Chapter 1: Introduction

This chapter provides the outline of the project description covering the background of the project, an introduction, technical features of the project, time line of the project and the company profile.

1.1Project Description

Multirotor UAV (unmanned aerial vehicles), namely tricopter, quadacopter, hexacopter and octacopter have become more popular in recent years [1]. Similar to the single rotor helicopters, they possess the ability to hover on specified spot but with an added advantage that they are far more maneuverable, while they can move left right, up down just as well forward and backward. The multirotors are becoming more popular and viable in industrial applications as the battery technologies are used to control and power the copters and it helps the copters to become lighter and lasts longer. They are more cost effective compared to single rotors as single rotors are more expensive, more complexity in designing and prone to failure as complexity in designing. UAVs are currently being used in several industrial applications such as mining, oil and gas industries in order to avoid the workers from hazardous environments. They can also use in the field of agriculture where today's crop and harvesting scouting techniques are quite simple, inefficient. Crop scouting hundreds or large number of acres is inconceivable through old strategies. This drawback in the existing system leads to the development of a new system, which is efficient and cost effective as multirotors are substantially simpler and more crash-resistant, safer due to lower propeller speed. Existing system does not meet the requirement of the current situation where there are lots of constraints involved in the precision agriculture.

Unmanned aerial vehicles are being researched and developed for all possible terrains to be ground, water or air. Considering their capability and versatility to perform autonomous decisions and undertaking operations that are virtually impossible for humans. Hence demand for UAVs in present and future global market is formidable. The multirotor hexacopter is used in the field of agriculture in order to capture the images of the plants and identify the infected region and apply pesticides only to the infected part instead of applying to the entire plantations which helps the farmers and decision makers to scout the crop easily

and also improvise the technologies used in the field of agriculture. The project will be carried out in the following phases:

- **Trajectory Planning:** Trajectory planning includes the flight of a hexacopter in the air with respect the various inputs given by the sensors and actuators by identifying the location of the multirotor via GPS trackers.
- **Image Capturing:** During the hover in the air the images of plantations has to be captured with respect to the speed and GPS trackers so that proper images could be recorded easily.

The technical features of the project includes

- Switching the positions of hexacopter when different inputs given by sensors and actuators.
- Capturing images during the hover flight with maximum and minimum speed.
- Handling sudden changes in the safe landing decisions during the flight when the hexacopter come up with obstructions.

The Figure 1.1 shows the entire timeline of project divided into 20 weeks phases in order to achieve the designed objective within stipulated time period where each phase comprises of a standard work. The project was carried out in five phase's literature survey, requirement analysis, design, coding, testing, each phase has been allotted with sufficient time span in order to achieve the goal. Firstly literature survey is carried out on existing and proposed system to identify cons and pros in both the system. Based on the outcome from literature survey requirement analysis phase is carried out and designing was started with respect the clients requirements. Individual module was designed and implemented to and integrated as the major module, the entire application was designed into two phases trajectory planning and image capturing which include 4 major modules in it view, auto setup, gimbal setup, auto pilot mode. Unit testing was carried for each module with different inputs and output, on the success of unit testing integration testing was started where all the sub modules were combined into one and test plans and test cases were derived for n number of sample inputs.

After the completion of all the 5 phase's final report was started user manual to make user to understand the application in an easier way.

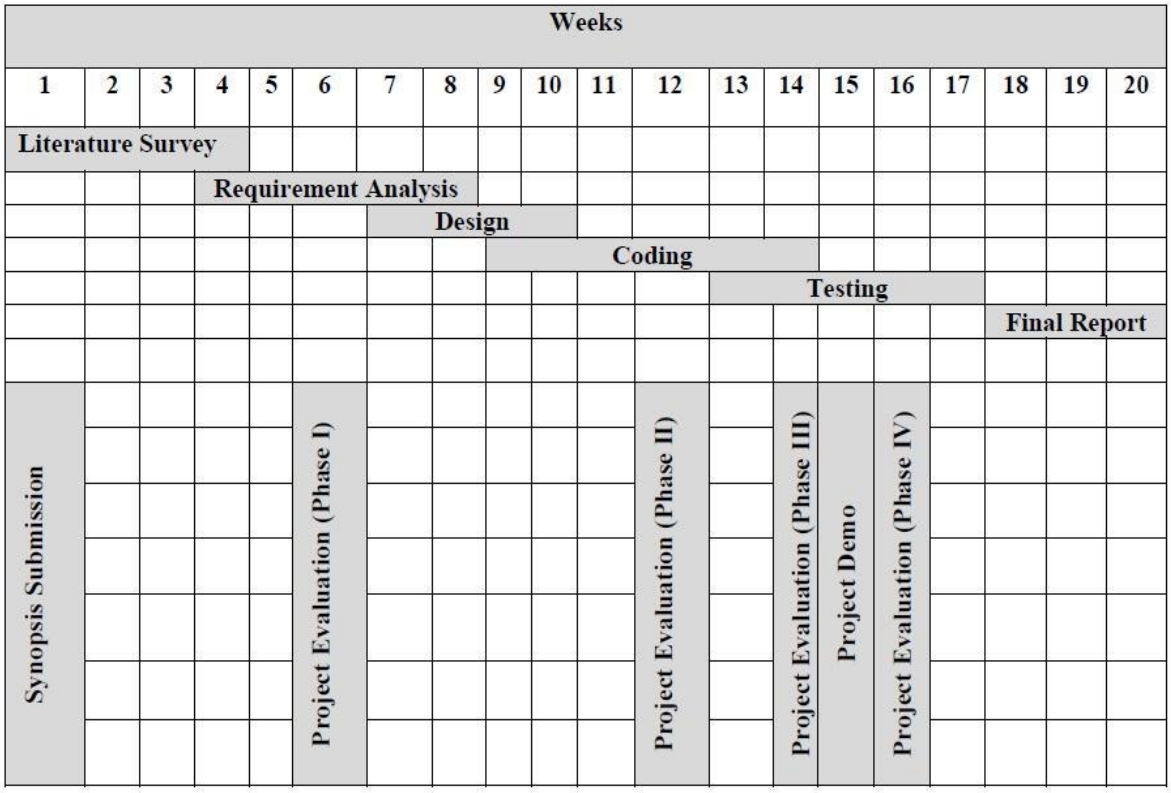

Figure 1.1 – Timeline of the multithreaded software system

1.2 Company Profile

i2Soft Technologies is one of the principle ICT associations which offers an intensive line of programming and organizations for general and wander customers, Its things and organizations enable customers to have a substitute taste of inventive thing and organization in IT division.

