this is to use Land Observation Satellite (Landsat) which was used from 1970. The Landsat contains various sensors which can receive electromagnetic spectrum. As our country does not own any Landsat, it is necessary to design a system which is effective in monitoring Geo-information using the available technology exist in our country. UAV is a very important system for retrieve geo-information in comparatively smaller areas. UAV was the best choice because one of the main objective of this thesis was to make a low cost land observation and geo-information retrieve system. For constructing the UAV we had studied "Unmanned Aerial Vehicle RC Quadcopter" by Raghendra Panchal and understand the basics of the construction of Quadcopter. For fulfilling the other missions of this thesis which are monitoring crops and disaster induced damages using the UAV, we had studied "Thermal and Narrowband Multispectral Remote Sensing for Vegetation Monitoring From an Unmanned Aerial Vehicle" and "Autonomous drones for disasters management: Safety and security verifications" written by Jose A. J. Berni , *Student Member, IEEE*, Pablo J. Zarco-Tejada, Lola Suárez, and Elias Fereres and Ludovic Apvrille ,Yves Roudier , Tullio Joseph Tanzi respectively[1][2]. From these literature we had gathered a vast knowledge regarding the crop monitoring system and disaster induced damage observation technique. Balancing mechanism of quadcopter was illustrated in "WIRELESS CONTROL QUADCOPTER WITH STEREO CAMERA AND SELF-BALANCING SYSTEM" by MONGKHUN QETKEAW A/L VECHIAN [6]. For better quality image and smooth flight, stabilization is very essential when the flight is controlled manually. To monitor a specific area by manual controlling, the UAV pilot should be trained enough otherwise the path will not be followed appropriately. The process or following a specific area for monitoring, a software named Mission Planner makes the task simpler. The APM is integrated with the Mission Planner software. Mission Planner software is a very precious software for researcher and novice because this software facilitate the UAV pilot to fly the UAV automatically and follow the desired path automatically. In Mission Planner software, an area which we want to observe need to be selected from the Google Maps. After selecting the area, the software automatically generate the way points and the UAV followed the way points automatically, and the camera take a series of images of that area. We had studied about the mission planning from a literature named "Unmanned aerial systems for photogrammetry and remote sensing: A review" written by I. Colomina , P. Molina. All these literatures was helpful for leading us to the appropriate path for completing our objectives.

1.3.1 Fundamentals of Remote Sensing

"Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information."

In much of remote sensing, the process involves an interaction between incident radiation and the targets of interest. This is exemplified by the use of imaging systems where the following seven elements are involved. Note, however that remote sensing also involves the sensing of emitted energy and the use of non-imaging sensors.

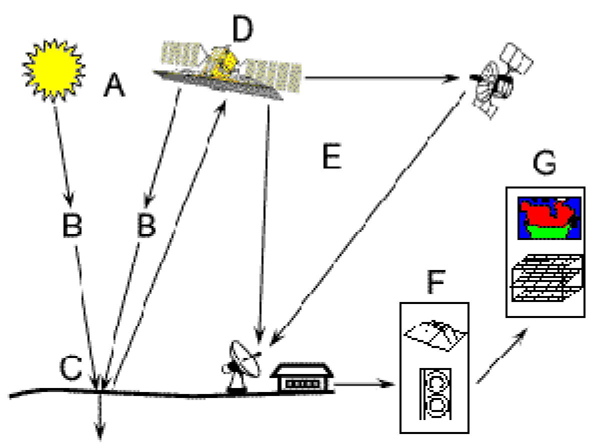


Figure 1.1: Fundamental of remote sensing

1. Energy Source or Illumination (A) - the first requirement for remote sensing is to have an energy source which illuminates or provides electromagnetic energy to the target of interest.

2. Radiation and the Atmosphere (B) - as the energy travels from its source to the target, it will come in contact with and interact with the atmosphere it passes through. This interaction may take place a second time as the energy travels from the target to the sensor.

3. Interaction with the Target (C) - once the energy makes its way to the target through the atmosphere, it interacts with the target depending on the properties of both the target and the radiation.

4. Recording of Energy by the Sensor (D) - after the energy has been scattered by, or emitted from the target, we require a sensor (remote - not in contact with the target) to collect and record the electromagnetic radiation.

5. Transmission, Reception, and Processing (E) - the energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station where the data are processed into an image (hardcopy and/or digital).

6. Interpretation and Analysis (F) - the processed image is interpreted, visually and/or digitally or electronically, to extract information about the target which was illuminated.

7. Application (G) - the final element of the remote sensing process is achieved when we apply the information we have been able to extract from the imagery about the target in order to better understand it, reveal some new information, or assist in solving a particular problem.

1.4 Need for Crop Monitoring

Remote sensing provides the status of the health of vegetation. The spectral radiative response of a crop field depends on phenology, stage type and crop health and they could be well monitored using multi-spectral sensors. Thus remotely sensed data can be used in GIS for further analysis to provide field level information of ownership and management practices.

Examining the ratio of reflected infrared to red wavelengths is an excellent measure of vegetation health. This is NDVI. Healthy plants have a high NDVI value because of their high radiative response of infrared light, and relatively low radiative response of red light. Areas of consistently healthy and vigorous crop would appear uniformly bright. Stressed vegetation would appear dark amongst the brighter, healthier crop areas. In Figure 1.1, radiative response from various mediums is shown.

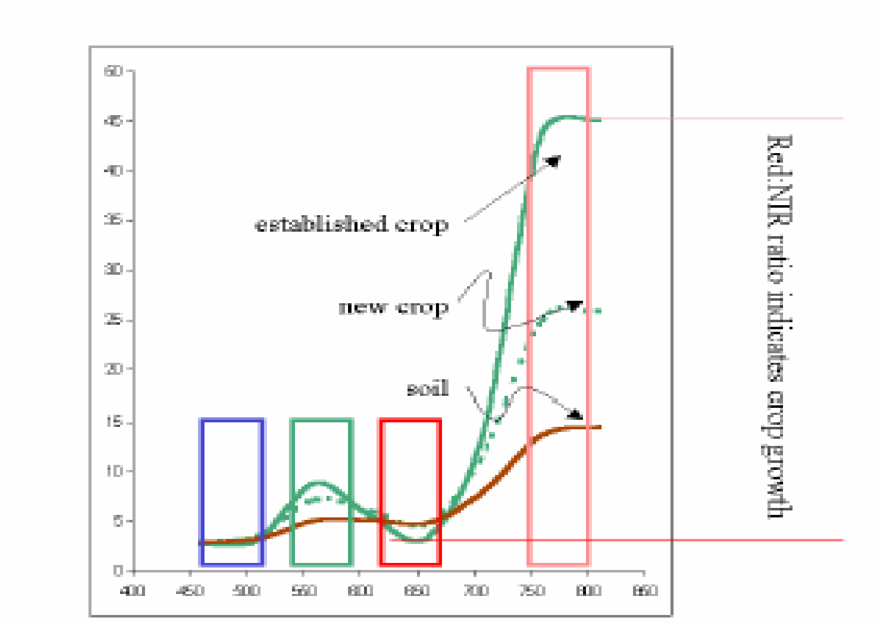


Figure 1.2 Theory of NDVI determination – NIR radiative response significantly influenced by green plant material.

Estimation of crop yield is usually done by detecting the land cover change seasonally and annually. Seasonal change provides information of agricultural change, while annual change indicates land cover or land use change, which may be called as real change. Spectral radiative response is assumed to be different with respect to the type of land cover.

1.5 Spectral Radiative Response of Land Covers

For any given material, the amount of solar radiation that is reflected (absorbed, transmitted) varies with wavelength. This important property of matter allows us to separate distinct cover types based on their response values for a given wavelength. When we plot the response characteristics of a certain cover type against wavelength, we define what is termed the spectral signature of that cover.

In some instances, the nature of the interaction between incident radiation and earth's surface materials will vary from time to time during the year, such as might be expected in the case of vegetation as it develops from the leafing stage, through growth to maturity and, finally to senescence. The term 'spectral signature' is sometimes used to describe the spectral response curve for a target. A typical spectral radiative response curve of the most common earth surface materials viz., water and vegetation is shown in Figure 1.3

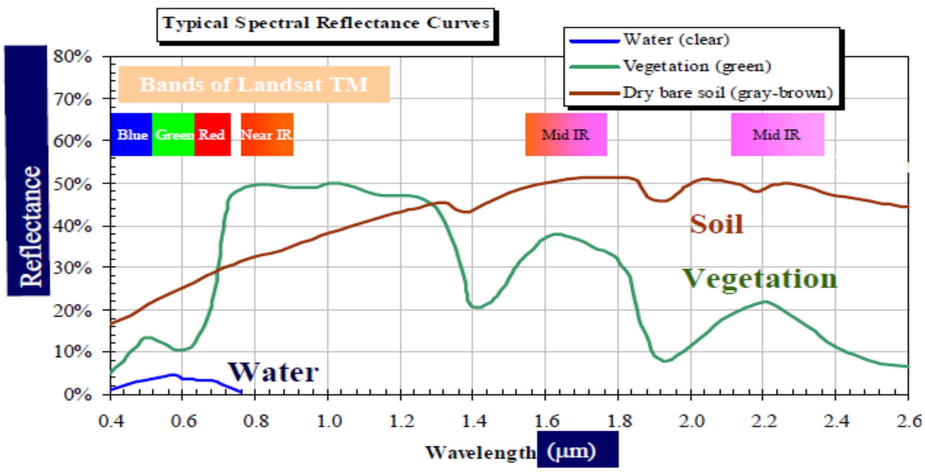


Figure 1.3 Spectral radiative response of vegetation, soil and water.

Vegetation has a unique spectral signature which enables it to be distinguished readily from other types of land cover in an optical/near-infrared image. The radiative response is low in both the blue and red regions of the spectrum, due to absorption by chlorophyll for photosynthesis. It has a peak at the green region. In the near infrared (NIR) region, the radiative response is much higher than that in the visible band due to the cellular structure in the leaves. Hence, vegetation can be identified by the high NIR but generally low visible radiative responses.

The radiative response of bare soil generally depends on its composition. In the spectral radiative response curves shown in Figures 1.4 and 1.5, the radiative response increases with increasing wavelength. The radiative response of clear water is generally low. However, the radiative response is maximum at the blue end of the spectrum and decreases as wavelength increases. Hence, clear water appears dark-bluish. Turbid water has some sediment suspension which increases the radiative response in the red end of the spectrum, accounting for its brownish appearance.

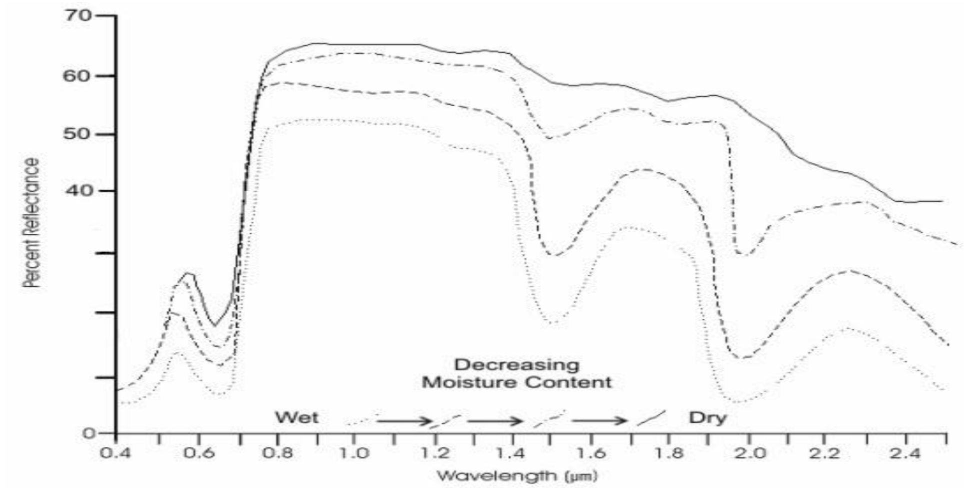


Figure 1.4: Variation in the spectral radiative response characteristics of vegetation according to leaf moisture content.

1.6 Soil

The spectral radiative response of soil is controlled, for the most part, by six variables

a) Moisture content
b) Organic matter content
c) Particle size distribution
d) Iron oxide content
e) Soil mineralogy
f) Soil structure

Of these variables, moisture content is the most important due to its dynamic nature and large overall impact on soil radiative response.

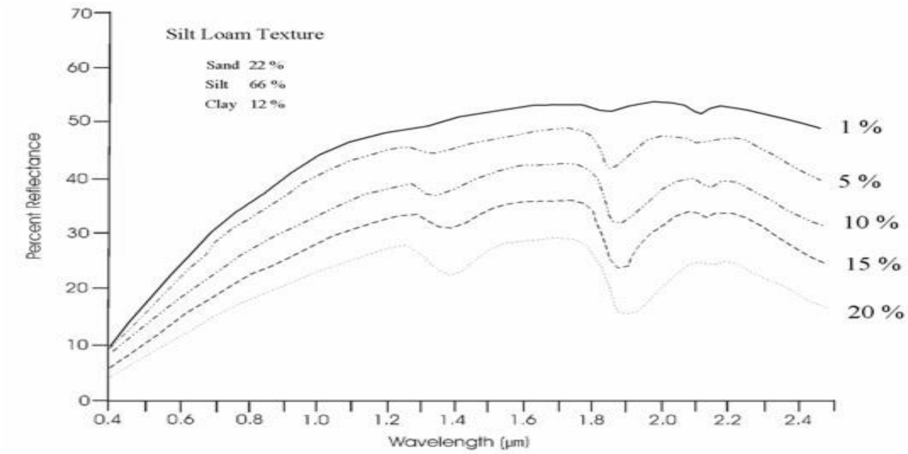


Figure 1.5: Variation in the spectral radiative response characteristics of soil according to moisture content.

1.7 Water

There are three types of possible radiative response from a water body

a) Surface (specular) radiative response
b) Bottom radiative response
c) Volume radiative response

Only volume radiative response contains information relating to water quality. For deep (> 2 m) clear water bodies, volume radiative response is very low (6-8 percent) and is confined to the visible wavelengths.

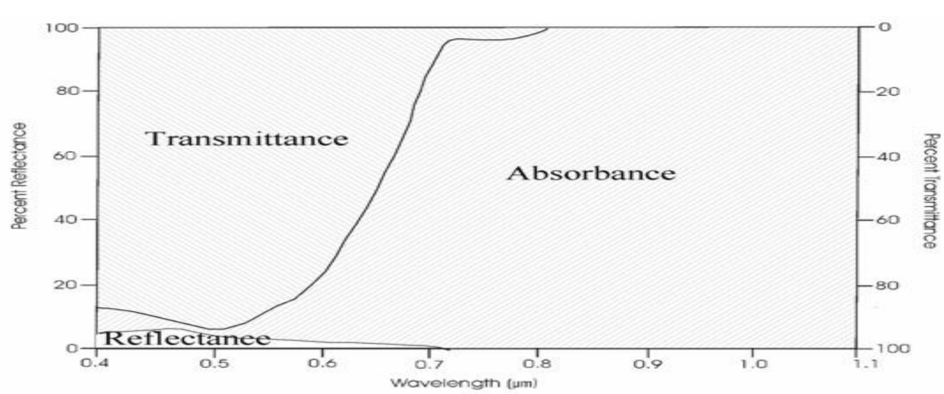


Figure 1.6: Spectral radiative response characteristics of deep, clear water.

Clear water reflects very little solar irradiance, but turbid water is capable of reflecting significant amounts of sunlight. As the chlorophyll content of a water body increases (resulting from an increase in algae, phytoplankton, etc.) its blue-light radiative response decreases while its green-light radiative response increases

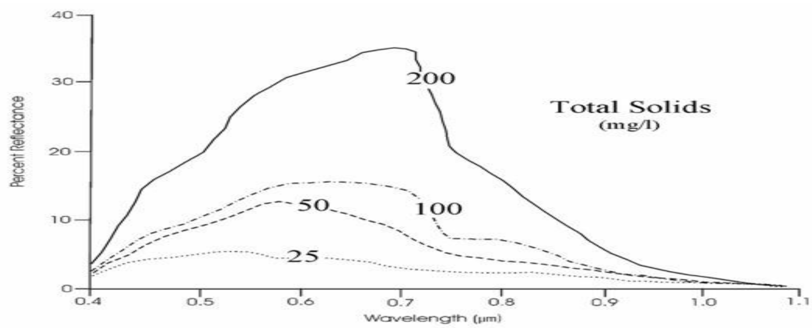


Figure 1.7: Variation in the spectral radiative response characteristics of turbid water according to the content of suspended solids.

Chapter-2
DRONES AND BASICS

Drones or UAVs or Unmanned Aerial Vehicles are kind of machines which can fly without having any presence of human pilot inside the vehicle. These kind of machines can be controlled through computers or by simple remote controls. In terms of classification of these drones, there is no set standard. Drones are being design in various shapes and sizes according to our use.

2.1 Basic Principle

The design of any drone can consists of multiple rotor with multiple propelling wings according to our requirement. Those multiple motors can induces pull action and push action such as different movement. We have design a Quad copter, having four motors with four propelling wings. The left and right induce pull action, while the front and back induce push action.

A microcontroller board can be known as the brain of the robot. These board are being designed in such way so that the drone can be auto piloted.

Combination of inertial measurement unit, microcontroller can consists of 3 axis gyro, 3 axis accelerometer and a barometric pressure gauge. RC transmitter which is being used to navigate the drone, GPS chip can be introduce to the robot for further improvement as GPS chip can give us precise latitude and longitude value. [7]

2.1.1 Working mechanism of Quad-Copter

To make anything fly, the weight need to balance to generating an equivalent force (Lift) and also balance moments about its center of gravity by generating opposite moments. By using four rotors a quad copter generates the required moments and lift force. Generating lift might be simple, but generating moments in order to stabilize the machine and generating control forces to move its quite complex for our desired location or on a desired path.

2.1.2 Multirotor Coordinate System

While discussing the piloting and multirotor construction, a certain way of communication is require for different movements of the multirotor. In 1700s mathematicians described the orientation of rigid bodies in space. From there they have developed a system where a set of three angles has being explained, in this case, for the orientation of the multirotor three special dimensions are being used . These three dimensions or angles are known as **roll, pitch, and yaw**.

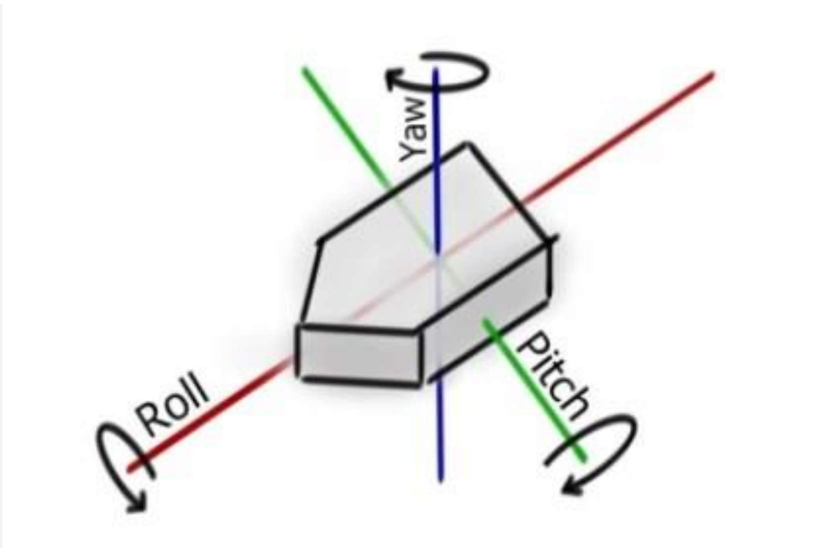


Figure 2.1 Orientation of quad-copter roll, pitch and yaw

To describe the orientation of the quadcopter, we use three angles: roll, pitch, and yaw.

- The quad copter can tilt side by side and this can be describe by the roll angle of the multirotor. If we tilt our head towards one of your shoulders the rotation of quad copter about roll axis are same. This rolling of the multirotor causes it to move sideways.
- The forwards and backwards movement of the quad copter are being cause for the pitch angle of the multirotor. When we tilt our head in order to look up or down these movements are same as the rotation about the pitch axis. As the multirotor pitching causing it to move forwards or backwards.

- The yaw angle of the multirotor can able to describe the bearing, or, in other words, rotation of the craft as it stays level to the ground. When we shake our head to say “no.” this particular movement is the yaw movement of the quad copter.