Values & Beliefs: Since i2Soft advancements were begun it worked as per an arrangement of center values and advantages which are basic to achieve our prosperity as an organization and as people. To end up one of the main programming designers of Bangladesh was troublesome yet at the same time we made it by giving world-class programming answer for

enterprise and additionally individual, and to end up the most productive advertiser of ICT empowered with best administrations however best practice execution and considering the territorial qualities.

Client is the spirit of i2Soft, i2Soft is continually flourishing to convey the inventive and best items and administrations, and it keeps up the secrecy about every last client's business and gives the most noteworthy and best level of administration. Whatever business you are in a retailer, an advertiser, a maker, or an administration supplier expansive scale or little scale, you will have some IT emotionally supportive network, and your reliance to IT is expanding in view of the many-sided quality in business administration.

Report Organization

The entire report is classified into 5 chapters with each chapter taking up certain unique feature related to the work. Chapter I are Introduction gives brief introduction to the project, Chapter II Literature Survey, Chapter III describes SRS deals with the detailed requirements such as functional and nonfunctional requirements and various constraints related, Chapter IV System Design includes Block diagram, data dictionary, module specification and context diagram Chapter V Detailed Design Document Specification deals with describing the UML diagrams and block diagrams with respect to the project, Chapter VI Implementation with screen shots of the entire project. Chapter VII Software Testing with test cases and screen shots of test cases. Chapter VIII depicts the conclusion of the project. Chapter IX Future Enhancement specifies the advanced techniques.

It also includes APPENDIX A with Bibliography with all the papers, articles, books, websites referred to develop the proposed system. APPENDIX B includes User Manual in order to help the users to understand the working of the application with instructions given in the software itself.

Chapter 2: Literature Survey

This chapter gives an overview about the existing and proposed system along with feasibility study, details about tools and technologies and motivation of the project.

2.1 Existing and Proposed System of Multithreaded Software System

Multirotor UAVs are a keen platform for several autonomous aerial robotics research projects, research divides into either indoor applications or outdoor applications. Agriculture is the field which has been barely touched by UAVs and today's crop scouting techniques are simple, inefficient. Scouting hundreds and thousands of acres of agricultural crops is not possible through the previous and existing techniques.

The wireless sensor technology is used in the field of agriculture in order to replace some traditional and old techniques and automate the rice crop checking techniques utilizing WSNs to help the ranchers progressively observing and accomplishing accuracy horticulture to expand the rice generation [2].The agricultural innovation is one in every of the simplest method and higher than medical innovation to assist the individuals within in the poorest countries of the world to live more pleasant and comfortable lives [3]. The importance of greenhouse in horticulture in order to meet the needs of world's economy, and the author mainly talks about the benefits of utilizing remote sensor innovation for practical nursery administration [4].In [5] admission control and congestion control, routing issues in wireless mesh networks are highlighted. The author proposes the algorithm to perform the load balancing and multipath routing in wireless mesh networks.

The mechanical transformation in Indian cultivating where exactness horticulture is being a system of applying the correct measure of water, manure, pesticides and so forth at the perfect time and right area in the agribusiness ranch to enhance the nature of the harvests [6].Environment checking framework is utilized for exactness agribusiness in view of remote sensor systems in a red bayberry nursery alongside remote server by means of GPRS continuously and Google maps incorporated to take care of the issues happening in the customary accuracy farming [7]. In [8] the technique for measuring the moisture of agricultural soil by real-time method is used in order to reduce the manual working of

farmers by introducing the micro-controller RF module to check the moisture status in the soil. The wireless sensor network technology is used in irrigated system to improve or optimize the usage of the water for agricultural purpose with help of soil moisture and temperature sensors used in the crop field [9]. The agricultural information technology and architecture of intelligent agriculture has been incorporated for analyzing the features of agricultural data in every aspect of agriculture and has become most popular in enhancing the production in agriculture [10]. The advantage of utilizing the information and communication technology in the field of agriculture to develop the rural sided areas by initiating the IT-ICT based services in Asian region [11].

To build and implement the autonomous system to make farming more productive and efficient. The autonomous hexacopter allows farmers ability to scout, diagnose and identify the affected region and irrigation blockages in an agricultural setting using UAV in conjunction with thermal cameras in less time. Farmers and decision makers can get all required information with minimum span of time to enable management decisions based on current crop status. The modular design for the system will be more flexible and adaptable. The use of murex's to protect resources across threads makes the design robust. This system is currently in use with a variety of simultaneous projects, including field searching and multiple object tracking, all tied in together with user detection interface.

The high tech precision agriculture helps in bringing green revolution to India by producing tremendous rural wealth in supportable and ecological sound way [12]. The design and implementation unmanned aerial vehicles in the field of agriculture can be employed to implement to spray the chemicals on crops with the help of wireless sensor networks [13]. The development of a remotely operated Quadcopter system through graphical user interface by using wireless communication system, it specifies about the quadcopter balancing and stability during the hover in the air and maximum time taken to fly and reach to the destination spot [14]. The image processing techniques are used in the field of agriculture for weed detection, fruit grading etc., based on the analysis the image processing techniques takes less time compared to the traditional methods and also helps in improvement of decision making [15]. In [16] it specifies about agriculture as the backbone of the Indian economy. This is the one of the purpose behind distinguishing the ailment in plants that assumes indispensable part in the field of agriculture. Contaminated plants are basic and

entirely normal however in the event that appropriate consideration is not taken then it might prompt genuine impacts on plants. An algorithm is implemented for image processing technique to automatic the disease detection in plantations and crops. In [17] paper speaks about greenhouse environment and observations made on crop analysis techniques in order to help the farmers for month to month future expectation to know the consumption for growing crops and also helps in growing disease free crops.

2.2 Feasibility Study

- **Economic feasibility:** The economic feasibility study is used to analyze the project cost to determine whether the project could be completed or not[18]. The developed software system does not involve much complex hardware requirements. It works well with limited resources such as 1GB Ram, 100GB Hard disk, Radio transmitter. This proves that the hardware resources involved in system are economically feasible and cost effective.
- **Behavioral feasibility:** Behavioral feasibility study mainly deals with how fast the users will respond to the development of new system [18]. The multithreaded software system designed here holds a well-defined user interface that does not includes any complications. Hence user need not to spend more time to understand the user interface design part and it easily responds to the emergency changes made in the flight plan thus the application is more feasible on behavioral terms.
- **Technical feasibility:** The technical feasibility study determines whether the technologies that is going to be used in the proposed system is available and how it could be incorporated in the organization [18]. The multithreaded software system is developed using PID algorithm so that it satisfies all the requirements of the system to perform in any climate conditions. The system uses autonomous flight intelligent techniques and image processing techniques.

2.3 Tools and Technologies

- **Platform - .NET Framework 4.0:** The .NET Framework is an essential component in windows operating system which helps in integrating distinctive programming languages like, C#, visual basic and visual C++. It compromise of Common

Language Runtime (CLR) and sets the class libraries. .net framework acts as bridge to make sure the interoperability between applications which are created using different programming languages. It makes improvements in reuse of code, code specialization, managing the resources, developing the applications, security and deployment of programs created in different programming languages. .NET Framework offers different web applications such as ASP.NET web forms, web pages and MVC in it [19].

- ✓ It provides consistent object oriented programming model across the different programming languages.
- ✓ Enables the code written in different languages to interact with each other.
- ✓ Cross-platform support specifies that windows platform which supports CLR can execute .net application.
- ✓ Ease of deployment.

- **ASP.NET:** ASP.NET is a web platform which is used to deliver the interactive and data-driven web applications over the web/internet. It is built on .net framework so that all the features of .net framework is available in asp.net applications which can be written in any platform that provides all the services that you require to build enterprise- language that is compatible with CLR, the major advantage of CLR is inheritance, type safety and many more. ASP.NET includes all the necessary services that are required to build the enterprise web application with minimum coding and provides access to class libraries in .NET Framework [20].
  - ✓ Better performance.
  - ✓ Cookie-less session.
  - ✓ Greater scalability.
  - ✓ Improved Security.

- **IDE:** ASP.NET and Visual Studio incorporate powerful tools within the IDE. User gets code editors that have the web baked in at their core. They can additionally understand that Cascading sheet selectors will work on the actual application

program, and immediately refresh a dozen connected browsers with browser link and then supply to administration then distribute the site to any server or the cloud[21].

- **SQL Server:** SQL server is a structured query language developed by Microsoft. It is a relational database management system, a software product developed with primary functions for storing and retrieving data as per other software applications request which may run on any computer across the network. It is designed as RDBMS to work with enterprise environment; SQL Server is extensions from Microsoft that includes several features in it such as exception and error handling, transaction control, row processing and many more [22].

2.4 Hardware and Software requirements of multithreaded software system for an autonomous hexacopter

The software requirements specification of multithreaded software system report enlists enough and important necessities that are required for the task improvement and usage. To portray and infer the fundamental necessities we need a reasonable and through comprehension of the product to be developed and deployed.

Tools Used:

Software Requirements:

- Integrated Development Environment : Visual Studio 2010
- Front end : ASP.NET 4.0
- Back end : SQL Server 2008

Hardware Requirements:

- Operating System : Windows 7
- Processor : 1GHz
- RAM : 1GB
- Disk Space : 4.5GB

Chapter 3: Software Requirements Specification

This chapter gives the detailed explanation of general description, functional and non-functional requirements along with assumptions and dependencies and external user interface, performance requirements, design constraints.

Software requirement specification diminishes the effort, time and cost required for performing to achieve the desired goal by developers. A decent SRS is one which depicts how the application will connect with the equipment of the framework and clients in a wide assortment of genuine circumstances, it additionally assesses the parameters, for example, working pace, reaction time, accessibility, convey ability, practicality, security and pace recuperation from antagonistic occasions [23][24].

The basic idea of a multithreaded software system for an autonomous hexacopter is to build and implement the autonomous system to make farming more productive and efficient. The autonomous hexacopter allows farmers ability to scout, diagnose and identify the affected region and irrigation blockages in an agricultural setting using UAV in conjunction with thermal cameras in less time.

- ## Definitions, Acronyms and Abbreviations

  PID- Proportional-Integral-Derivative.

  UAV- Drones are commonly known as unmanned aerial vehicles, an aircraft without a human pilot [25].

  GPS – Global Positioning System is a space based or satellite based navigation system [26].

  Hexacopter – It is a multirotor UAV with six motors, it is commonly referred as 6-motor helicopter.

  Radio Controller – It is used to control any device with help of hand-held radio transmitter

  Throttle – A device used to control the flow of fuel or speed of engine.

  Yaw– A moving aircraft

  Roll– Moving in a particular direction

Thermal camera – A non-contact device that detects infrared rays and converts into electrical signal to produce the thermal images

Autopilot – Automatic pilot [27].

GUI – Graphical User Interface [28].

Gimbal – A device to support the camera as horizontal in moving vehicle

Sensors and actuators– Sensors is a device that detects, measures, records and respond to a physical property, actuators is responsible for moving or controlling the mechanism of the system [29].