  The final terminology that describe orientation of a quad copter is, throttle of the multirotor. The altitude of the multirotor is being controlled by throttle.[6]

2.2 The Physics of Quad-copter Flight

2.2.1 Steering

While flying our quadcopter, it is very important to understand the movement of the multirotor and how it can be control perfectly. The rotational speed of the motors causes different movements of multirotors. The right way is to adjust the relative speeds of the motors, keeping in mind that the rotational speed of the motors determines how much lift each prop produces. The rotation around any of the directional axes (roll, pitch, and yaw) are being determined by the flight controller as it causes the multirotor to rotate at different speed, also same goes to gain or lose altitude.

2.2.2 Roll and Pitch

The flight controller makes the motors to spin faster on one side of the multirotor than the motors on the other side causing the multirotor to rotate about the roll or pitch axes, by meaning one side of the multirotor will have to lift more than the other side, causing the multirotor to tilt.

So, for example, to make a quadcopter to roll right or rotate about the roll axis clockwise, the flight controller will control the movement of two motors on the left side of the multirotor to spin faster than the two motors on the right side. The left side of the quadcopter will then have more lift than the right side, causing the multirotor to tilt.

Similarly, to make a quadcopter pitch down, that is rotate about the pitch axis clockwise, now the flight controller will do the opposite. It will make the two motors on the back of the quadcopter to spin faster than the two motors on the front, making the craft to tilt in the same way when our head tilts as we look down.

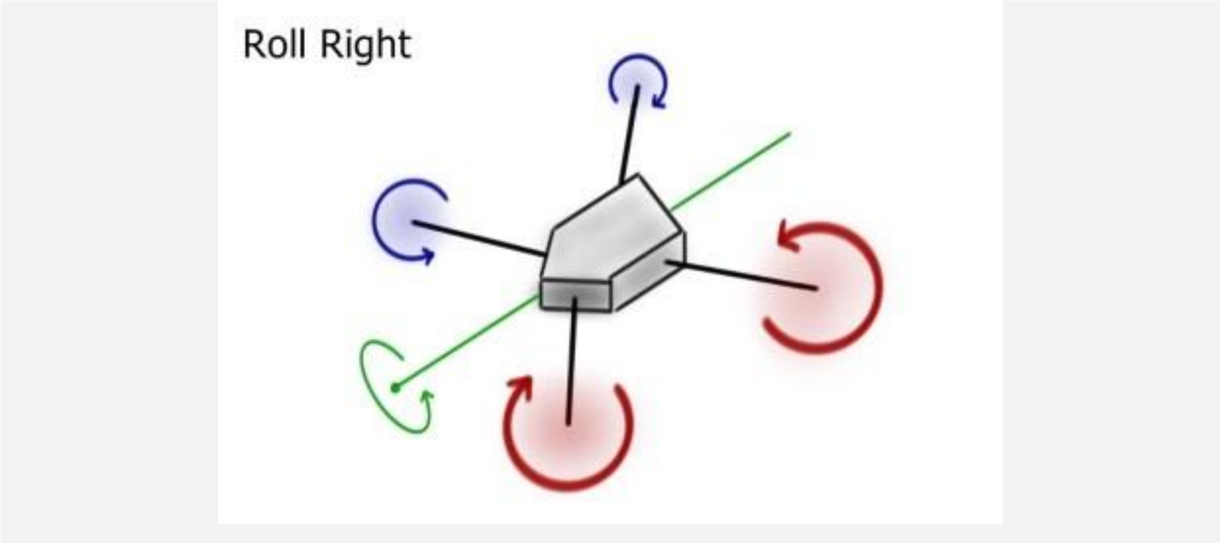


Figure 2.2(a) Quad-copters roll left or right by altering the relative speeds of the left and right motors.

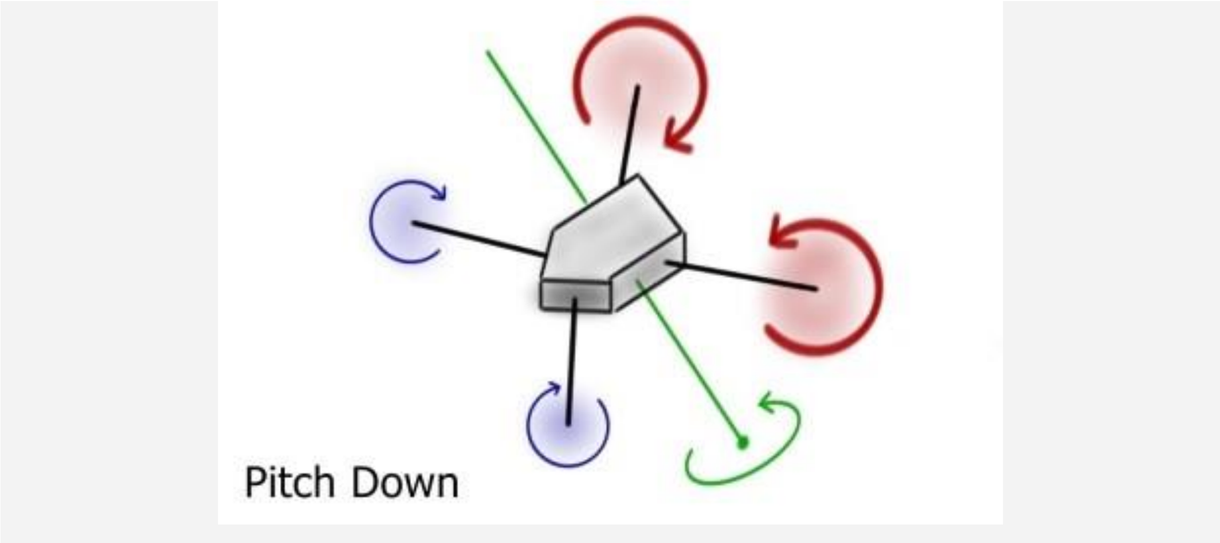


Figure 2.2(b) Quadcopters pitch up and down by adjusting the relative speeds of the front and back motors.

The same principles apply for multi-rotors with more than four motors as well.[6]

2.2.3 Yaw

Controlling the multi-rotor's rotation about the roll or pitch axes is easy but complex task will be the yaw axis. First, let us discuss about how we will be able to prevent rotation about the yaw axis. When assembling and programming multirotors, we have setup the motors in such way so that each motor spins in the opposite direction than its neighbors. In other words, using a quadcopter as an example once again, if we start from the front-left motor, it is moving clockwise, the motors' rotational directions can alternative, CW, CCW, CW, CCW. To neutralize, or cancel out each other or motor's tendency to rotate the multirotor we have use this rotational configuration.

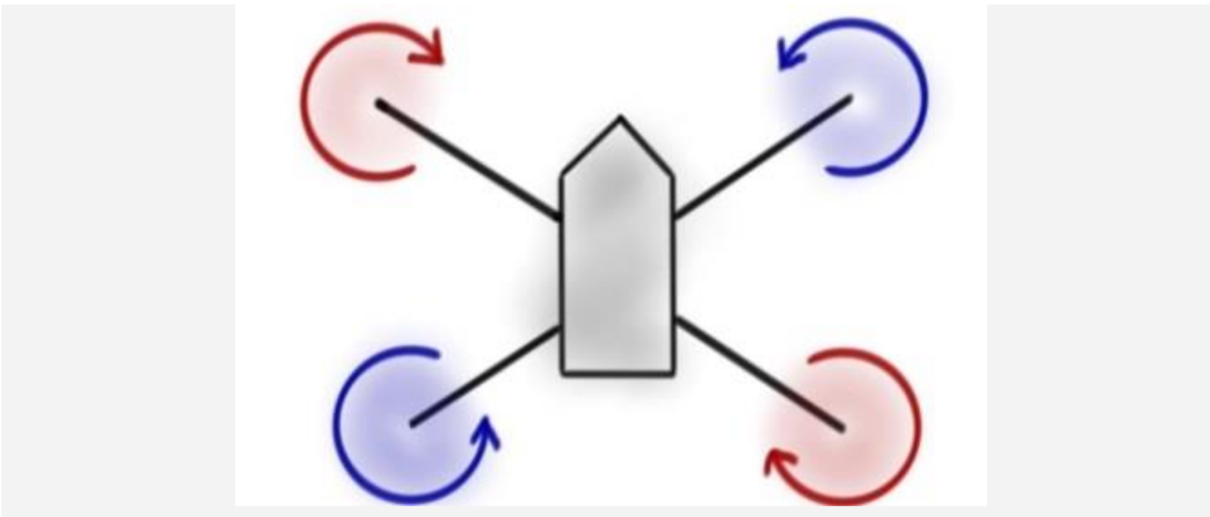


Figure 2.3(a) configure of each motor to spin in the opposite direction than its neighbors.

When a prop spins, for example, in clockwise rotation, the multirotor will have a tendency to spin counter-clockwise according to the conservation of angular momentum. This is due to Newton's third law of motion, "for every action, there is an equal and opposite reaction." The body of the multirotor will always tend to spin in the opposite direction than the rotational direction of the propellers.

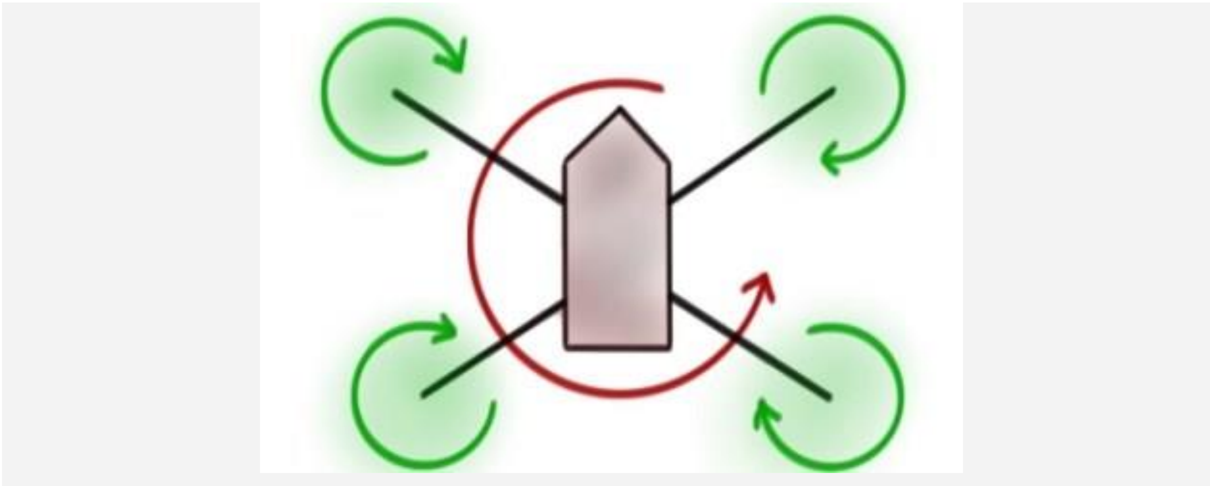


Figure 2.3(b) Note that we do not set up our quadcopters, or any other multirotors, this way. If we were to have all the rotors spin clockwise, the multirotor would start spinning uncontrollably in a counterclockwise direction.

As an example let us discuss about helicopter working mechanism. As helicopters have two rotors and in order to lift the aircraft the larger main rotor is the main reason behind it, and the small rotor on the tail that lets the helicopter to spin in different direction. Imaging what if in mid-flight, tail rotor of the helicopter fells off the aircraft while the big main rotor kept spinning. The common thoughts probably will be, the helicopter would start spinning. According to the law of conservation of angular momentum, this kind of rotation would be caused as the rotation of the propeller in the opposite direction.

So we can say that, each of the four rotors quadcopter tends to make the multirotor to rotate in the opposite direction than their spin. So we are canceling out this effect so that the multirotors does not spin about the yaw axis by using pairs of rotors spinning in opposite directions.

So therefore, when we actually rotate the multirotor about the yaw axis, the flight controller will slow down the opposite pairs of motors compare to the other pair. By meaning the angular momentum of the two pairs of props will have no balance and the craft rotates. By slowing down different pairs of motors we can make the multirotor rotate in either direction.[6]

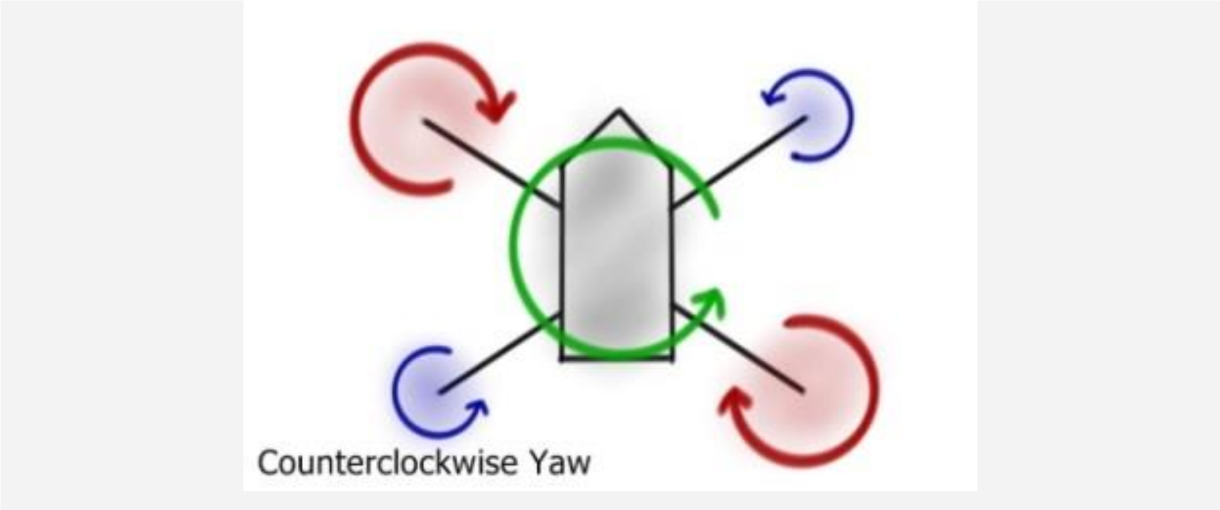


Figure 2.3(c) by making diametrically opposite motors (that spin in the same direction) spin at different rates, the craft can be made to yaw. In this case, the clockwise-spinning motors are faster than the counterclockwise-spinning motors, so the craft yaws counterclockwise.

2.2.4 Hovering/Altitude Control

Now that we understand steering principle of the multirotor, let us quickly discuss a much simpler term, which is hovering. To make the quadcopter or multirotor hover, which means it will stay at a constant altitude without rotating at any other direction. For this movement a balance of forces is required. When the lift is produced by the rotors the flight controller will have to counteract the force of gravity. So we can say that the mass of the multirotor times gravitational acceleration is equal to the force of gravity acting on the multirotor. The lift produced by the multirotor is equal to the sum of the lift produced by each of its rotors. Therefore, to maintain a constant altitude the force of gravity has to be equal to the force of the lift produced by the motors.

To ascend or descend, therefore, the flight controller disrupts this balance. The craft will gain altitude if the lift produced by the multirotor is greater than the force of gravity. If the opposite is true, the multirotor will fall when the lift produced by the multirotor is less than the force of gravity acting on the multirotor.[6]

2.2.5 Movement

So as far as we have discussed how, by adjusting the relative speeds of the multiple motors, the flight controller can tilt the multirotor in many direction. Well, the main reason we are able to move the quadcopter is the tilting of the multirotor. By tilting the multirotor in different directions, it can be made to move forward, backward, left, or right. For example, it moves forward when the multirotor pitches down (clockwise around the pitch axis).

The reason the multirotor moves when it tilts, some of the lift produced by the rotor is directed horizontally while normally all of the lift is directed downward. It pushes the multirotor due to sideways component of the lift.

Now can say that we are sacrifice some of the multirotor's downward thrust to move the craft horizontally. While moving around multirotors tend to lose altitude due to less thrust is directed downward while the multirotor is tilting. Some flight controllers have a feature called "altitude hold" which means the flight controller have its own ability that automatically adjusts the motor speeds in order to make the craft maintain a constant altitude while its moving.

2.3 Different types of multirotor

As multirotor is being designed according to its use. There are different types of multirotors that can be easily differential by its design, shape and configuration

2.3.1 Tri-copters

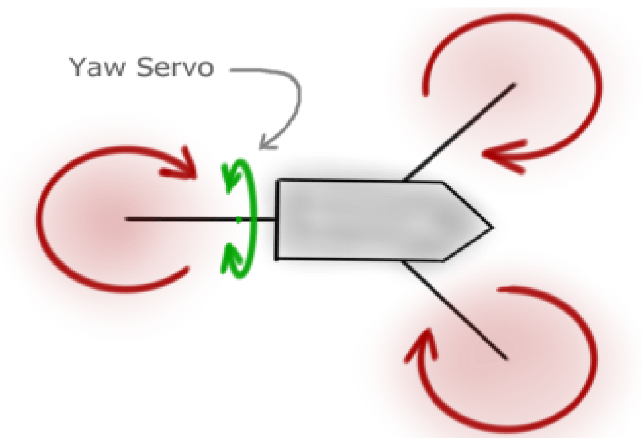


Figure 2.4 Tri-copters with three motors. On the rear motor, there is a servo for yaw control.

Tri-copters have three motors. The shape of the tri-copter can be Y shape or T shape.

Two motors are being mounted in fixed positions. What it makes it unique is the rear motor, by using servo motor it is being tilted. This servo mechanism gives the multirotor yaw control over the craft. As they have few motors the tri-copter is least expensive because servos are generally much less expensive than the brushless motor. Another benefit is that the widest angle 120 deg. between the front two motors. As it has few motors on the craft motors consume much power, making low lifting power. The structure of the tri-copters is not that good, if it crashes the damage can be maximum.

2.3.2 Quadcopter

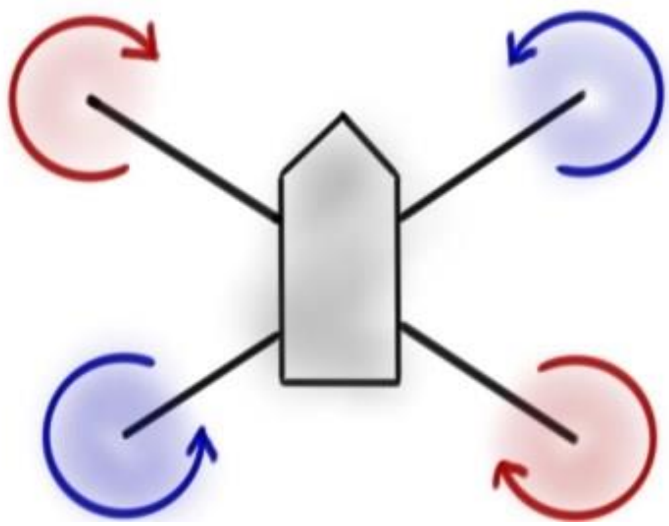


Figure 2.5(a) Quadcopters have four motors. Each motor spins in the direction opposite its neighbors so that the quadcopter does not spin while in flight.

Quadcopter is the most popular multirotor because of its structure, shape, capability, stability and ease of control. Quadcopter have four motors, the shape can be define as X configuration or Y4 configuration. Mechanically is simpler that tri-copter. Due to four motor they can lift higher weight than tri copter. The quadcopter is much more stable able stay airborne for longer period. Less expensive than octa or penta copter. Flight time depends on design according to requirement. Furthermore in term of control it is quite easier.

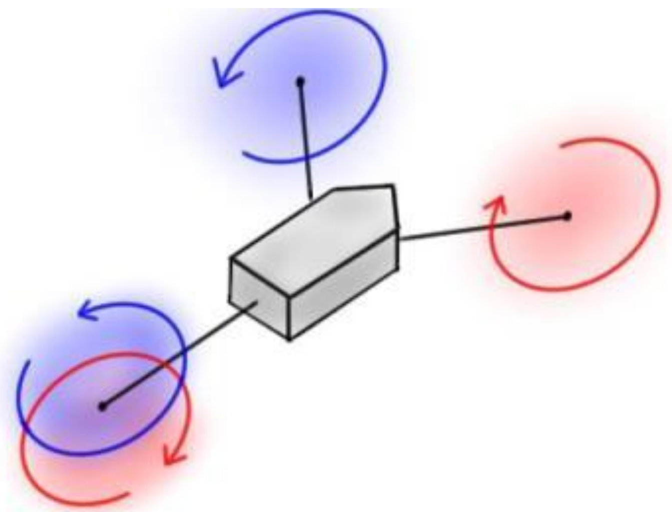


Figure 2.5(b) Y4 quadcopters have four motors but they are arranged more like a tri-copter.

An Y4 quadcopter looks like a tri-copter, but in rear motor a servo motor is being mounted. Underneath the first motor second brushless motor being mounted that help the quadcopter to achieve yaw control. They have more lifting power and more robust due to the lack of servo mechanism.

2.3.3 Hexa-copter

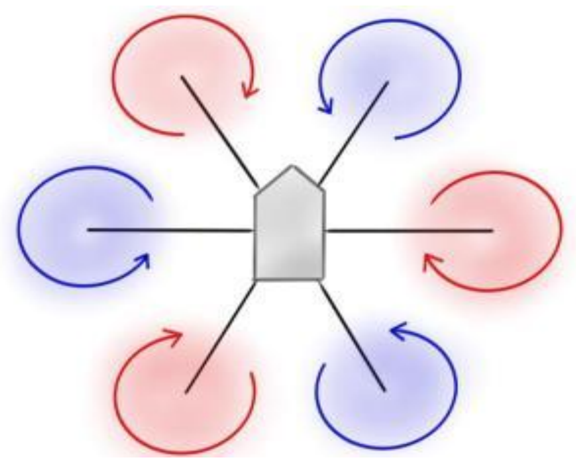


Figure 2.6 Hexa-copters have six motors.

Hexa-copter have six motor, extra two motor makes it more unique and effective. The motors on hexa-copters are arranged in pairs with one turning counterclockwise and one turning clockwise.

In other words, hexa-copter have three motors in clockwise and three motors in anticlockwise spinning rotation. Due to six motor the Hexa-copter is much more stable, if one the motors shuts down somehow, automatically the opposite motor being shut down by the flight controller, So that it works more like a quadcopter, leading it to have less chances of an accidental crash. Though it has much higher capability but the hexa-copter is much more expensive.

2.3.4 Octa-copter

Figure 2.7 Octa-copters have eight motors.

The octa-copter is something that you can fly if you need horsepower, it have eight motors which gives it a deadly look, relatively most expensive multirotor than quad copter or hexa-copter. X8 copter have two motors per arm mounted one on top of the other,

Looks more like a quad copter but with extra power but overall efficiency of the system is less than the efficiency of a quadcopter.

Chapter 3

Design of the total system

3.1 Quad-copter

3.1.1 Overall Connection and Structure

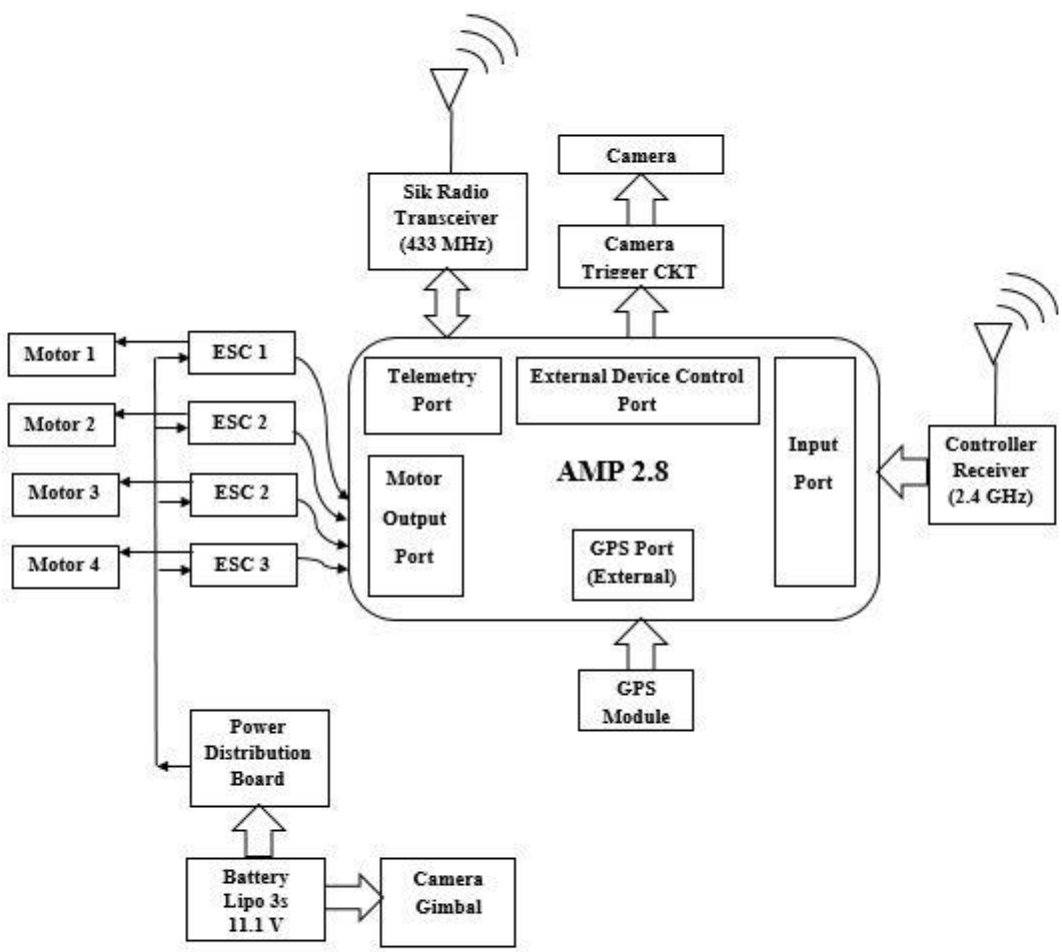


Figure 3.1(a) Overall block diagram of Quad-copter

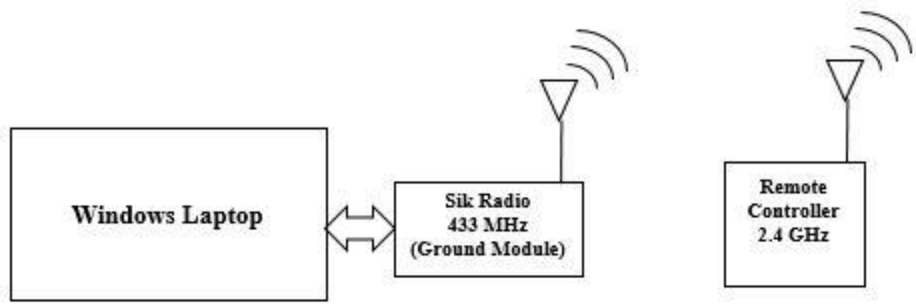


Figure 3.1(b) Overall block diagram of ground station unit.

We made the structure of the whole quad-copter with the locally available parts. The main frame was made with 1/2" “CPvc” pipe which is used usually in plumbing. “CPvc” pipe has less weight and more durable then “UPvc” pipe. The size of the arm is 28 cm each thus the radius of the quad become 30 cm. The main controller is housed inside “RFL Bowl” which have simple yet durable lock system which is easily accessible. Inside the bowl we painted in black to protect the Ardupilot from direct sunlight. As it is air tightened bowl made for house hold work it also protects the flight controller from external air on flight time which make the copter more reliable during the flight. As we are using camera gimbal for image stabilization we have to have ground clearance than the height of the gimbal thus we end up with the 10cm ground clearance from the quad-copter base. Our final weight of the copter is 2200 gram so we decide the motor capable of executing minimum of thrust of 1100 gram as the equation of motor selection is

Motor min thrust = [total weight / 4] * 2

= [2200 / 4]*2

= 1100 gm

This sum up the motor selection. This also helps to select propeller size. We selected propeller size of 11*4.7 which can deliver 1100 gm thrust. Here, 11 = diameter of prop (in inch) And

4.7 = pitch of prop (in inch)

Figure 3.1(c) Structural design and measurement of Quad-copter.

Figure 3.1(d) Our designed Quad-copter.

3.1.2 Hardware

3.1.2.1 Flight Controller

The Brain of any multirotor is the flight controller which does many operation while flying.

We have used the new APM 2.8 flight controller. Onboard sensors are exactly the same as with APM2.6 but this version does not have an onboard.

The APM series is one of the most popular flight controller in market, which is also known as ardupilot. It’s an open source autopilot system having many features. The user can turn any fixed, rotary wing or multirotor into full autonomous vehicle. It has the capability to perform mission using GPS with waypoints. Since it has no internal compass, we can use an external compass which can be mounted wish APM 2.8. To avoid magnetic interface the compass need to be far away from the power and motor source.

Figure 3.2(a) AMP 2.8 flight controller

While hovering the multirotor create vibration which can alter the sensors values. To avoid any vibration while flying we have used a shock absorber which is being mounted underneath the flight controller board.

Figure 3.2(b) AMP 2.8 flight controller with shock absorber

Features:

- Arduino Compatible
- Includes 3-axis gyro, accelerometer and magnetometer, along with a high-performance barometer
- Onboard 4 Megabyte Data flash chip for automatic data logging
- Optional off-board GPS, uBlox LEA-6H module with Compass.

- One of the first open source autopilot systems to use Invensense's 6 DoF Accelerometer/Gyro MPU-6000.
- Barometric pressure sensor upgraded to MS5611-01BA03, from Measurement Specialties.
- Atmel's ATMEGA2560 and ATMEGA32U-2 chips for processing and USB functions respectively.

Data Sheet:

- 3-Axis Gyro
- 3-Axis Accelerometer
- High Resolution Altimeter
- 5Hz GPS Module
- Dimension: Approx. 70.5x45x13.5mm
- Weight: 31g
- Weight: 43g (With Vibration Damping Plate)

3.1.2.2 Motor:

Selecting motor is one the most difficult task while building a copter, there are lots of math and aerodynamics are involved in designing a copter. To choose a motor we first need to calculate the total weight, and number of motor we are using. A rule of thumb is **Required Thrust per motor = (Weight x 2) / 4** from this equation we will find the thrust per motor, too much thrust can make the copter hard to control. According to our calculation the required thrust per motor is 1kg, so we have selected "**SUNNYSKY V2216-10 KV900 Out runner Brushless Motor"** due to its excellent performance and features. The prop adaptor of this series is mounted to the motor can with 3 screws, it gives better centralization and balance. The Features are given below

Figure 3.3 SUNNYSKY V2216-10 KV900 Out runner Brushless Motor

Features:

- Long-life Japanese NMB ball bearings.
- Efficient Japanese Kawasaki stator steel
- Rare earth magnets stable up to 180℃
- Oxygen free pure copper wires
- CNC machined aluminum case
- Silicone wire leads
- Patented balance techniques
- Unique wiring method

Specifications:

Model: V2216-10 900KV

Stator diameter: 22mm

Stator length: 16mm

Shaft diameter: 3mm (no exposing part)

Motor size: Φ27.8×34mm (diameter x length)

Weight: 75g

Idle current @ 10V: 0.4A

Cell number: 2-4S

Max current: 20A

Max power: 210W

Max efficiency current: 5-17A, >80%

Internal resistance: 135mΩ

Prop adaptor shaft diameter: 5mm

Prop	Volts (V)	Amps (A)	Watts (W)	Thrust (g)	Thrust (oz)	Efficiency (g/W)	Efficiency (oz/W)
1047	7.4	7.3	54.02	590	20.81	10.92	0.39
	10	11.4	114	920	32.45	8.07	0.28
	11.1	12.7	140.97	1050	37.04	7.45	0.26
11X7	7.4	8.6	63.64	680	23.99	10.69	0.38
	10	12.7	127	1020	35.98	8.03	0.28
	11.1	14.5	160.95	1120	39.51	6.96	0.25

Figure 3.4 SUNNYSKY V2216-10 KV900 Out runner Brushless Motor Datasheet

3.1.2.3 ESC:

- **ESC** stands for **Electronic Speed Controller**. It converts the PWM signal from the flight controller or radio receiver, and drives the brushless motor by providing the appropriate level of electrical power. In terms of ESC suggestions having 20% extra Amps is a good rule of thumb to ensure the ESC do not burn out, but while in conservative flights the copter will hardly fly at max throttle, and most ESC have a burst Amp rating that they can sustain for 10-30sec. But if you are undecided about two ESC ratings, it is always better to go to the higher value, this is again a good idea, but if we are using a larger ESC can also use more battery, so it's something to think about. We have selected 60 A which supports 3s and 4s battery using CMOS technology.

Figure 3.5 60A Electronic Speed Controller

3.1.2.4 Gimbal

Gimbal is a very important hardware for aerial photography. It balances the camera horizontally throughout the flight time so that the camera remain stable. The top part of the gimbal contain a shock absorber it reduces the vibration while flight time. Two BLDC motor is connected with the built in circuit. Viewing angle of the camera can be set manually where the camera remain fixed on a certain position. Main advantage of gimbal is the position of the camera doesn't demands on the orientation or movement of the quad copter. If the quad copter vibration is high while in flight time it won't have any effect on the camera.

Figure 3.6 two axis gimbal

Features:

•Simple structure and light weight, CNC aluminum alloy structure

•Brushless motor direct drive

•With anti-vibration rubber balls, easy to adjust

•with 2pcs 2208 motors and gimbal controller, sensor

•with motor protector which can help heat dissipation

•Weight is about 212G, total weight with GOPRO3 is about 285G.

3.1.3: TIGGER CIRCUIT

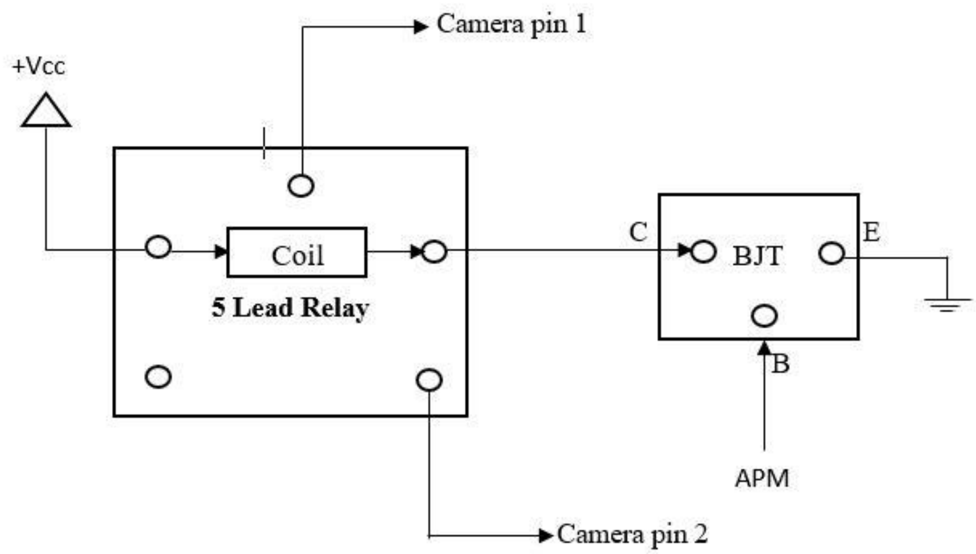


Figure 3.7(a) Block diagram of Camera trigger circuit

In APM there were no external pin or communication device such as Wi-Fi or Bluetooth to make communication between the sensors (Camera) in order to take image. To trigger the camera pin we have designed a trigger circuit with BJT and 5 lead relay. 5V biasing voltage was being supply to the relay, two output pin was connected with the camera trigger pin. We have used npn BJT, the base terminal input signal is connected with the APM. APM send the command for camera to trigger, while in mission plan it can take continuous image automatically.

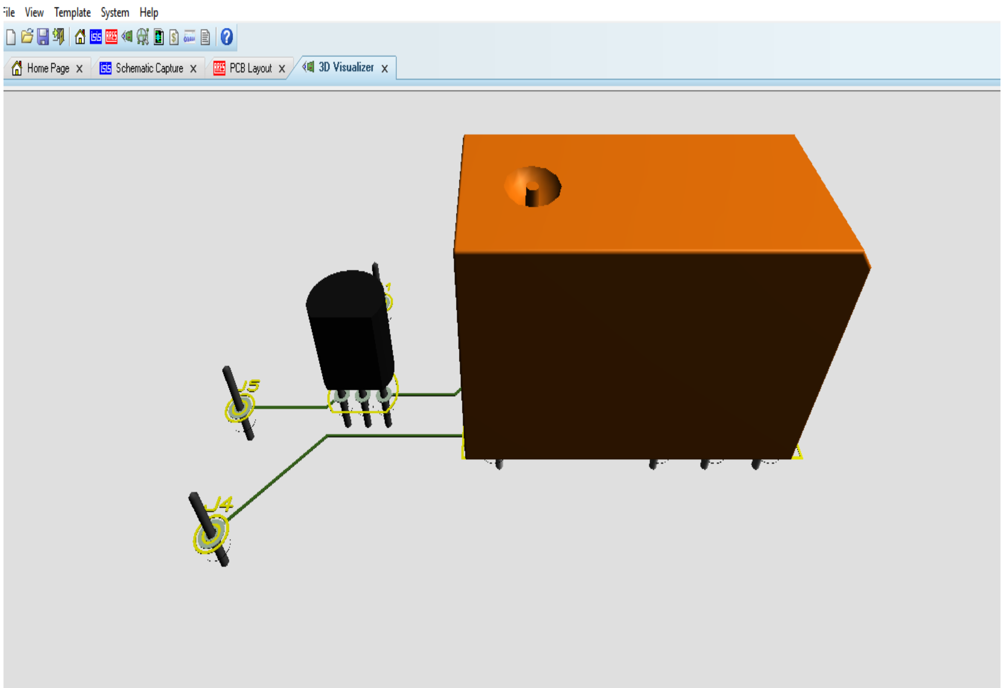


Figure 3.7(b) 3D diagram of Camera trigger circuit

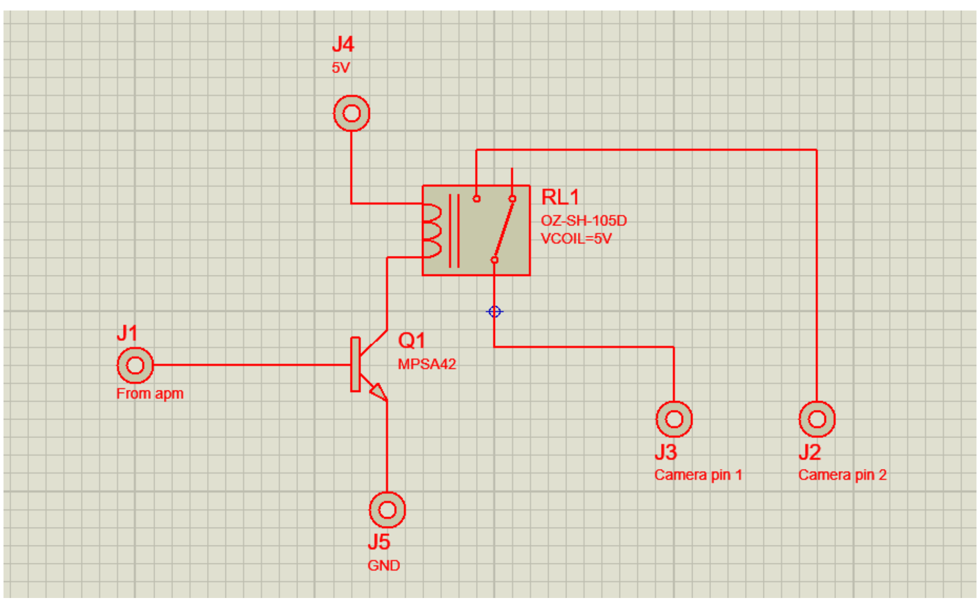


Figure 3.8(c) Circuit diagram of Camera trigger circuit

3.1.4: COMMUNICATION

3.1.4.1 Telemetry Radio:

To fly any multirotor or to pass or receive information from the flight controller we need a channel or a source. Telemetry Radio's basic principle is transmitting information from a distant using radio waves.

We have selected a 433 MHz Sik telemetry Radio which is small, light and open source radio platform having a range of 300m. An open source firmware has been specifically designed to work MAVLink and to be integrated with the Mission Planner, Copter, Rover and Plane.