- **Overview:** A Software requirement specification is that the whole description of behavior of the system to be enforced. It defines the general description, user characteristics, general constraints, assumptions and dependencies and other system behavior like functional requirements, external interface requirements, and performance requirements of the product along with nonfunctional requirements.

General Description

- **Product Description:** The project involves the formation of test cases for every given input through sensors and GPS systems. The PID controller algorithm implemented in trajectory planning will perform the operations to possess the ability to hover on the spot in the fields and the images captured through thermal cameras will be extracted using suitable image processing algorithm
- **Product Functions**
  - The core system involves the interactions with sensors and actuators to provide the sample inputs to the system.
  - Trajectory planning will be done with suitable algorithm implementation.
  - Images are captured using thermal cameras with the help of sensors and GPS trackers the objects are detected based on the location.

3.1 User Characteristics:

People who mainly use this product are:

Farmers: Farmers and decision makerslike middle men's and market vendors can obtain all the required information with minimum delay to enable management decisions based on the crop status. The autonomous hexacopter allows farmers ability to scout, diagnose and identify the affected region in agricultural setting using UAV in conjunction with thermal cameras in less time, and they can improve their agricultural methods in terms of production.

- **General Constraints**
    1. Farmers and decision makers like middle men's and market vendors has privilege to change the auto settings of the system.
    2. Farmers and decision makerslike middle men's and market vendors can change the properties of the system.
    3. Farmers should have prior knowledge about the climate conditions to fly the hexacopter.
    4. The code should be optimum and should follow the industry standards.
- **Assumptions**
    1. Basic knowledge about handling the hexacopter in terms of given sample inputs and GPS based navigation techniques based on the different plantations in the field.
    2. Along with the agricultural field knowledge the farmers should have an basic knowledge about image processing technique to extract the images to detect the object as per the given requirements.
    3. Assuming the hexacopter flying speed, height and distance for the given flight time span.
- **Dependencies:** Smooth working of software depends upon certain resources
    1. Hardware and software components must be well organized.
    2. Complete hovering of hexacopter depends on the climate conditions.
    3. Hexacopter must be dependable on FailedSafeMode landing techniques.
    4. Full time connection between sensors, GPS trackers and Radio controller must be fixed.

3.2Functional Requirement: The project includes mainly two major modules handling the hexacopter and object detection using image capturing techniques.

- **View Module:** It gives complete outline of the hexacopter status before it start flying.
    1. Input – Verify the status of all the components.
    2. Processing – Based on previous status the current input status of all the components will be verified and modified.
    3. Output– The status of all the components are in good condition and ready to hover.
- **Auto setup Module:** Initial setup of the inputs are given and verified.
    1. Input – Temperature, wind speed, cruise speed are given as input to the climate conditions setup.
    2. Processing – Based on the current climate conditions the given inputs are verified and modified.
    3. Output– Successful initial setup is done for climate conditions.
- **Gimbal setup Module:** Gimbal setting is done for the thermal cameras.
    1. Input – Gimbal switch, manual control, automatic control, camera time slot are given as input.
    2. Processing – The camera is switched on along with the speed control of the hexacopter.
    3. Output– Images are successfully captured with the help of gimbal setting.
- **Autopilot Module:** It gives default flight mode during hover in the air.
    1. Input – Basic gain and FlightSafeMode landing techniques are initialized by default.
    2. Processing – It automatically switches to autopilot mode when the multirotor come across the obstruction less in the air
    3. Output–Successful fly and landing of hexacopter.

External Interfaces Requirements

- **User Interface Requirements:** The user interface for installing the framework is perforce. This is used to get latest developed automation code. The Visual Studio IDE can be used to trigger the automation.
    - User interface takes place through the keyboard to give different input values and mouse to control the hexacopter in air along with capturing the image.

- **Performance Requirements**
  - The application should be responsive at any point of time during the execution.
  - Prominent flight speed must be there while capturing the images during the fly in air.
  - The interaction with the ground station and hexacopter must be good to achieve fault tolerance.

Design Constraints

- **Standard Compliance:** The project should follow the norms specified by the users/clients. Performance should not be an issue because interaction between front end tool and back end tool is done using the visual studio IDE. The generated output which shows the results of each sample input must be easier to understand and identify the problems and verify manually.
- **Hardware Limitations:** The framework needs 10GB RAM during its execution. Else there is a chance that automation may break due to out of memory error.Front-End Development tools are focused on the user interface and user experience.

3.1Non Functional Requirements

- **Availability:** The availability of application or software refers to ensure the use of application at any point of time, irrespective of the location and climate conditions.
- **Security:** The security of application refers to be safe and secure to ensure the integrity of the application such that there is no harm to the users and users data by any means.
- **Portability:** With the minimum requirements the application must be compatible and capable of working on any platform.
- **Reliability:** The changes made in the front-end with various different inputs must be reflected in backend in order to check the working of the application during the rise of problems.
- **Usability:** The application must be given with well-structured user manuals, well-formed GUI’s for the users to learn how to operate the system.

Chapter 4: System Design

This chapter gives the detailed design and explanation of system perspective, block diagram, data dictionary, module specifications and context diagram.

4.1 System Perspective

Problem Definition: In the large and open and obstruction less areas it is a known fact that a plants health can be told by its thermal image using UAV where Plant leaves absorb most wavelengths of visible light but it reflect green light and also the invisible infrared light. The reflection of green light is attributed to chlorophyll and other pigments, while infrared reflection is from the internal structure of the plants leaves. Unhealthy plants reflect less infrared light and this difference can be detected using a thermal imaging camera which causes disease, pest infestation, frost and water stress in the plants. This leads to practical applications, for example: pesticides can be selectively applied only to affected regions and irrigation blockages can be detected and fixed early. UAVs are being used in conjunction with thermal cameras in an agricultural setting, but the process is yet to be atomized.