Figure 3.9 Telemetry Radio (quad-copter communication unit)

Features

The main features of the Sik Radio are listed below:

- Very small size
- Light weight (under 4 grams without antenna)
- Available in 900MHz or 433MHz (v2 only) variants
- Receiver sensitivity to -121 dBm
- Transmit power up to 20dBm (100mW)
- Transparent serial link
- Air data rates up to 250kbps
- MAVLink protocol framing and status reporting
- Frequency hopping spread spectrum (FHSS)
- Adaptive time division multiplexing (TDM)
- Support for LBT and AFA
- Configurable duty cycle
- Built-in error correcting code (can correct up to 25% data bit errors)
- Demonstrated range of several kilometres with a small omni antenna
- Can be used with a bi-directional amplifier for even more range
- Open source firmware
- AT commands for radio configuration
- RT commands for remote radio configuration
- Adaptive flow control when used with APM
- Based on HM-TRP radio modules, with Si1000 8051 micro-controller and Si4432 radio module

Status LEDs

The radios have 2 status LEDs, one red and one green. The meaning of the different LED states is:

- Green LED blinking - searching for another radio

- Green LED solid - link is established with another radio
- Red LED flashing - transmitting data
- Red LED solid - in firmware update mode

3.1.5: POWER Source

Every device needs a power source that will make it run or useable, so for quad copter there is specific requirement in selection of power source. We have selected “Turnigy nano-tech 6000mah 3S 25~50C Lipo Pack”. This Nano tech lipoly batteries were designed to have greater performance, it allows electrons to pass more freely from anode to cathode with less internal impedance. In short, having less voltage sag and a higher discharge rates than similar lithium polymer batteries. Due to higher voltage under load, straighter discharge curves and excellent performance giving the pilot stronger throttle punches.

Figure 3.10 Turnigy 3s 11.1V battery

Specification:

Capacity: **6000mAh**

Voltage: **3S1P / 3 Cell / 11.1V**

Discharge: **25C Constant / 50C Burst**

Weight: **468g (including wire & plug)**

Dimensions: **153x48x30mm**

Balance Plug: **JST-XH**

Discharge Plug: **4mm bullet-connector**

3.2: GROUND STATION UNIT

3.2.1 HARDWARE

3.2.1.1 RC Controller:

To control any multirotor we need a controller which send and receive commands through transmitter.

We have selected RadioLink AT9 due to its quality built design, features and price. It has 9 channels on the R9D receiver, compatible with S.Bus, Telemetry module, the menu of the controller is more straight forward and easy to access. The AT9 have lot of switches and knobs on the top, they can be setup according to use. There are three three-way switch and five two-way switch and also multirotor mode.

Figure 3.11 RC Controller RadioLink AT9

FULL TYPES AND FUNCTIONS

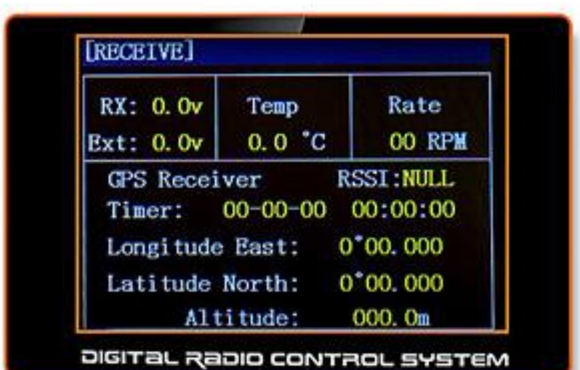
Suit for all airplanes including helicopter
8 swash plate models,
fixed wing 2 airfoils 3 rears,
gliders 4 airfoils 2 rears and aircraft.

FAST RESPONSE

It takes 3ms only for 9 channels to response parallel,
which is less than the average time 20ms.

LONG DISTANCE STABLE OPERATING

DSSS spread spectrum mode supplies
better performance in anti-interference
QPSK modulation mode
Actual measurement: 900 meters
ground and 1.5kms air



DATA TELEMETRY

Adopt two-transmission technology of
Radiolink AT10 10CH radio control,
support signal strength, receiver voltage monitored,
and extending battery voltage,
temperature, motor RPM, GPS etc.

VIBRATION ALARM

PRECISION 4096

4096 section precision,
0.25us per section,
Servo anti-shake rudder.

MINI RECEIVER

Size: 41*23*14mm.
The smaller size the receiver is, the more convenient to fix.
R9D is even smaller than a normal 9channel receiver.

USB UPDATING

Updated by a USB cable on the company website, which keeps all time the most advanced system and program.

HUMANIZED SWITCH POSITIONING

Two knob switches,two slicer swith,
three three-way switches,
four two-way switches, a reset trainer switch.
Support multiple aerial control mode and PTZ control.

RadioLink AT9 Transmitter Spec and Features:

- Dimension : 183mm x 193mm x 100mm
- Weight : 880g
- Frequency : 2.4Ghz ISM (2400mhz ~ 2485mhz)
- Modulation mode : QPSK
- Channel bandwidth : 5.0mhz
- Spread Spectrum : DSSS
- Adjacent channel rejection : >38dbm
- Transmitter power : <100mW (PCB testing), < 20dbm (3 meter air testing)
- Operating current : <105mA
- Operating voltage : 7.4V ~ 15V
- Control range : 0.9km on Land, 1.5km on Air
- Channels: 9-Ch / 5-9 Ch is customizable
- Simulator mode : under simulator mode, the RC output is switched off
- Screen : 2.8 inches 16 color screen, 240 x 320px
- Switches : 3 x 3-way switch, 5 x 2 way switch (1 is the reset switch)
- Compatible mode : All 120 and 90 degrees swashplate helicopter / All Fixed-wing and Glider / Five Flying Model / Multi-Rotors

3.2.1.2 Telemetry Radio:

To fly any multirotor or to pass or receive information from the flight controller we need a channel or a source. Telemetry Radio's basic principle is transmitting information from a distant using radio waves.

We have selected a 433 Mhz SiK telemetry Radio which is small, light and open source radio platform having a range of 300m. An open source firmware has been specifically designed to work MAVLink and to be integrated with the Mission Planner, Copter, Rover and Plane.

Figure 3.12 Telemetry Radio (Ground Station unit)

Features

The main features of the Sik Radio are listed below:

- Very small size
- Light weight (under 4 grams without antenna)
- Available in 900MHz or 433MHz (v2 only) variants
- Receiver sensitivity to -121 dBm
- Transmit power up to 20dBm (100mW)
- Transparent serial link
- Air data rates up to 250kbps
- MAVLink protocol framing and status reporting
- Frequency hopping spread spectrum (FHSS)
- Adaptive time division multiplexing (TDM)
- Support for LBT and AFA
- Configurable duty cycle
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- Based on HM-TRP radio modules, with Si1000 8051 micro-controller and Si4432 radio module

Status LEDs

The radios have 2 status LEDs, one red and one green. The meaning of the different LED states is:

- Green LED blinking - searching for another radio
- Green LED solid - link is established with another radio
- Red LED flashing - transmitting data
- Red LED solid - in firmware update mode

3.2.2: SOFTWARE

3.2.2.1 Mission planner

Mission planner is an open source software used for conducting an aerial survey mission by integrating with the flight controller board. This software is a part of the ground station of the UAV which runs on Windows based computers.

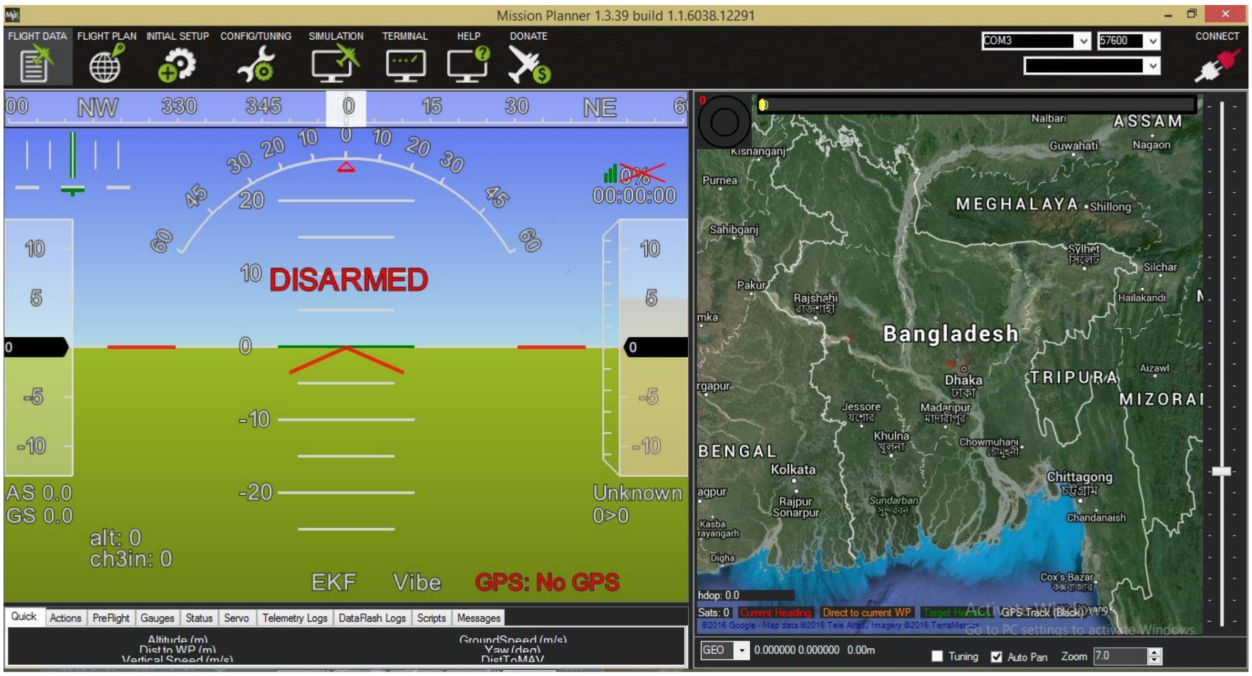

Figure 3.13: Interface of Mission Planner

3.2.2.2 ERDAS Imagine

ERDAS Imagine is a professional software used to visualize, classify, modelling, analyzing and interpret images for geometric correction, GIS Integration, image Orthorectification, Multispectral Classification, Image Analysis, Image Mosaicking , Digital Terrain Modelling and Map Production. This software is used by archeologists, biologists, engineers, geologists, hydrologists, soil scientists and so on.

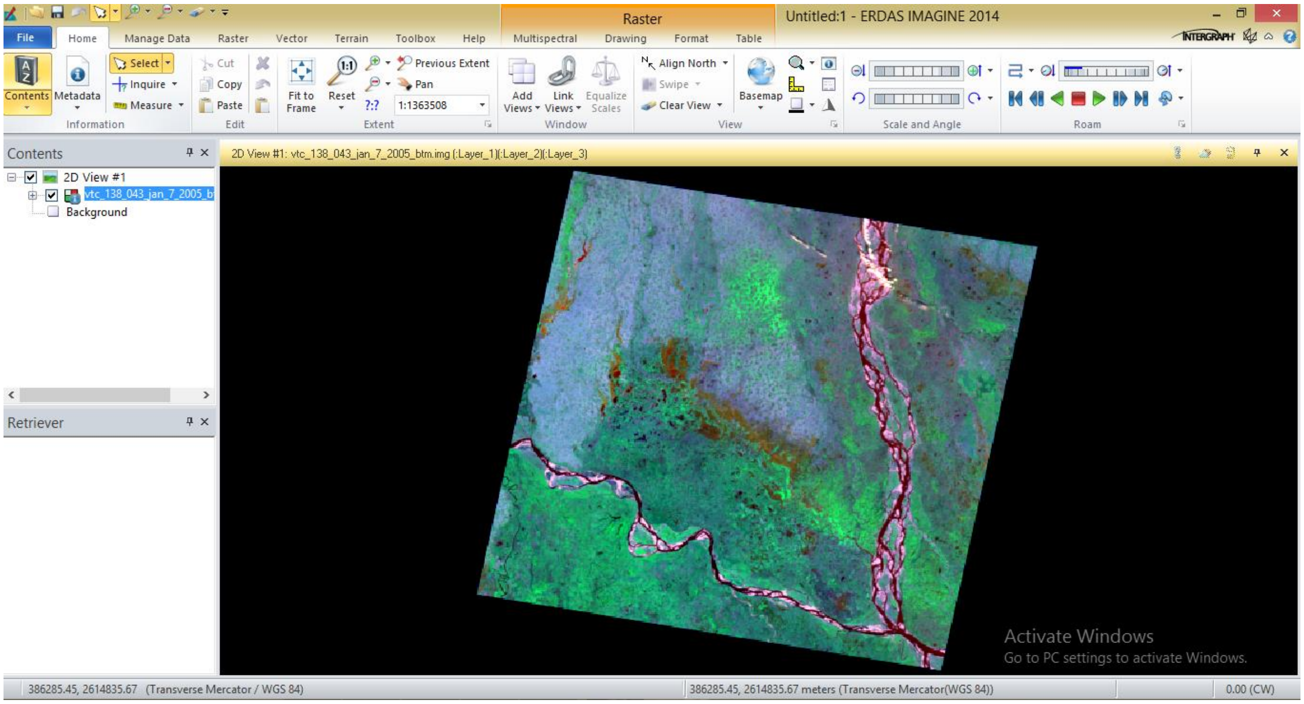

Figure 3.14: Interface of Erdas Imagine

3.2.2.3 AgiSoft

Agisoft is an automatic mosaic software which combine multiple aerial images into one image by placing images side by side or over and under. The converted mosaic image can be used on land mapping and land observation in term of crop monitoring. It can create ortho-rectified 2D photo mosaic, which fulfills our demand. The methodology of Agisoft image processing is not like placing images in numerical order, rather it takes the image pixel value and matches with other images. While processing of the image it doesn’t loss any kind of data or it doesn’t duplicate any data to mosaic the image just to complete its task, so it is very important for remote sensing.

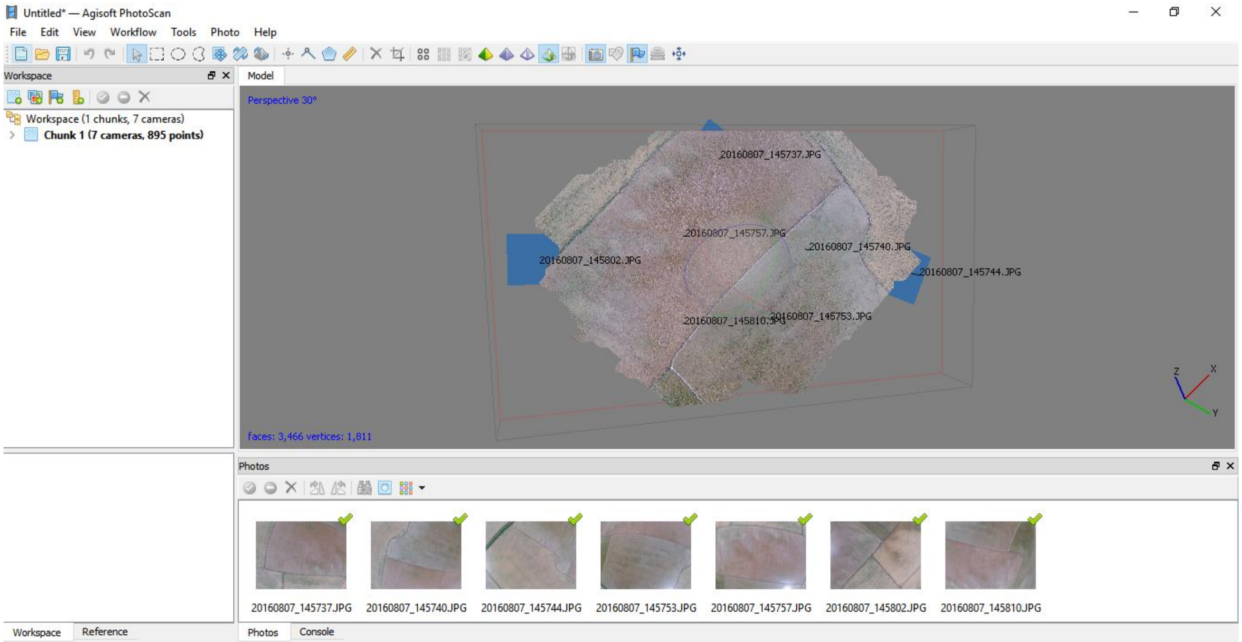

Figure 3.15 Interface of AgiSoft

Chapter 4
Sensor and Its Characteristic

4.1 Ardupilot:

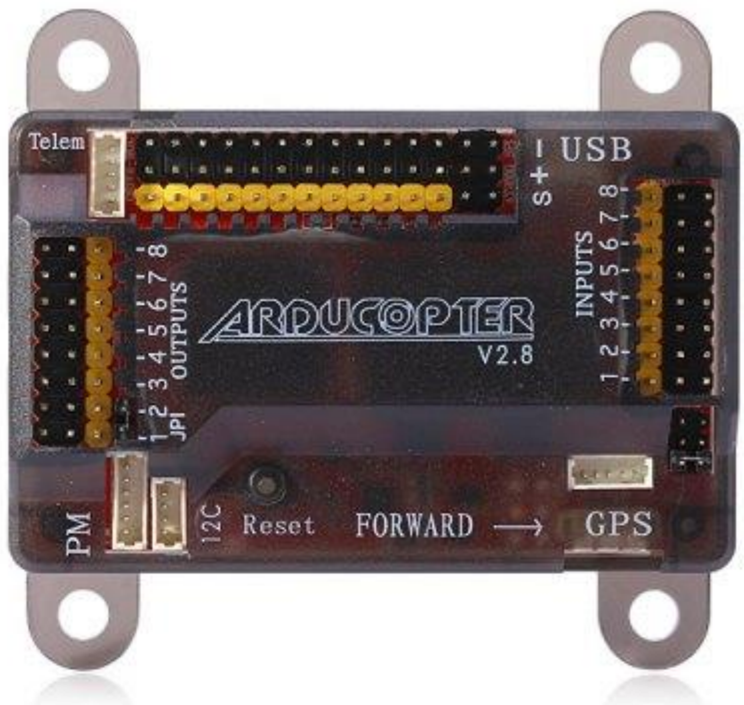

Figure 4.1 Ardupilot

Ardupilot which is also known as ardupilot Mega-APM is an open source unmanned aerial vehicle (UAV) platform. It is able to control autonomous multicopters, fixed-wing aircraft and ground rovers. It is based on the Arduino open source electronics prototyping platform. It has features like programmable 3D way points, fully programmable actions at waypoints, flight simulations,inflight reset, Optimization of 3 or 4 channels airplanes etc. The adaptability of ardupilot makes it exceptionally prominent in the DIY field. This takes into account a huge number of uses, for example multicopters and fixed plane drones. The adaptability and simplicity of establishment has permitted the Arduoilot platform to be incorporated foe an assortment of missions. The mission planner has permitted the ardupilot board to be utilized for mapping missions, search and rescue, and surveying areas. There are various flight controller boards like CC3D, NAZE32, KK2, 3DR, Pixhawk etc. We have used APM 2.8 because its feature that goes very well with our project. It has features like Arduino compatible ,Onboard 4 Mega Byte Data flash chip for automatic data logging, Optional off-board GPS, uBlox LEA-6H module with Compass, uses intenseness's 6 DoF Accelerometer/Gyro MPU-600& auto level firmware. It is an open source and has auto pilot mode along with high performance barometer.

4.2 Barometer:

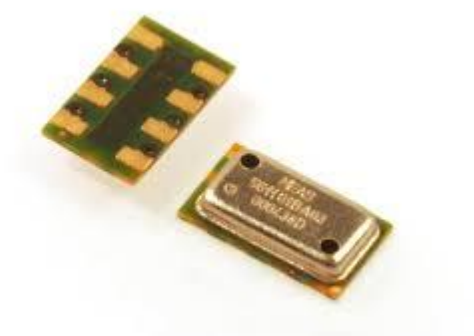

Figure 4.2 Barometer

APM 2.8 has a highly effected barometer. The barometer APM2.8 has updated to MS5611-01BA03 which is from measurement specialties. In our project we have kept up the height of quad 2m-50m.APM2.8 has a barometer high resolution module of 10cm which implies the height that this barometer can vary from +-0.1m which is more precise. It is likewise viable as our one of the principle assignment is mission planning. In mission planning we set GPS co-ordinate information in quad copter, in where the quad go and take photograph. Entire this project happens in autopilot mode .There will be no control from ground station. So, in this situation keeping up the height is most vital which this barometer can accomplish all the more decisively.

4.3 3axis gyro:

Figure 4.3 3axis gyro

Gyro is another imperative thing to keep up the balance of quad copter. It senses the angular velocity which is known as the motion. After detecting the angular velocity I offers yield to the ardupilot.APM2.8 has utilized the MPU-6000 gyro.

4.4 Camera:

Figure 4.4 HD dv Sports

We have used full HD dv sports 1080p camera in our project. The purpose for choosing is it has sensible prize furthermore meet our every demands. We could have used go pro camera as a part of our venture but it has cut thrice much prize then our camera. One of the primary center of our undertaking is to fabricate a minimal cost quad copter and along these lines we needed to run with this camera. The sensor that has been utilized as a part of this camera is 1/3inch CMOS digital image sensor. This sensor has some astounding components. It gives fantastic execution in near infrared (IR).As we are catching the picture 20 m above starting from the earliest stage. So another thing we need to consider is the resolution of the image which is 12 MP. It is additionally small in size since quad copter cannot carry bigger weight. Its weight is 58 grams with battery. Another magnificent component of this camera is the charging capacity. It can continue recording for roughly 70 minutes in 1080p without giving the external power supply. It has 900mah Removable battery. Another critical component is that it is waterproof, dustproof and shockproof. We can easily mount this in the bottom of the quad copter. So, the camera we used is completely suitable for our quad.

Chapter 5
Mission Planning and Implementation

5.1 Basic Instruction of Mission Planning

The ground control station of the UAV is done using a software named Mission Planner. The software is integrated with the flight controller board through wireless communication system. In this project, the Sik Radio v2 is used for wireless telecommunication. During flight operation, the performance of the UAV can be monitored from the Mission Planner as it shows real-time data and position of the UAV. Moreover, the software is also used for uploading mission commands and setting of the parameters of the mission plan. The UAV based mission plan can be categorized into three types, surveillance, transportation and mapping. The mission can be automatic and manual depending on the types of mission. It is advised not to perform manual mission plan for the amateur UAV pilot. For surveillance and transportation, stability of the UAV plays a vital role for a successful mission. In automatic mission commands, the UAV will automatically fly from the home point towards the destination, finish its task by moving through the given way points and finally return to home location. The automatic mission planning undergoes less vibration and shaking, higher precise path completion and is safe for amateur UAV pilot as chances of damage is less compared to manual mission plan. The time of flight for completing the mission, number of way points and number of photos depends on the type of camera and the altitude value [4]

5.2 Operation and Execution of Mission Planning

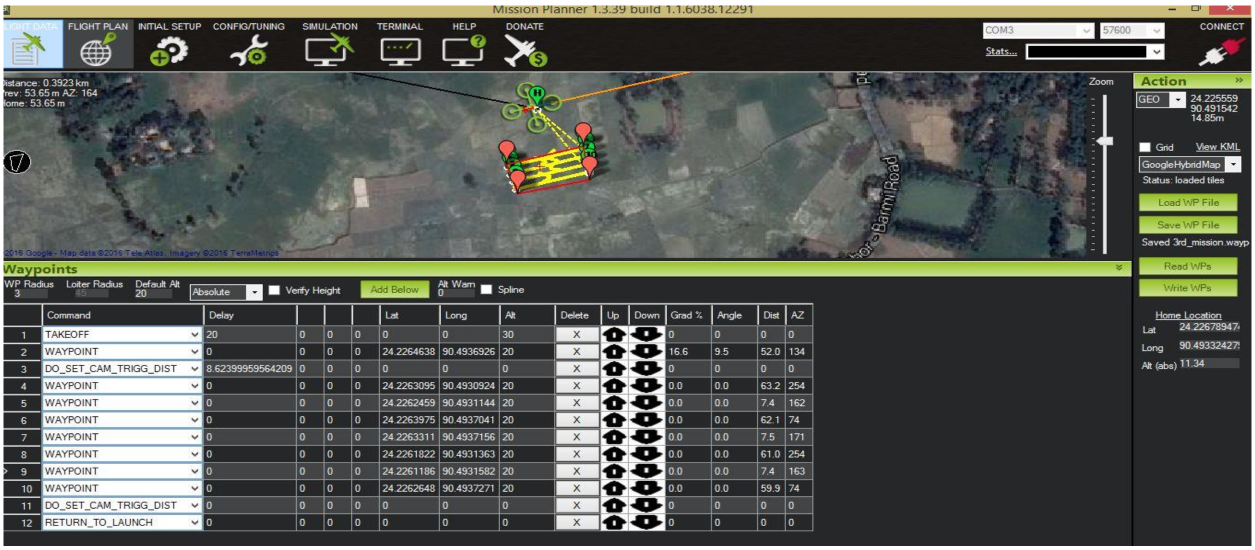

Figure 5.1(a): Mission planner software interface showing the mission way points

The purpose of the mission for this paper is to monitor a certain area to retrieve the geo-information by observing vegetation, soil and water condition of that area. The mission is done by taking multiple aerial photos from the camera that is mounted on the UAV, then the photos are organized in mosaic format to get the whole picture of the area. The mission is done in the automatic mode to avoid shaking and due to lack of takeoff and landing space availability. The shaking will cause unfocused and blurred image quality which will make it difficult to process the images for extracting data and will maximize the errors and wrong values. On the other hand, automatic mission plan will not only enable greater stability of the UAV during time of flight but also capture greater quality pictures.

Mission planner is a very sophisticated while at the same time user friendly software and can be used by both researchers and novices. It allows the user to have a wide set of data of the mission which helps the researcher to analyze the mistakes and develop and modify the mission for a better result. Before planning the mission, we should always concentrate about the objective of the mission. For example, remote sensing based missions require high quality images so that retrieval of data through image processing will be easy and accurate. In this thesis, we should take some necessary steps for capturing better quality images. Rice fields are generally situated in plain surface where large trees are not very abundant. In this sort of situation, we had performed the mission in a lower altitude level. There is lower chance of collision between the UAV and the larger objects and most importantly, lower altitude means the area per pixel becomes smaller, producing better quality of image. In this thesis, the altitude was set to 20m for better resolution of the image. The barometer located in the flight controller board shows altitude level during the time of flight. Simultaneously, the GPS mounted on the UAV can also determine the altitude level by calculating its relative distance with the orbiting satellites. In this mission the barometer altitude level is almost equal to the GPS altitude level, which signifies that the altitude level with respect to home location is accurate. The images below shows the graph of altitude levels of both the barometer, GPS and the overlapping of the two respective graphs.

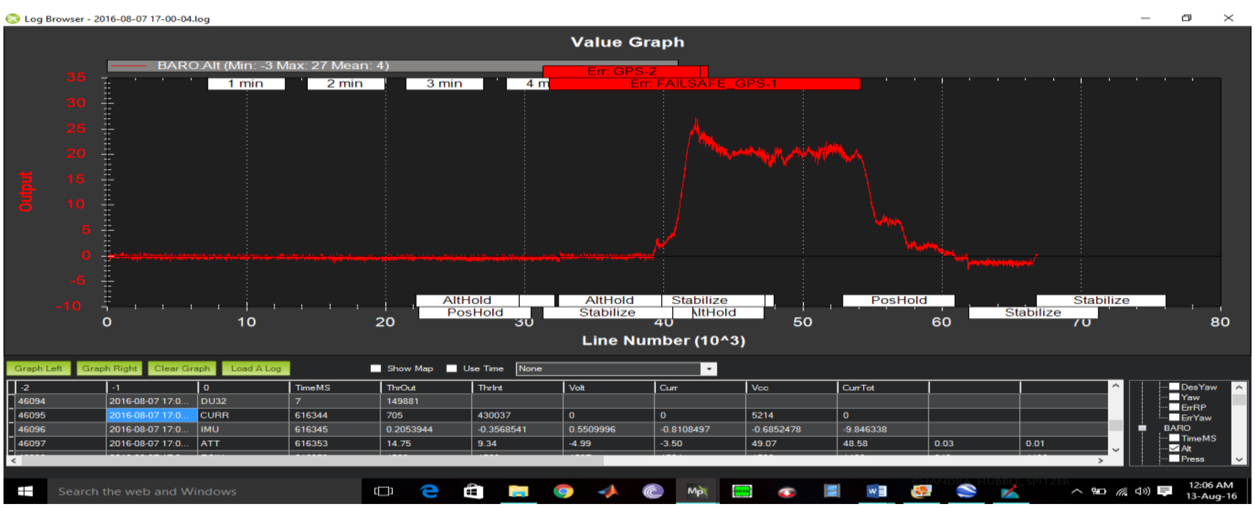

Figure 5.1(b): Output altitude values from the barometer during the time of flight

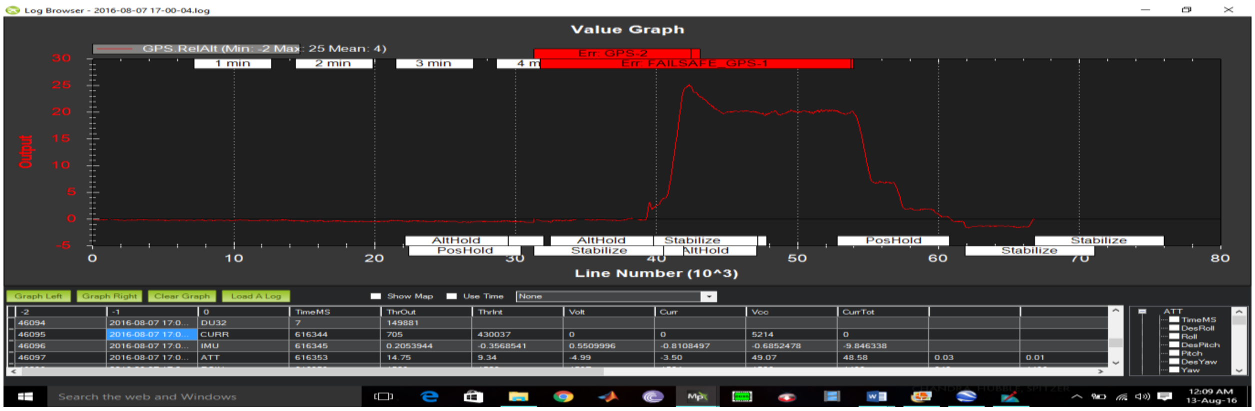

Figure 5.1(c): Output altitude values from the GPS during the time of flight

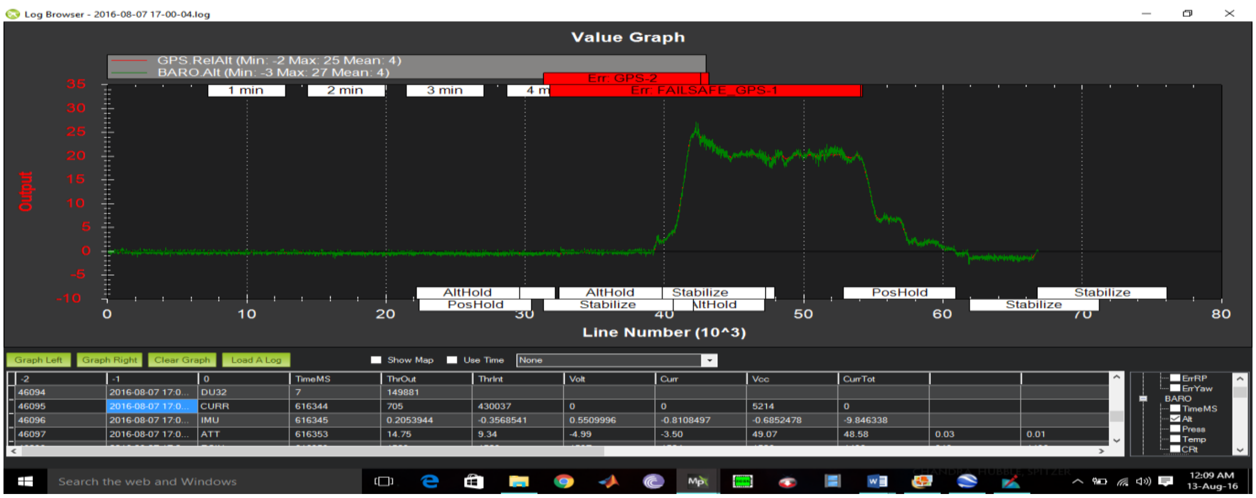

Figure 5.1(d): Overlapping of altitude values of barometer and GPS during the time of flight

On the contrary, in terrain and hilly lands, or in forests, the altitude should be high enough to avoid any sort of collision, but as a result the area per pixel increases which will degrade the quality of image. The battery power is a crucial factor in any type of UAV. If the altitude is set to be very high then it will consume more power from the battery and can perform less time of flight. The mission which is performed in this project was done in an open field plain surface used for paddy cultivation. The altitude was set to 20m for better quality images but in hilly area the altitude should be set to more than 100m for performing the mission safely. From the mission planner software, the particular camera used in the mission can be selected. Using the specification of the camera, the focal length and resolution is automatically calculated by the software. The focal length values and resolution was used to calculate the total area and distance covered on the mission, total number of pictures, total distance between the images. All these information and output data are shown in the mission planner.

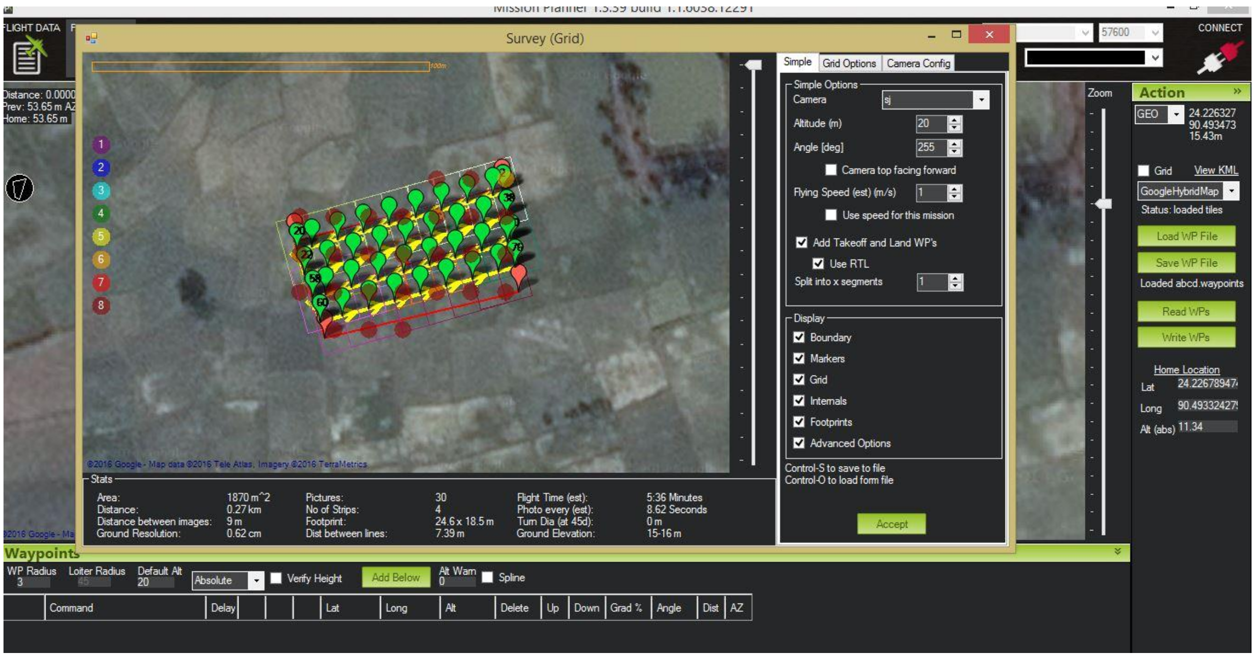

Figure 5.1(e): The figure showing the output values of the mission.

In the above figure

The area of the mission path	1870 m^2
Distance	0.27 km
Distance between images	9 m
Ground Resolution	0.62 km
Pictures	30
Number of strips	4
Footprint	24.6 x 18.5 m
Distance between lines	7.39 m
Flight time	5.39m Minutes

Figure 5.1(f): Google earth 3D image of mission path

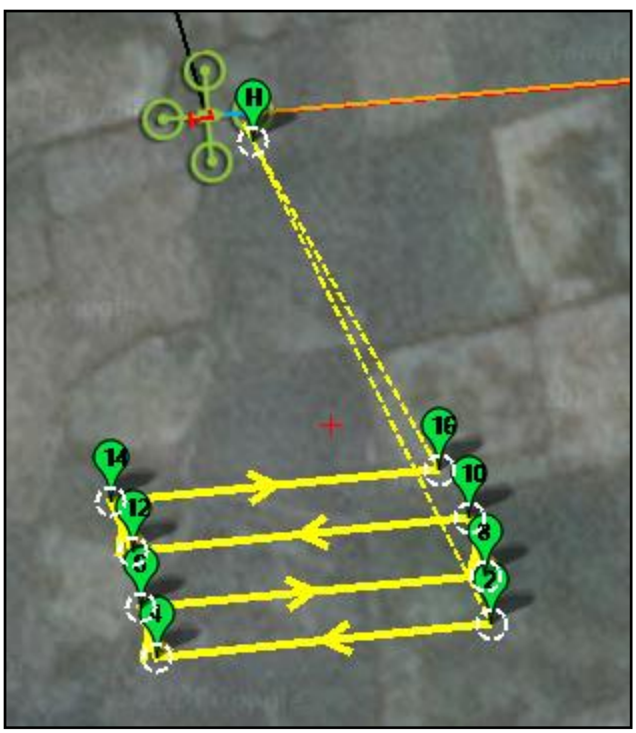

Figure 5.2: Way points showing in Google Earth image

During the setup of the mission plan, we had to give input of the location from the Google map. We can see from the above image that the way points were automatically set up by the mission planner software in sequential order. The mission planning operation was done in such a way that the UAV fly from the home location (H) to its way point (2). Between these time periods the camera was not triggered and so no photos were taken. The camera was first triggered when the UAV first reached the way point 2.

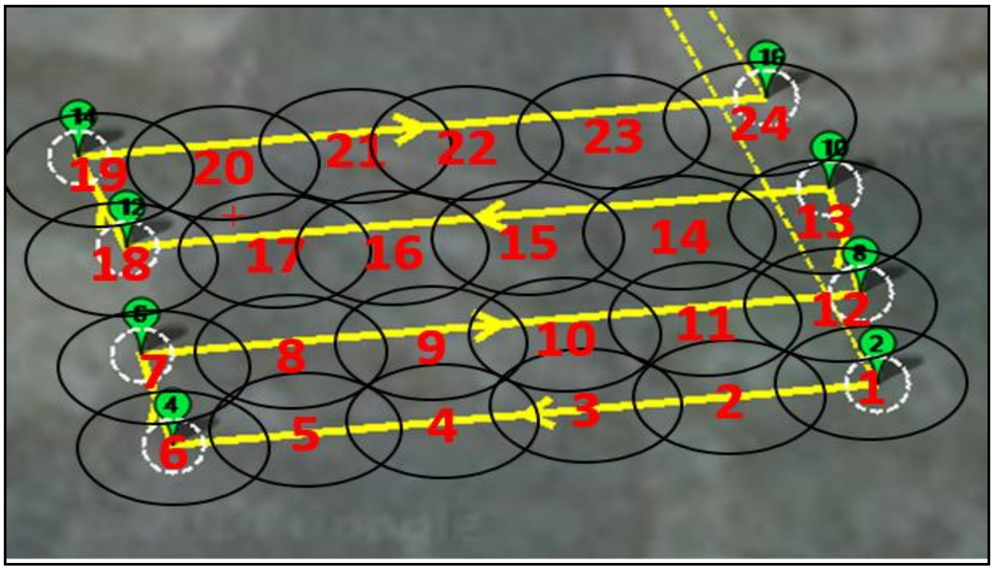

Figure 5.3 Sequence of overlapping of images

When the UAV reached the way point 2, the first image was taken and it continues in sequential order till it reached the way point 16. When the UAV move from way point 2 to 4, it captured 6 images named 1-6 (red colored), after that the UAV move from way point 4 to 6, 8-10, 10-12, 12-14 and finally 14-16. At way point 16, it captured its last image and returned to home location.

All the sequential numbered images were then further mosaicked to get the overall picture of the area. The mosaicked was done by overlapping the image with one another and the software overlaps in such a manner that the one picture will overlapped with its nearby images. For example, the first figure 5.2 captured at way point number 2 was overlapped with image number 2, 11 and 12. Similarly, the Figure 5.3 was overlapped with 1,3,10 11, 12. Throughout the process the mosaicked operation was constructed by pixel by pixel overlapping.

Chapter 6

Georeferencing and Digital Mosaicking Operation

Georeferencing is the process of assigning real-world coordinates to each pixel of the raster. This enables overlay of different images and geospatial data by assigning fixed geographical coordinates such as latitude and longitude information in an appropriate projection system. These coordinates are obtained by doing field surveys - collecting coordinates with a GPS device for few easily identifiable features in the image or map. Using these sample coordinates or GCPs (Ground Control Points), the image is warped and made to fit within the chosen coordinate system.