Block Diagram

Block diagram are represented as alignment of diverse figures how the components of a system are interrelated to each other and how the dependency is created between each other. It also includes the system operations and inputs to be supplied to the application at various stages and how the work flow of system produces the output at every stage through the execution of the process [30][31]. The below block diagram gives the clear view about the various components involved and work flow of interaction between the components of multithreaded software system.

Figure 4.1: Block Diagram of autonomous hexacopter

The Figure 4.1 includes major 3 phase's in block diagram with input data collection, trajectory planning and image capturing phase's. The requirement analysis is the collection of data related to the trajectory planning and image capturing techniques, later pre-deployment flight planning and field deployment planning are calculated based on the inputs given from sensors and actuators. Based on the given input GPS preprocessing and initial climate, speed, camera settings are done. Each initial setup is cross verified with sample input to capture the image during the hover in the air.

Data Definition/Dictionary

Table 4.1: Auto setup Module

Field Name	***Type***
Flying speed	Integer (primary key)
Cruise speed	Integer
Wind speed	Integer
Tilt	Integer
Summer	Integer
Winter	Integer
Vertical	Integer
Horizontal	Integer

Table 4.1 describes the database design of the auto setup module of autonomous hexacopter which stores climate data in database.

Table 4.2: gimbal setup

Field Name	***Type***
Output	Integer (primary key)
m_pitch	Integer
m_roll	Integer
a_pitch	Integer
a_roll	Integer

Table 4.2 describes the database design of the gimbal setup module which stores the basic gain values in the database

Table 4.3: Auto pilot mode

Field Name	***Type***
Pitch	Integer
Roll	Integer
Yaw	Integer
Vertical	Integer

Table 4.3 describes the database design of the auto pilot setup module with pitch, roll, yaw, vertical data are stored in database.

- ## Module Specification

Module 1: View: This module provides the complete outline of the components used in hexacopter.

- View module mainly gives the status of battery by verifying it.
- It checks and verifies GPS and camera status.
- It gives the safe landing options with start point and safe landing.

Module 2: Auto setup: This module provides the initial setting for hexacopter to fly in the air.

- Auto setup ensures the climate conditions in order to fly the hexacopter in the air.
- It ensures initial setup along with throttle, pitch, roll, yaw settings.
- It ensures the position hold accuracy, cruise speed, crosswind speed, and maximum tilt.

Module 3: Gimbal setup: It ensures the camera settings along with the speed of the hexacopter.

- Image capturing technique includes gimbal setup in order to capture the images.
- Manual control and automatic control speed has to be verified for every second in order the capture the proper images with respect to the desired height and distance of the area.
- If any obstructions occur during the hover in the air it has to make sure to land under FailedSafeMode technique.

Module 4: Autopilot Mode: It maintains the default setting mode during the fly when obstructions arise.

- It ensures the autopilot mode when there is problem in the hexacopter in the air.
- It ensures the control on hexacopter during the emergency changes in the input.

- It ensures the safe landing of hexacopter at given range of setup.

4.2 Context Diagram

A Context Diagram is a drawing that outlines the border associated with the organization, or a part of a system, and its surroundings, demonstrating the units that collaborate with it. This illustration basically is a high level view of a structure to be represented. It is believed that a context diagram in general terms is similar to a block diagram [32]. The below context diagram gives the clear view of input and output control flow of multithreaded software system.

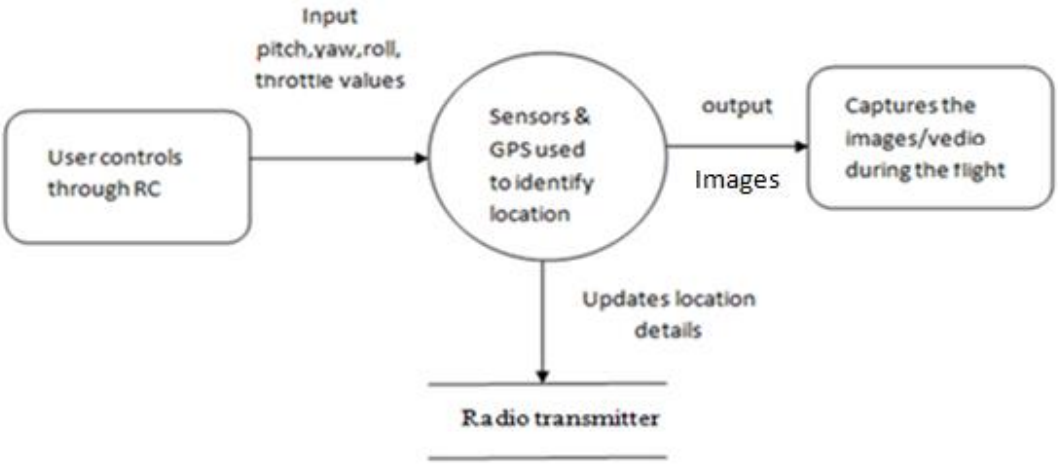

Figure 4.2 Context diagram of autonomous hexacopter

The Figure 4.2 represents the entities associated with the system and also discusses about the external sources that interact with the system. Initially hexacopter is handled by radio controller with respect the inputs such as basic gain pitch, yaw, roll, throttle values are recorded by sensors and GPS in order to identify the location and capture the images of infected region in the plants. The outputs generated during the hover will be updated in the radio controller along with location details to cross verify the working of autonomous hexacopter.

Chapter 5: Detailed Design

This chapter gives an overview about the brief description of system design along with all the UML diagrams and Data flow diagrams, and it also describes about the detailed design approach followed in the implementation.