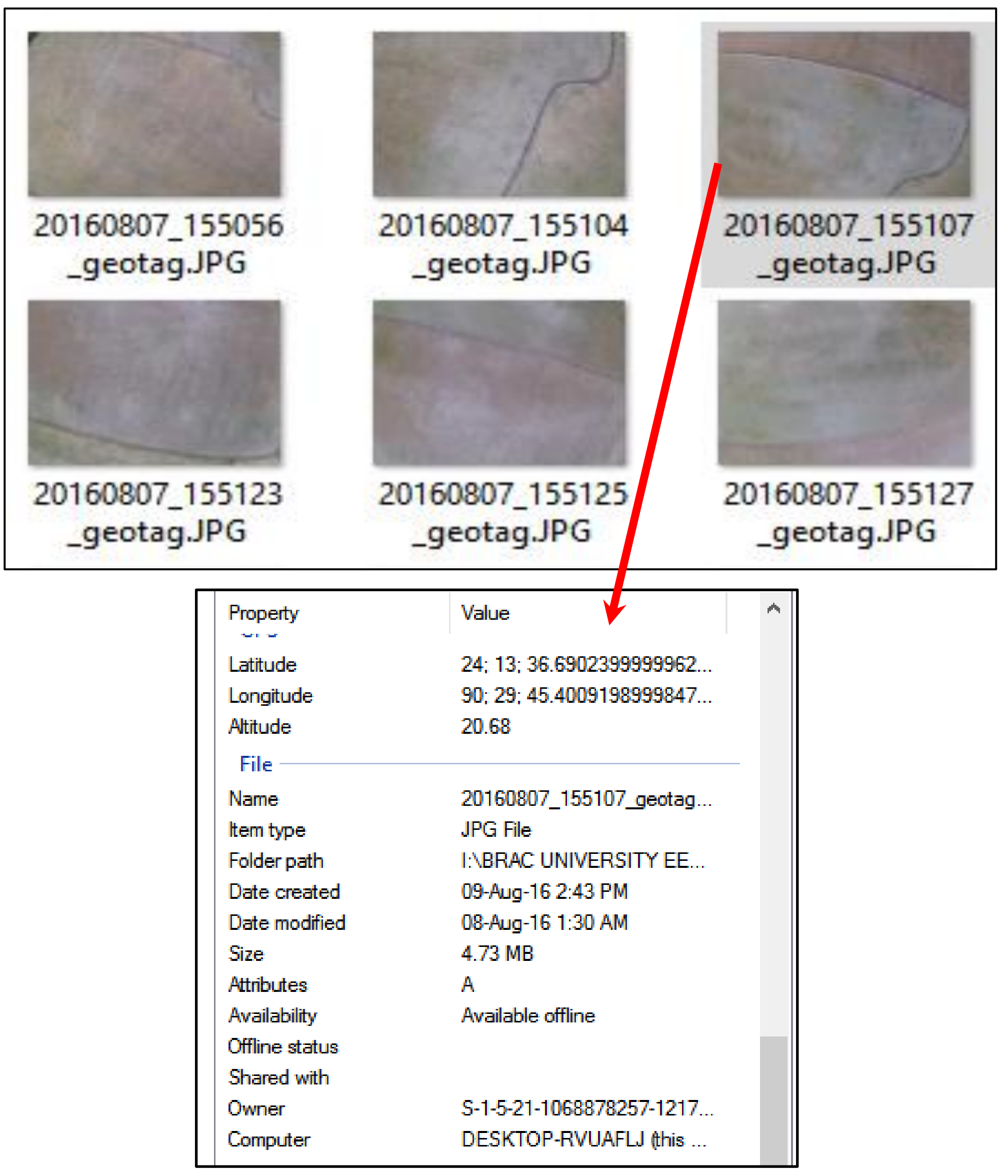

Figure 6.1: Image information dialogue box containing information on the image acquisition along with the GPS-record of the location of the image acquisition under a given mission plan

In the present work, the image acquisition system (in the present work, it is multispectral optical remote sensing device) is equipped with Global Position System (GPS) on board the moving carrier (drone) that moves over the study area under observation maintaining a specific height for each of the imaging sequence as programmed in the mission plan. Such an arrangement largely facilitates the image acquisition operation ensuring better positional accuracy of the surface features in the digital image.

Figure 6.2: Digital mosaic of two consecutive image frames after necessary correction and geo-referencing operation. The relatively rough water surface with certain textural pattern is readily visible in the image areas corresponding to water area.

GPS based positioning is an important part of geo-observation and information retrieval process. The mechanism to have geo-referencing point in each image acquisition is very much essential for positional accuracy of the surface features in GIS platform. While taking the image the position is also recorded with high precision in positioning.

Figure 1.3: Individual image frames of a total of about 26 images acquired by the optical sensor on board the drone during over pass over the area under the present study.

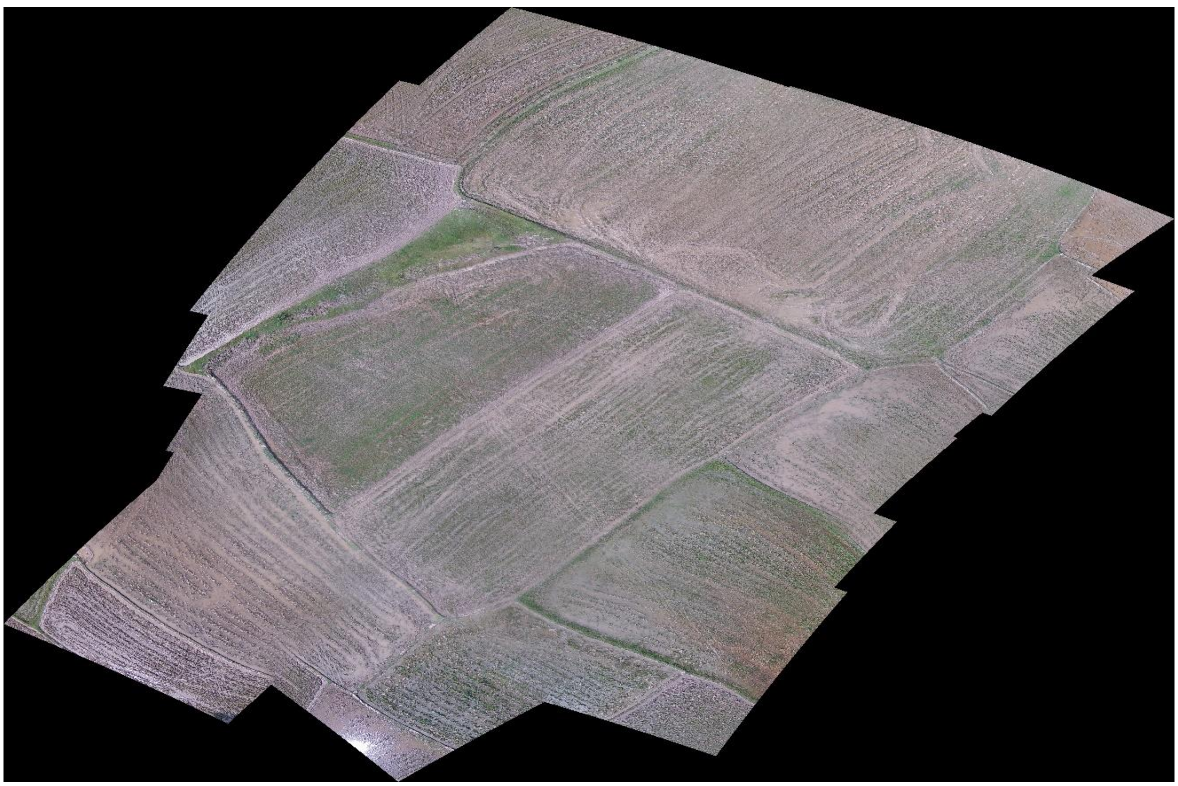

Figure 6.4: Series of acquired images have been digitally mosaicked. The images have been geometrically corrected and geo-referenced using the ERDAS Imagine - a professional image processing software. The whole areas appear to be in a single block.

All the raster image blocks are geometrically corrected and geo-referenced using the ERDAS Imagine image processing software available at SPARRSO RS-GIS Laboratory. Geometrically corrected individual image blocks after mosaicking provides a single block image covering relatively large area.

Chapter 7
Spectral Characterization and Retrieval of Geoinformation

7.1 Spectral Properties of Surface Features

During the field campaign, the alfalfa was fully grown. The low altitude airborne imaging system was lifted to elevations of 5, 10, and 20 meters and spectroradiometric measurements were taken of the alfalfa target, as well as digital photographs in the visible and infrared range. Spectroradiometric measurements and photographs in the visible and infrared range were taken over the target area (figure 5.2 and 5.3). Preliminary results found that there were no significant differences in the spectral signatures in the visible range, while there was a significant difference among the spectral signatures in the NIR range as the balloon was elevated. The study found that the spectral signature of the target can changed as a function of altitude, with higher reflectance indicated as the elevation increased.

Figure 7.1: Multispectral image acquired by the sensor on board the drone while moving over the agricultural field. Red line shows the spatial profile drawn over the image. In the in site spectral responses due to variation in surface features.

UAS have also been deployed for post-disaster imagery collection after other earthquakes cross the globe. Following an earthquake in L'Aquila, Italy in 2009, quad-copter UAS were deployed to evaluate their potential applications for fire service response. After the devastating 2010 earthquake in Haiti, a private company flew a sUAS to assess damage to orphanages in the remote mountains outside Port-Au-Prince. Real-time imagery relayed by the UAS indicated that the critical 3 infrastructure of the orphanages remained intact, which allowed recovery efforts to be concentrated in other locations. A United States Air Force Global Hawk UAS also conducted missions to Haiti to inspect the damage to roads and airports. The extensive range and endurance of the Global Hawk, with the ability to fly daily missions between Maryland and Haiti, was of great value to the operation due to the lack of sufficient infrastructure near or in Haiti. During these 14 hour missions, over 700 high-resolution images were collected.

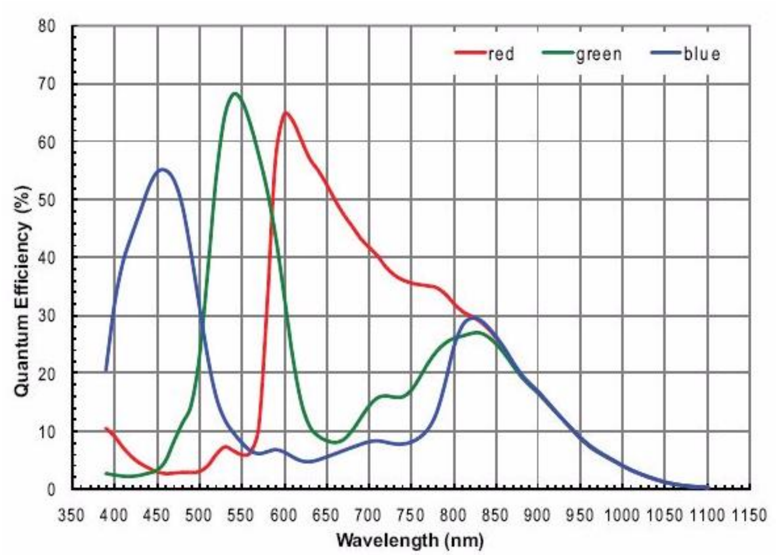

Figure 7.2: Color sensor spectral characteristics corresponding to CMOS Digital Image Sensor, Quantam

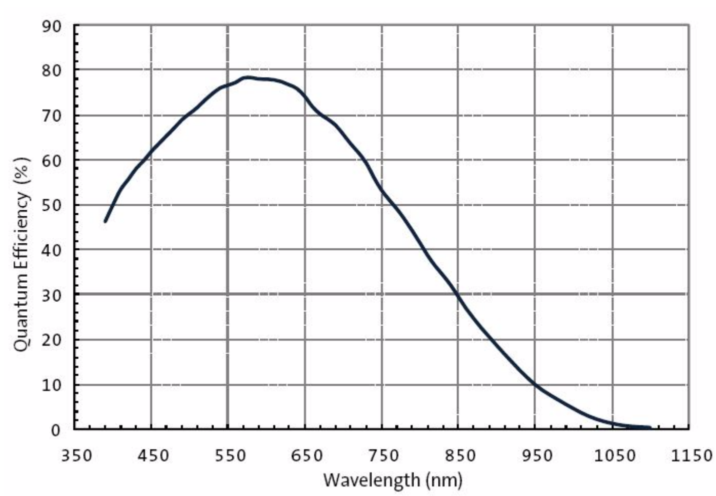

Figure 7.3: Quantum Efficiency Sensor, Monochrome Sensor, Spectral Characteristics.

Table 1. Key Parameters

Parameter		Typical Value
Optical for mat		1/3-Inch (6 mm)
Active pixels		1280 X 960 = 1.2 MB
Pixel size		3.75 nm
Color filter array		Monochrome RGB
Shutter type		Electronic rolling shutter
Input clock range		6-50 MHz
Output clock maximum		74.25 MHz
Outp	Parallel	12-blt
Max.	1.2 Mp (full FOV)	45 fp6
	720 pHD (reduced F0V)	60 fp6
	VGA (full FOV)	45 fp6
	VGA (reduced FOV)	60 fp6
	800x800 (reduced FOV)	60 fp6
Responsivity at 550 nm (Mono)		6.5 V/lux-sec
Responsivity at 550 nm (RGB		5.6 V/lux-sec
SNR_{MAX}		44 dB
Dynamic range		82 dB
Suppl	I/O	1.8 or 2.4 V
	Digital	1.8 V
	Analog	2.8 V
Power consumption		270 mW (1280 × 720 fps)
Operating temperature		-30µ C to +70µ C
Package option		Bare die ILCC PLCC

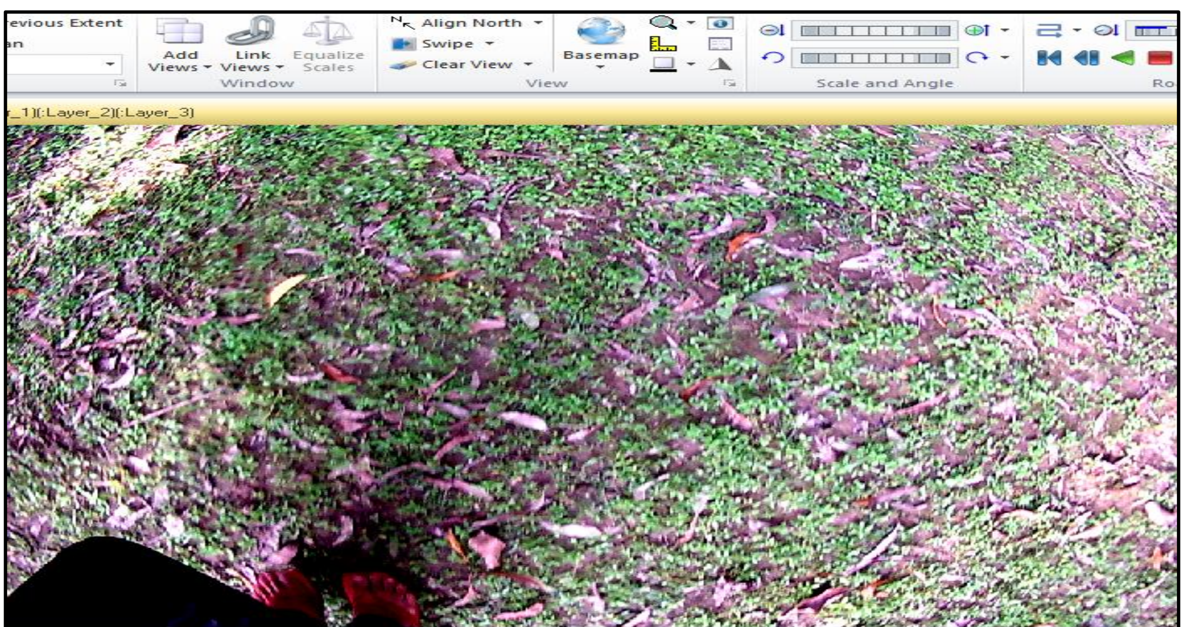

Figure 7.4: Spectral colour composite of multispectral image acquired by the sensor on board the drone over an area observed near the ground level. The spatially distributed vegetation cover and soil areas are visible in the image.

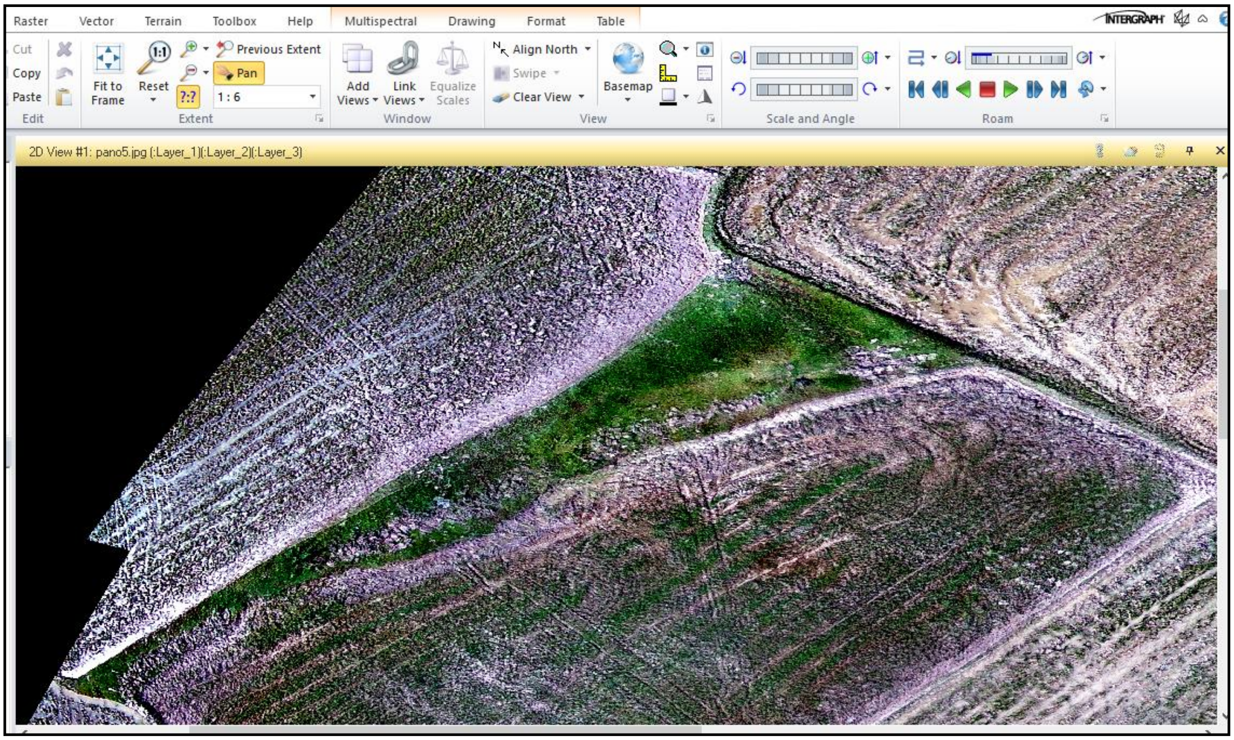

Figure 7.5: Multispectral image (RGB) acquired by the sensor on board the drone over the agricultural field. In the image no significant presence of agricultural crop is noticed over the area under observation during the time of image acquisition.