- **Object Modeling:** this model mainly describes about the various classes their attributes, functions and their relationships with each other. This project mainly identifies three different classes as the main classes that are very much involved in major activities that are related to the function of application [33]. The identified classes are admin, view, gimbal, and autopilot and auto setup.
- **Dynamic Modeling:** This modeling is basically used to definite the behavior of the system over time [34]. The various diagrams associated with this modeling concept are:
  - Use case Diagram of autonomous hexacopter
  - Sequence diagram of autonomous hexacopter
  - Activity diagram of autonomous hexacopter
  - State machine diagram of autonomous hexacopter.
- **Functional Modeling:** This model specifically describes the concepts of transformation of data that is how the outputs are derived from given inputs and produces a list of results related to such computations. With respect to the project, first identify the inputs and outputs at first level. Construct related data flow diagrams, describe functions associated and identify various constrains as a part of functional modeling [35].

5.1 Class Diagram

Class diagram provides the graphics notation for modeling classes and their relationships by depiction the attainable objects. They're helpful for abstract modeling and for planning the particular programs. They are clear and easy to understand and work well in practice; we can use class diagrams to represent the structure of applications [36].

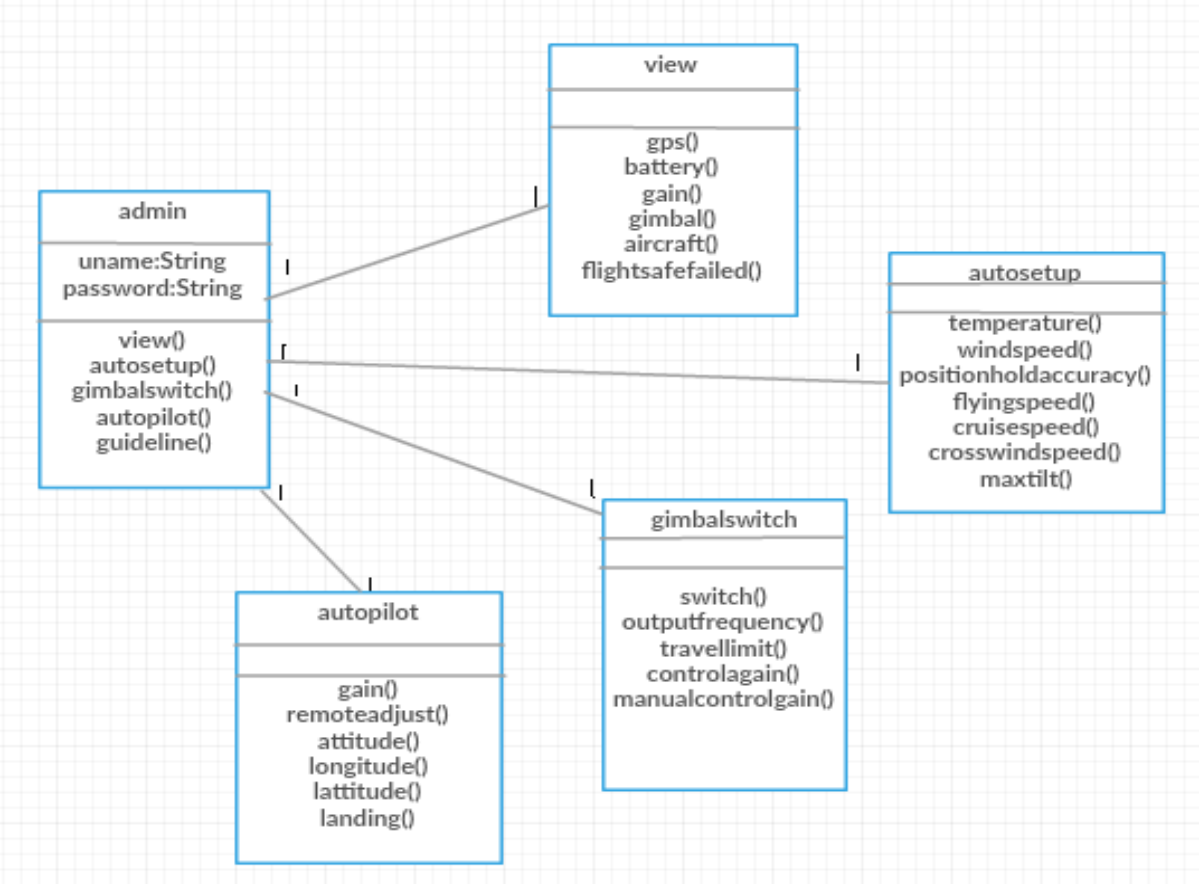

Figure 5.1: Class Diagram of autonomous hexacopter

The Figure 5.1 represents the class diagram with its classes, attributes and operations and relationship between the objects. The relationship between each class is one to one relationship where user is the admin who controls entire process flow of the application.

5.2Use case Diagram

A system includes a collection of use cases and set of objects. Every use case constitutes a slice of functionality that system provides to point out the entire functionality of the system at some level of detail. Equally each and every set of actors constitutes the whole set of objects that the system will serve [37].