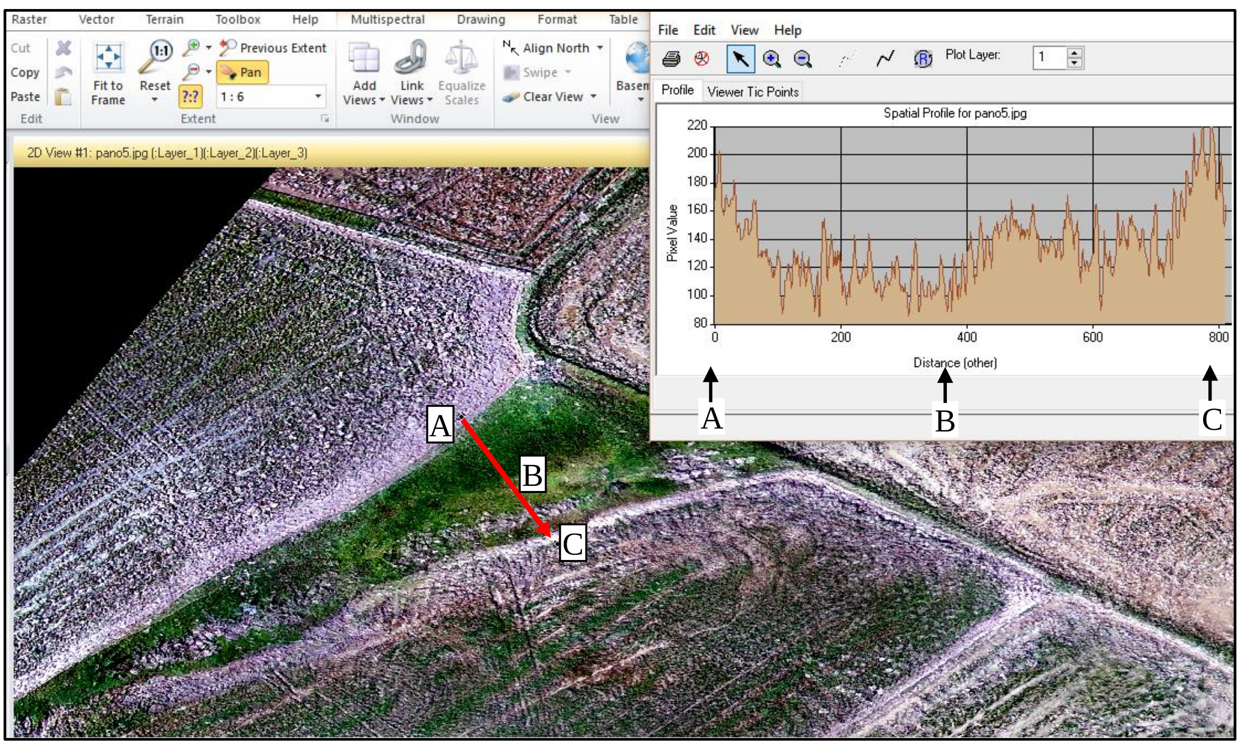

Figure 7.6: Multispectral image (RGB) acquired by the sensor under the present study on board the drone over the agricultural field. Red line shows the spatial profile drawn from the point A to point B over the image. In the in-site window, spectral responses of the surface features along the profile line have been plotted as a function of distance from point A to point C.

Figure 7.6 shows the multispectral image (RGB) acquired by the sensor under the present study on board the drone over the agricultural field. Red line shows the spatial profile drawn from the point A to point B over the image. In the in-site window, spectral responses of the surface features along the profile line have been plotted as a function of distance from point A to point C via point B.

It is to be noted that the spectral response values are relatively high on either side of the profile line towards point A and point C. The presence of relatively dry bare lands is readily observed over the area in the image. However, the presence of vegetation around the point B provides relatively lower spectral response value as is evident in the spectral response curve in the in-site graph. All these results indicate the dynamic behavior of the Earth's surface features in radiative responses in different spectral bands. The physical processes are also playing an important role in causing such variabilities in surface spectral responses.

Mosaicked image along with a spatial profile drawn along a straight line showing the variation

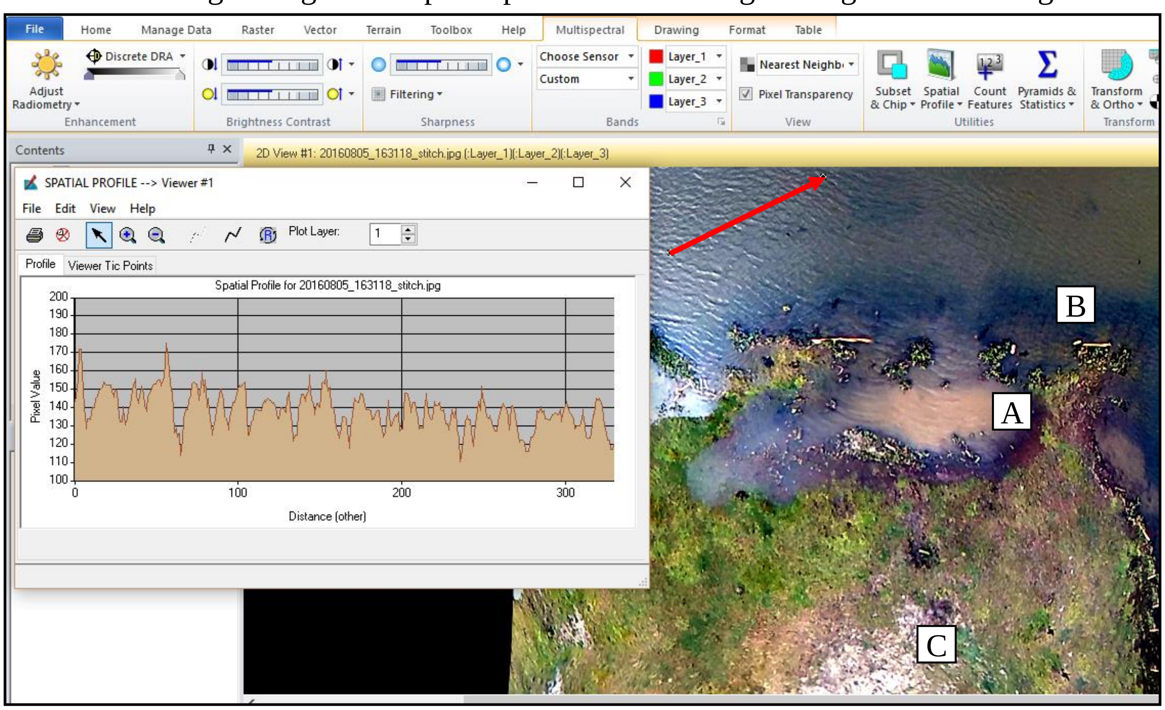

Figure 7.7: Multispectral image acquired by the sensor on board the drone over the agricultural field. Red line shows the spatial profile drawn over the image. In the in site spectral responses due to variation in surface features.

Figure 7.7 represents multispectral view of a part of the area under the present study as obtained from the multispectral sensor with three spectral bands. The land and the water area are very much distinct in the image. A significant variation in spectral response value is observed along the profile line in the in-site window where spectral response values are plotted as a function of distance along the profile line. A textural pattern is visible along the profile line over the water surface. The roughness of the water surface is very much visible in the image that is probably due to the presence of wind at the time of image acquisition.

Referring to point A in the figure, the relatively bright water area indicates the presence of sediment and background soil. While point B represents relatively clear water area with relative dark spectral response. A significant variability thus exists depending on the sediment content and background soil properties. Position C represents mainly bare soil area with relatively dry condition thus offers relatively high response value.

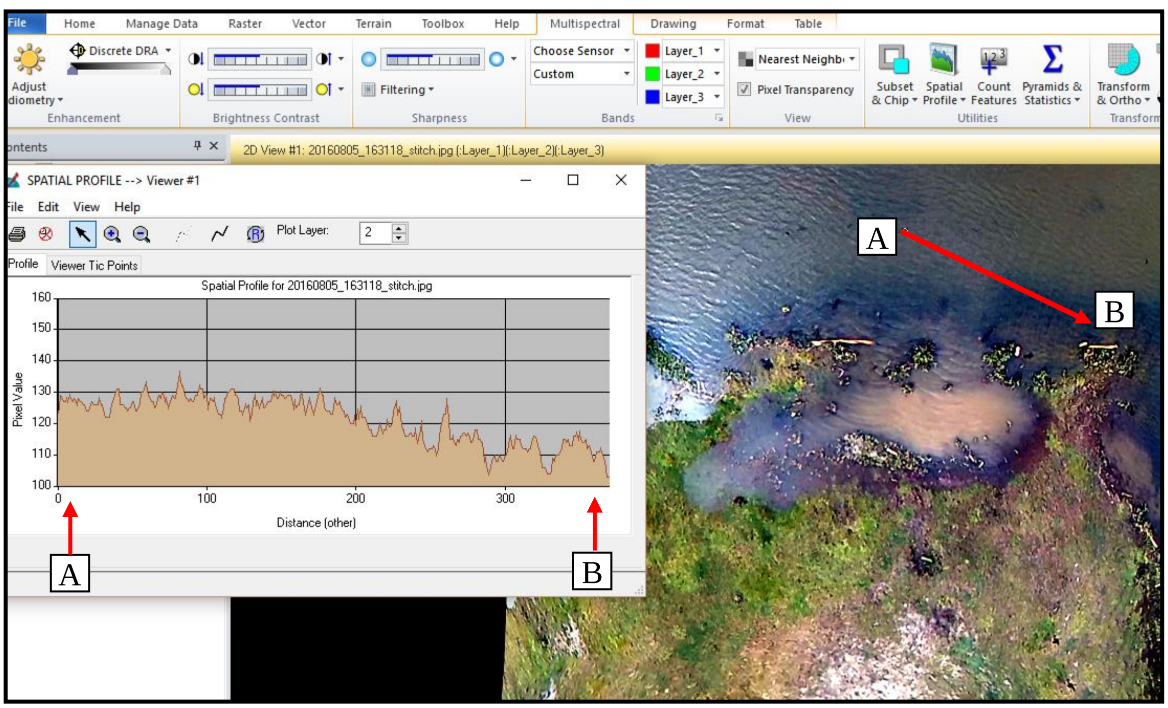

Figure 7.8: Multispectral image acquired by the sensor on board the drone over the agricultural field. Red line shows the spatial profile drawn over the image. In the in site spectral responses due to variation in surface features.

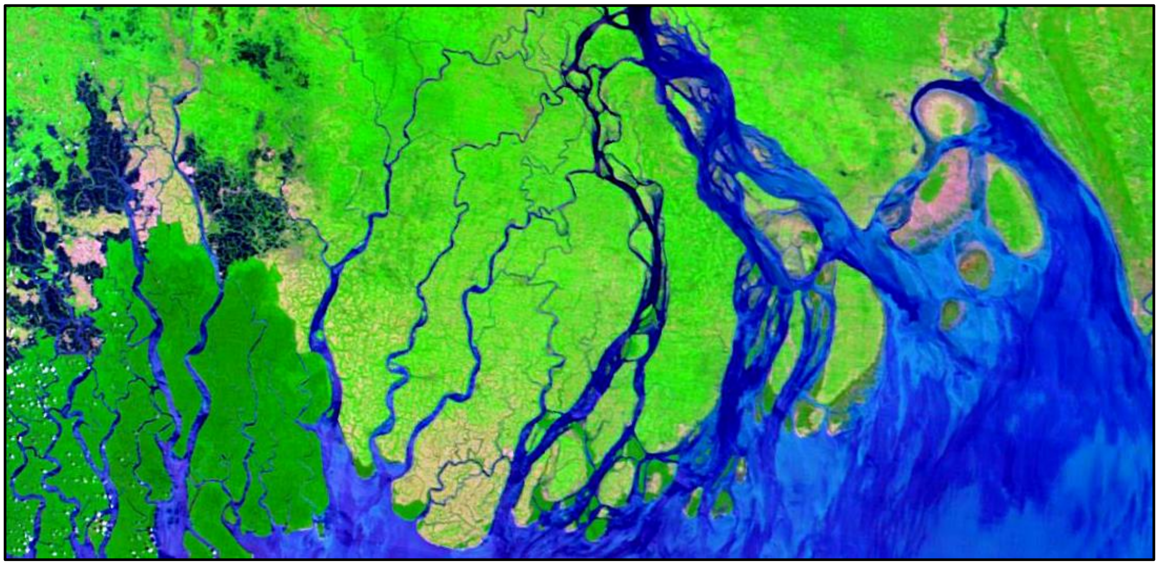

Figure 7.9: Spectral color composite image of Terra MODIS representing of the coastal area of Bangladesh.

Chapter 8

CASE STUDY ON THE GEO-ENVIRONMENTAL CONSEQUENCES OF CYCLONE AILA

A case has been studied on the consequences of cyclone Aila of 2009 in the southern part of Bangladesh in the Satkhira district. Landsat Thematic Mapper ™ time series data has been used for the purpose. Analysis of Time series satellite data have been analyzed to study the consequences of the devastating *Cyclone Aila* on agricultural crop field and geo-environment in selected areas under the Satkhira district. Figures 8.1 to 8.3 represent pre and post Aila situation as observed in high resolution images of Landsat TM, Google and other satellite data as available. A number of observation has been made based on the analysis of these figures that demonstrates the potential of RS-GIS technology over the areas under observation.

8.1 Water Logging in the Aila-Affected Areas

Cyclone Aila accompanied by storm surges flooded the villages and crop fields with seawater. The incoming sea water caused water logging in certain areas at different locations depending on the surface characteristics. During long duration water logging with high salinity most of the vegetation were seriously affected, died and disappeared.

8.2 Impacts on Crop Lands and Vegetation

Figures 8.1 represents satellite images of Landsat TM along with Google images corresponding to pre- and post-Aila situation in the study area. Different surface features are visible in the images. Figure demonstrates the variation of cultivated crop areas and depicts that most of the agricultural land and homestead vegetation in the study area were flooded and a significant part the green vegetation was damaged. Agricultural crop cultivation was disrupted in many areas due to salinity intrusion. Figure 8.3 represents part of areas under the Upazila Koyra in Khulna district as observed in high resolution satellite images of 2001 and 2014 corresponding to (a) pre-*Cyclone Aila* and (b) post-*Cyclone Aila* time sequences.

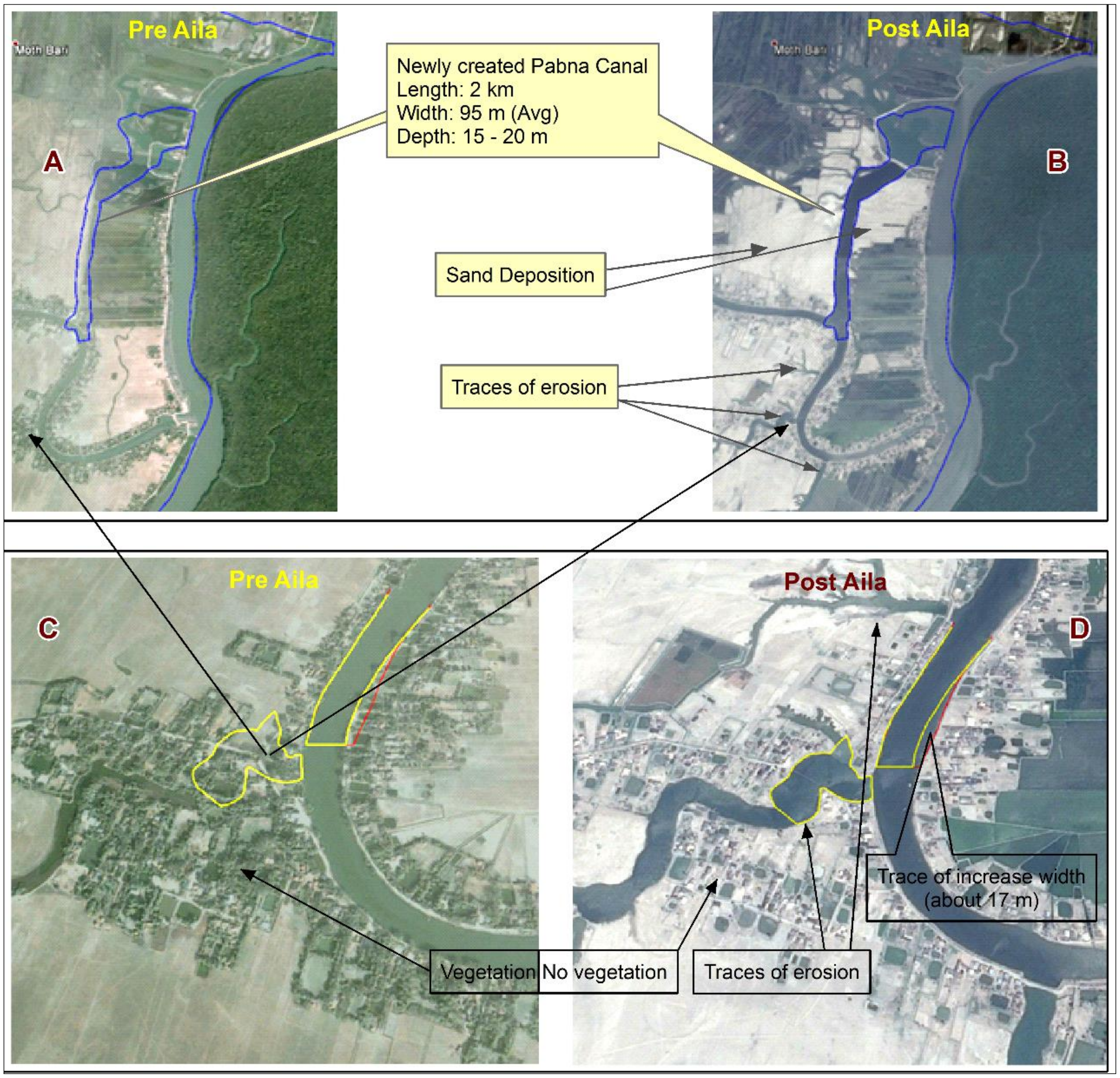

Figure 8.1: Part of Uttar Chak under Koyra union, Upazila: Koyra, District: Khulna as observed in Google images of 2001 and 2014 corresponding to (a) pre-Cyclone *Aila* and post-Cyclone *Aila* time sequences.

Comparison of figures 8.3(a) and 8.3(b) provides certain differences in surface feature configuration over the area. Figure 3(a) indicates the presence of vegetation and trees as textured elements distributed around the settlement areas. While most of the vegetation area disappeared on the post-Aila image (image on the right side). Moreover, the settlement areas also disappeared on the post-Aila image.

Aila introduced water logging in the area at different locations. During long duration water logging with high salinity most of the vegetation were seriously affected, died and disappeared.

8.3 Cyclone Aila-Induced Land Degradation

Cyclone Aila introduced dynamic changes in the geo-environmental configuration and composition of surface features over the study area with different cascading effects parameters and processes. Remote sensing spectral measurements are principally controlled by the interaction of radiative signal with different earth's surface materials.

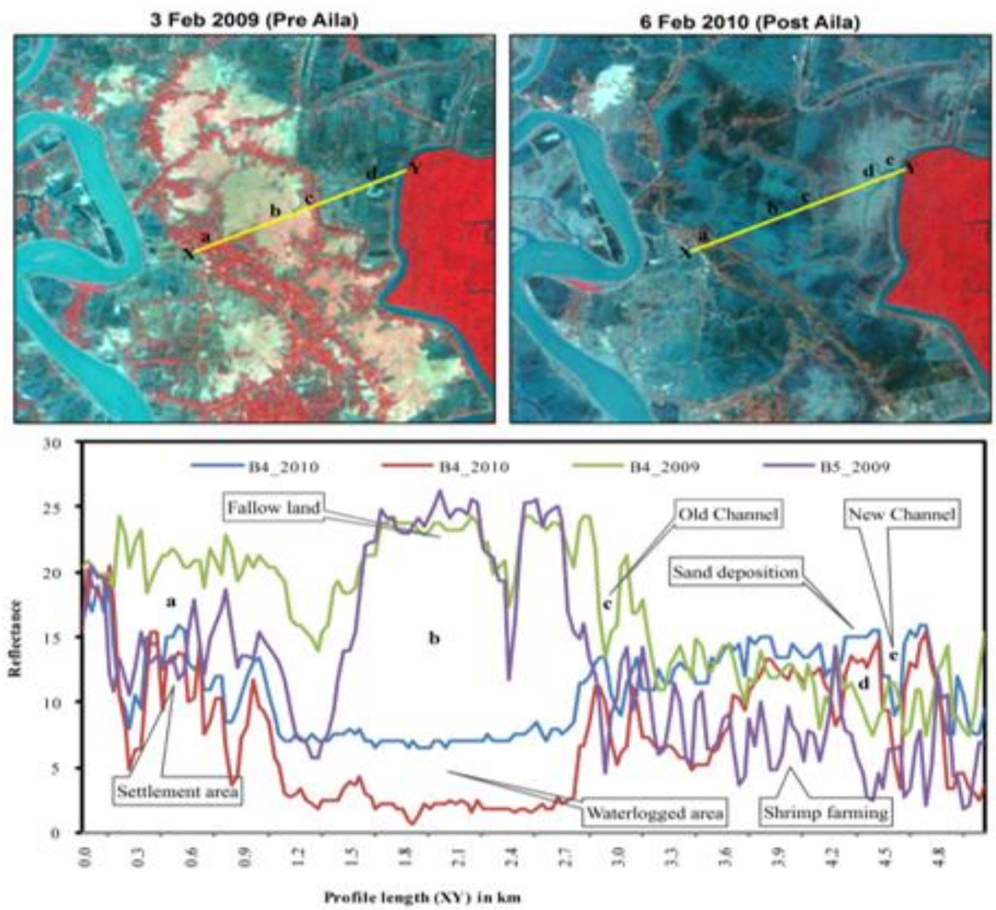

Figure 8.2: Landsat TM spectral colour composite images of February 3, 2009 and 6 February, 2009 representing pre-Aila and post-Aila situation respectively in the Koyra upazila under Khulna district with linear spatial profiles corresponding to three spectral bands on the two different dates as mentioned.

Figure 8.2 shows the Landsat TM spectral colour composite images of February 3, 2009 and February 6, 2010 representing pre-Aila and post-Aila situation respectively in the Koyra upazila under Khulna district. Landsat TM bands 3, 4 and 5 have been loaded in the R, G and B plains respectively of the display device. Spatial profiles have been drawn along a straight line over the two images. The graph in the lower part of figure 8.2 shows the variation of spatial profile of the reflectance values in band 4 and band 5 of Landsat TM on two different dates as mentioned. Along the profile a number of specific locations e.g., a, b, c and d has been considered over both the images as shown in figure. Dynamic variation in reflectance values along the profiles on two dates have been interpreted in terms of surface category, its condition and transformation into another category. Referring to location ‘a’ corresponding to settlement area in 2009 was affected by Cyclone Aila and presence of flood water is visible in 2010 after the Cyclone Aila.

Thus the spectral value corresponding to position ‘a’ dropped down significantly in 2010 as compared to that in 2009 prior to the Cyclone Aila`. Location ‘b’ represents fallow land in 2009 with high radiative reflectance value, while, the value significantly dropped down in 2010 due to water logging in the area causing high absorption of radiative signal.

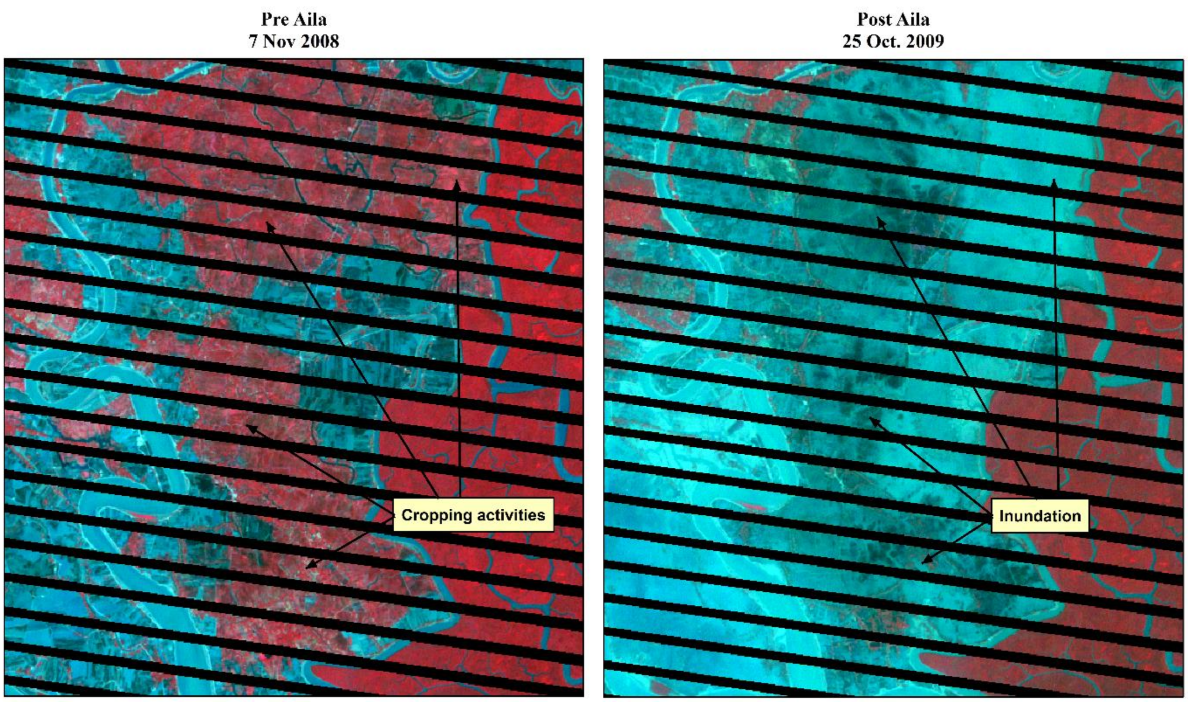

Figure 8.3: Extracted Google image shows the newly created Pabna canal and erosion along the Sakbaria River. The blue line on the left side indicates the before the *Cyclone Aila* width of Sakbaria river.

Analysis of satellite images of pre- and post-Aila time sequences postulates the involvement of a multi-fold land degradation process in the *Aila* affected areas. The mechanism includes (i) creation of new channels or canals and increase of depth and width of old channels or canals or rivers, (ii) erosion of upper fertile layers, (iii) deposition of non-fertile sand on fertile top layers and (iv) intrusion of salinity. Ultimately, land in the area loses its production capacity depending on the degrees of erosion. Creation of new channels and increase in depth and width of old channels is the cause of productivity loss for a long time or forever.

Chapter 9

Conclusions and Suggestion for Future Work

In the present study, combined triangular technology approach has been applied to provide specific operations for (i) satellite-based geo-information retrieval and updating, (ii) suitable platform for analysis and archival of huge volume of spatial data and (iii) accurate geographical positioning of surface features. Effects of temporally changing crop condition on the spectral response characteristics of potato crop canopy have been studied over the crop life cycle in view of monitoring growth and development of potato crop using satellite based measurement of spectral radiative response.

The adopted methodological approach consists of digital radiometric analysis of temporal and spatial variability of vegetation responses. Analysis depicts that satellite-derived radiative measurements performed at different wavelengths of radiation exhibit systematic variation between different surface types depending on the condition, properties and composition of the surface features.

The thesis project "Pilot Study on the Development of a Low Cost Land Observation and Geo-information Retrieval System for Emergency Monitoring of Agricultural Crop and Disaster-Induced Damages" was designed for the welfare of Bangladesh in fulfilling the purpose of crop monitoring and post disaster management. In Bangladesh, crop monitoring can facilitate a great deal of work not only to estimate the amount of yield but also in serving the food security purpose[1][2][3]. The Landsat is renowned for remote sensing operation for larger distances and its sensors are effective for receiving multiple spectral bands. But the problem arise in our country that, Bangladesh does not own any such land observation satellite. Bangladesh Space Research and Remote Sensing Organization (SPARRSO), the government organization responsible for remote sensing and space research based operations, has got license to receive satellite image from few international orbiting satellite. In many cases, it is not possible to receive the updated satellite image on time and these updated image is very expensive; moreover, many cases arise where close monitoring for a better resolution is required. So, it is obvious that satellite does not always fulfill the needs of land observation system and that is why we have designed a system which contains sensors for receiving spectral bands and can automatically fly to any given GPS co-ordinate and can cover certain area by taking aerial updated high definition aerial photos. This function with helps to overcome the limitations of satellite based remote sensing. The post disaster management monitoring operations using this system helps in finding out the remote areas where immediate help is required. The geographical location of Bangladesh is prone to environmental disaster. Every year large acres of crop field as the thousands of people of Bangladesh suffers due to this massive floods, cyclones etc. and due to this disasters all sort of communication system collapses. The breakdown of transportation and telecommunication system causes severe difficulty in the lives of human. Manned aerial vehicle like helicopters are sometimes used to observe those land but due to flood, landing of such vehicles become difficult. Thus, unmanned aerial vehicle acts as an effective method for observing those affected remote areas [2][4]. Using the UAV the affected area can be simultaneously identified and total number of affected people can be estimated. Moreover, the best possible way to help those affected people can be decided. Thus the quadcopter that was designed in this thesis can act as a vital system for effective and successful operation of these monitoring operations. Another important theme for this project is the use of locally available low cost electrical equipment, which reduces the maintenance cost.

The sensors (camera) used in this thesis can receive three spectral bands. Although, these three spectral bands are not enough when compared to the sensors of the satellite. However, this three sensors can effectively serve the basic monitoring of vegetation, soil, water and the amount of damage caused due to the disaster. In future, the modification for overcoming the limitations of this pilot study will be done. Implementation of more sensors which can receive more spectral band will enable the work to a great height in remote sensing and monitoring operations. This implementation of sensors will help to retrieve more information about the surface feature. Furthermore, the structure can be modified by implementing more efficient equipment like motors, esc, battery, and propeller. These implementation will increase the frequency power of the Radio controller and the battery capacity. Thus larger distances can be covered for monitoring. Thus, this image will integrate with the satellite image for validation purpose.

The final chapter includes a case study on the assessment and monitoring of the consequences cyclone Aila on the geo-environmental configuration and condition of the area to demonstrate the capability of space-based technology.

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Appendix

The updated sensors will be capable of receiving multispectral bands. These sensor readings will be almost similar to the satellite sensor readings. These sensor reading can be integrated with the satellite sensor readings and using the algorithm of SMAC (Simplified Method of Atmospheric Correction) [10], we can correct the images and a modified image will be obtained. Before correcting the image, the image was contaminated with external factors. These external factors are removed by the SMAC. The SMAC is a faster method for correcting the satellite images, thus the software will also capable of correcting satellite image too. In Matlab software, we have designed and createted a windows based executable software for SMAC which will show all constant used in SMAC.

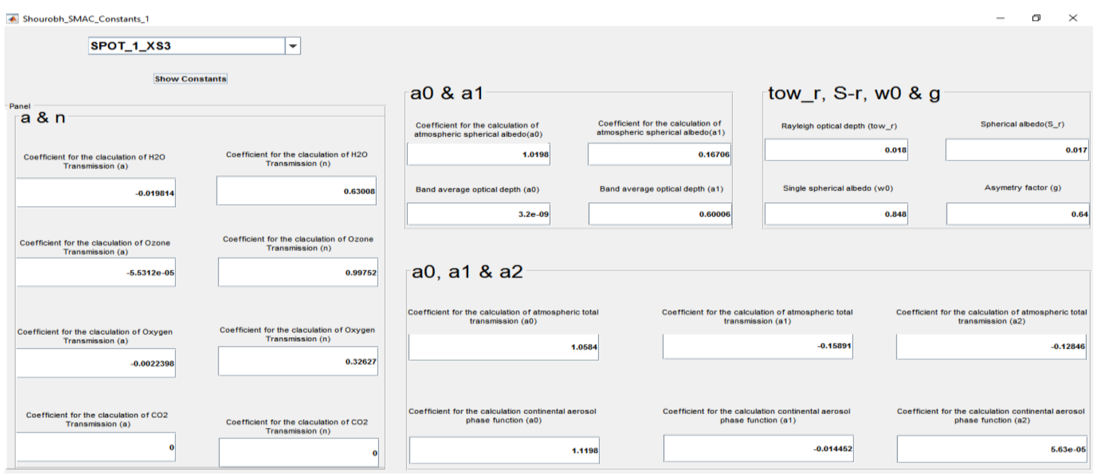

Fig: Interface of SMAC constant finder

The main objective of this pilot study was to design an information retrieval system and examine the feasibility of the system for understanding the effectiveness collecting geo-information. The result obtained after the data analysis and processing validate with our primary objective and thus the further modification is necessary for better information retrieval process.

MATLAB Code: Code for the SMAC constant viewer written by Md. Mojammel Haque, Sanando Jagati Chayan, Aynul Huda, Bijoy Talukder , with the help of MATLAB software support.

1

```
function varargout = Shourobh_SMAC_Constants_1(varargin)
% SHOUROBH_SMAC_CONSTANTS_1 MATLAB code for Shourobh_SMAC_Constants_1.fig
%      SHOUROBH_SMAC_CONSTANTS_1, by itself, creates a new SHOUROBH_SMAC_CONSTANTS_1 or raises the existing
%      singleton*.
%
%      H = SHOUROBH_SMAC_CONSTANTS_1 returns the handle to a new SHOUROBH_SMAC_CONSTANTS_1 or the handle to
%      the existing singleton*.
%
%      SHOUROBH_SMAC_CONSTANTS_1('CALLBACK',hObject,eventData,handles,...) calls the local
%      function named CALLBACK in SHOUROBH_SMAC_CONSTANTS_1.M with the given input arguments.
%
%      SHOUROBH_SMAC_CONSTANTS_1('Property','Value',...) creates a new SHOUROBH_SMAC_CONSTANTS_1 or raises the
%      existing singleton*.  Starting from the left, property value pairs are
%      applied to the GUI before Shourobh_SMAC_Constants_1_OpeningFcn gets called.  An
%      unrecognized property name or invalid value makes property application
%      stop.  All inputs are passed to Shourobh_SMAC_Constants_1_OpeningFcn via varargin.
%
%      *See GUI Options on GUIDE's Tools menu.  Choose "GUI allows only one
%      instance to run (singleton)".
%% See also: GUIDE, GUIDATA, GUIHANDLES
% Edit the above text to modify the response to help Shourobh_SMAC_Constants_1
% Last Modified by GUIDE v2.5 22-May-2016 00:01:50
% Begin initialization code - DO NOT EDIT
gui_Singleton = 1;
gui_State = struct('gui_Name',       mfilename, ...
                   'gui_Singleton',  gui_Singleton, ...
                   'gui_OpeningFcn', @Shourobh_SMAC_Constants_1_OpeningFcn, ...
                   'gui_OutputFcn',  @Shourobh_SMAC_Constants_1_OutputFcn, ...
                   'gui_LayoutFcn',  [] , ...
                   'gui_Callback',   []);
if nargin && ischar(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end

if nargout
```

2

```
    [varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});

else

    gui_mainfcn(gui_State, varargin{:});

end

% End initialization code - DO NOT EDIT

% --- Executes just before Shourobh_SMAC_Constants_1 is made visible.

function Shourobh_SMAC_Constants_1_OpeningFcn(hObject, eventdata, handles, varargin)

% This function has no output args, see OutputFcn.

% hObject    handle to figure

% eventdata  reserved - to be defined in a future version of MATLAB

% handles    structure with handles and user data (see GUIDATA)

% varargin   command line arguments to Shourobh_SMAC_Constants_1 (see VARARGIN)

% Choose default command line output for Shourobh_SMAC_Constants_1

handles.output = hObject;

% Update handles structure

guidata(hObject, handles);

global index;

index = 1;

% UIWAIT makes Shourobh_SMAC_Constants_1 wait for user response (see UIRESUME)

% uiwait(handles.figure1);

% --- Outputs from this function are returned to the command line.

function varargout = Shourobh_SMAC_Constants_1_OutputFcn(hObject, eventdata, handles)
% varargout  cell array for returning output args (see VARARGOUT);

% hObject    handle to figure

% eventdata  reserved - to be defined in a future version of MATLAB
```

3

```
function popupmenu1_Callback(hObject, eventdata, handles)

% hObject    handle to popupmenu1 (see GCBO)

% eventdata  reserved - to be defined in a future version of MATLAB

% handles    structure with handles and user data (see GUIDATA)

% Hints: contents = cellstr(get(hObject,'String')) returns popupmenu1 contents as cell array

%        contents{get(hObject,'Value')} returns selected item from popupmenu1

global index;

contents = cellstr(get(hObject,'String'));

popchoise = contents{get(hObject,'Value')};

index = 1;

%SPOT_1_XS1

%SPOT_1_XS2

%SPOT_1_XS3

%Landsat_5_TM_band_1

%Landsat_5_TM_band_2

%Landsat_5_TM_band_3

%Landsat_5_TM_band_4

%Landsat_5_TM_band_5

%NOAA_9_AVHRR_visible

%NOAA_9_AVHRR_near_Infrared

%Meteosat_1_visible

if(strcmp(popchoise,'SPOT_1_XS1'))

    index=1;

elseif(strcmp(popchoise,'SPOT_1_XS2'))

    index=2;

elseif(strcmp(popchoise,'SPOT_1_XS3'))

    index=3;

elseif(strcmp(popchoise,'Landsat_5_TM_band_1'))

    index=4;
```

4

```
elseif(strcmp(popchoise,'Landsat_5_TM_band_5'))

    index=8;

elseif(strcmp(popchoise,'NOAA_9_AVHRR_visible'))

    index=9;

elseif(strcmp(popchoise,'NOAA_9_AVHRR_near_Infrared'))

    index=10;

elseif(strcmp(popchoise,'Meteosat_1_visible'))

    index=11;

end

function popupmenu1_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end

function show_constants_Callback(hObject, eventdata, handles)

global index;

[a0_T a1_T a2_T] = database_a0_a1_a2_T(index);

set(handles.a0_three,'string',num2str(a0_T));

set(handles.a1_three,'string',num2str(a1_T));

set(handles.a2_three,'string',num2str(a2_T));

[a0_P a1_P a2_P] = database_a0_a1_a2_P(index);

set(handles.a0_four,'string',num2str(a0_P));

set(handles.a1_four,'string',num2str(a1_P));

set(handles.a2_four,'string',num2str(a2_P));

[wo,g] = database_wo_g(index);

set(handles.w0,'string',num2str(wo));

set(handles.g,'string',num2str(g));

[tow_r,S_r] = database_tow_r_S_r_ROD(index);

set(handles.tow_r,'string',num2str(tow_r));

set(handles.S_r,'string',num2str(S_r));

[a0_s,a1_s] = database_a0_a1_s(index);
```

5

```
[a_vap,n_vap]=database_a_n_vap(index);

set(handles.a1,'string',num2str(a_vap));

set(handles.n1,'string',num2str(n_vap));

[a_o3,n_o3] = database_a_n_03(index);

set(handles.a2,'string',num2str(a_o3));

set(handles.n2,'string',num2str(n_o3));

[a_o2,n_o2] = database_a_n_o2(index);

set(handles.a3,'string',num2str(a_o2));

set(handles.n3,'string',num2str(n_o2));

[a_co2,n_co2] = database_a_n_co2(index);

set(handles.a4,'string',num2str(a_co2));

set(handles.n4,'string',num2str(n_co2));

function edit1_Callback(hObject, eventdata, handles)

function edit1_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end

function edit2_Callback(hObject, eventdata, handles)

function edit2_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end

function edit3_Callback(hObject, eventdata, handles)

function edit3_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end

function edit4_Callback(hObject, eventdata, handles)

function edit4_CreateFcn(hObject, eventdata, handles)
```

6

```
    set(hObject,'BackgroundColor','white');

end

function edit6_Callback(hObject, eventdata, handles)

function edit6_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end

function edit7_Callback(hObject, eventdata, handles)

function edit7_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end

function edit8_Callback(hObject, eventdata, handles)

function edit8_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end

function edit9_Callback(hObject, eventdata, handles)

function edit9_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end

function edit10_Callback(hObject, eventdata, handles)

function edit10_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');
end

function edit11_Callback(hObject, eventdata, handles)

.
```

7

```
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end

function a1_Callback(hObject, eventdata, handles)

function a1_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end

function n1_Callback(hObject, eventdata, handles)

function n1_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end

function a2_Callback(hObject, eventdata, handles)

function a2_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end

function n2_Callback(hObject, eventdata, handles)

function n2_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end

function a3_Callback(hObject, eventdata, handles)

function a3_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end
```

8

```
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end

function n4_Callback(hObject, eventdata, handles)

function n4_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end

function tow_r_Callback(hObject, eventdata, handles)

function tow_r_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end

function S_r_Callback(hObject, eventdata, handles)

function S_r_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end

function w0_Callback(hObject, eventdata, handles)

function w0_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end

function g_Callback(hObject, eventdata, handles)

function g_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');

end
```

9

```
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end

function a2_three_Callback(hObject, eventdata, handles)

function a2_three_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end

function a0_four_Callback(hObject, eventdata, handles)

function a0_four_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end

function a1_four_Callback(hObject, eventdata, handles)

function a1_four_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end
function a2_four_Callback(hObject, eventdata, handles)

function a2_four_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end

function a0_one_Callback(hObject, eventdata, handles)

function a0_one_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

set(hObject,'BackgroundColor','white');

end
```

1

```
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white');

end

function a1_two_Callback(hObject, eventdata, handles)

function a1_two_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))

    set(hObject,'BackgroundColor','white'); end
```