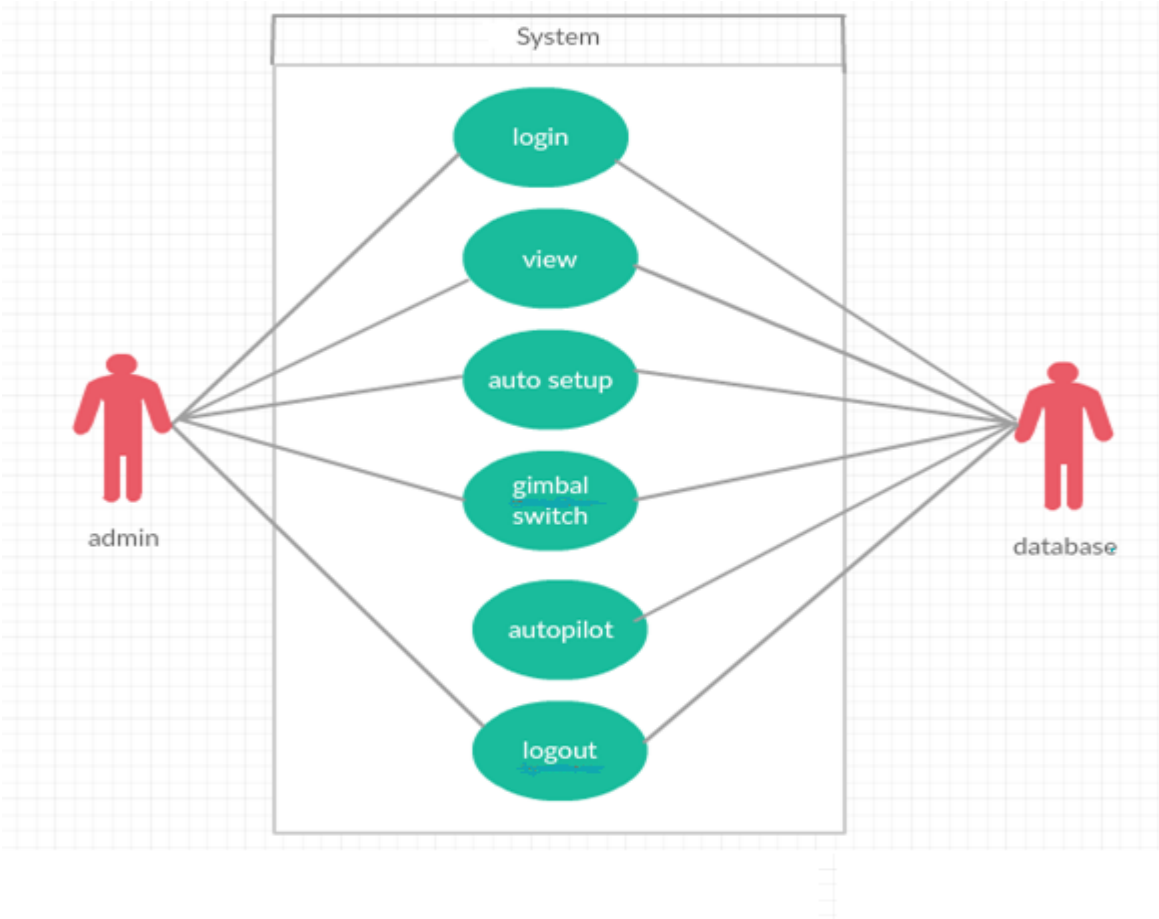

Figure 5.2: Use case Diagram of autonomous hexacopter

The Figure 5.2 clearly shows the interactions that take place within the application and the database; it clearly talks about various collaborations that takeplace during the development phase of the application.

5.3Sequence Diagram

Sequence diagram typically demonstrates the applicants involved in the collaboration and therefore the sequence of messages that stream between them. Sequence diagrams clearly describe the stream of messages between objects. Essentially seems to be additional advantageous once there are two objects so that their flow may be clearly shown. Thus sequence diagram show the contributors in an exceedingly communication and the sequence of posts among them [38].

Figure 5.3: Sequence Diagram of autonomous hexacopter

The Figure 5.3 indicates the steps involved in development of the front end of the multithreaded software system in a modular view indicating each sequence of activities associated with each phase of development and the order in which they are carried out in a systematic manner. The sequence diagram represents how the user interacts with the system; the sequence diagram is composed of user, view, auto setup, gimbal setup, auto pilot and database. Initially user logins to the system and review the outline of the hexacopter, later the initial setting and resetting of auto setup mode is done with appropriate input values, camera settings are updated with respect to the manual and automatic control gain, and in auto pilot mode the default mode settings can be done by switching between manual control gain and default control gain over the multirotor hexacopter.

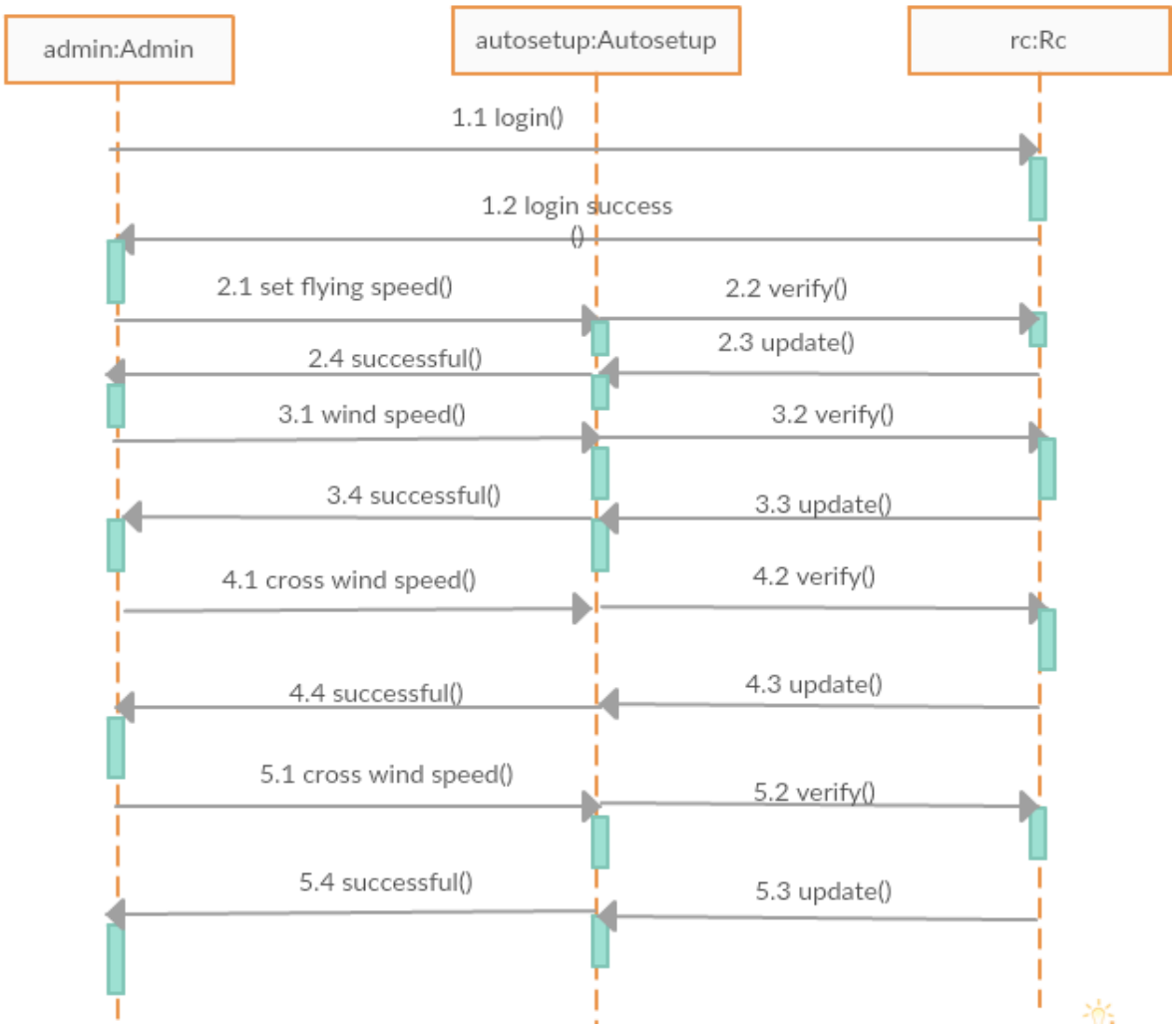

Figure 5.4: Sequence diagram for auto setup module

The Figure 5.4 describes the sequence diagram of auto setup mode where the climate conditions like temperature is set according to summer, winter and rainy seasons with a maximum range, the position hold accuracy range with vertical and horizontal position values, the distance covered by the speed of the hexacopter, the speed has to be specified according to the cruise speed and cross wind speed range along with the maximum tilt angle in the air in order avoid the collisions. The entire area covered by the drone can be calculated with respect to the seconds, hours based on the speed of the drone.

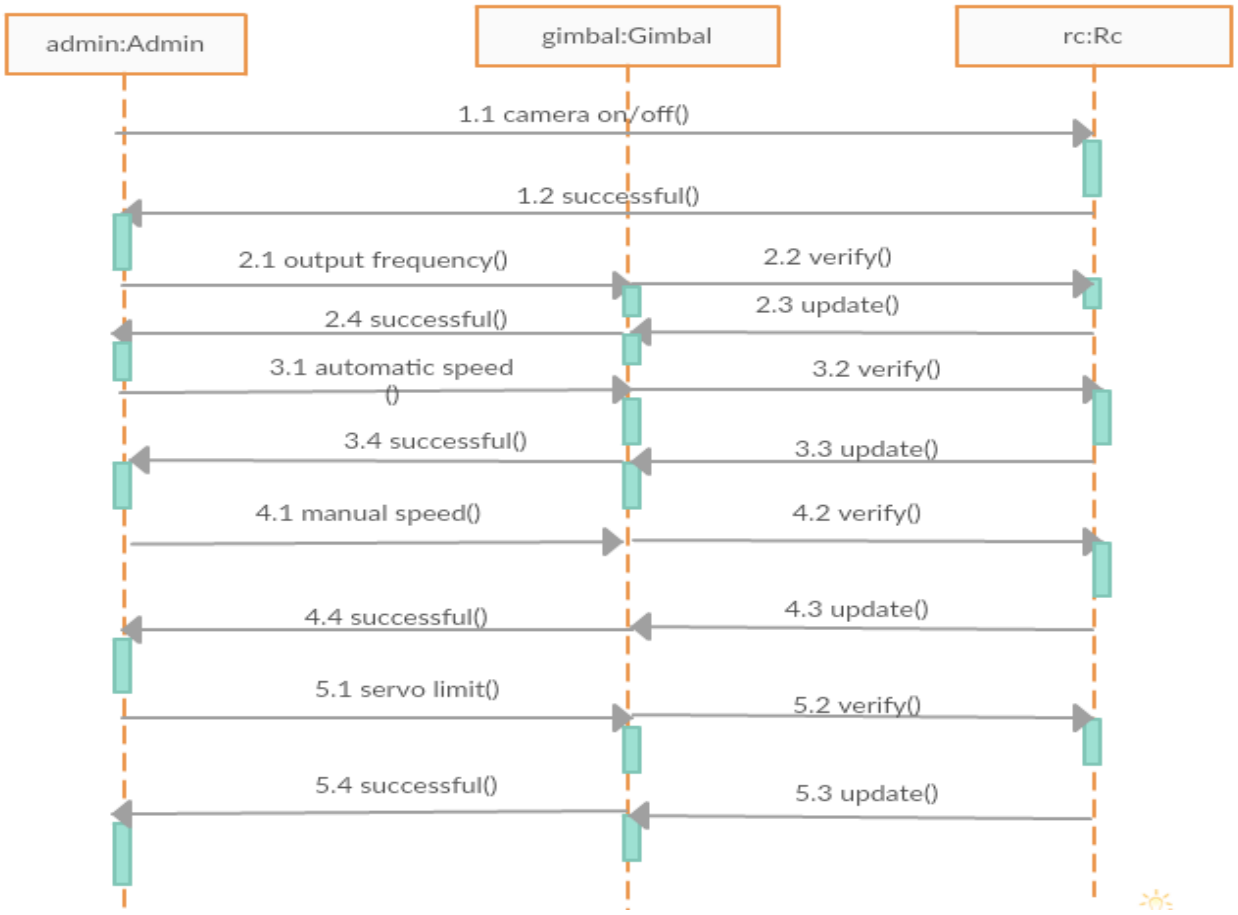

Figure 5.5: Sequence diagram of gimbal setup module

The Figure 5.5 depicts the initial setup for the thermal camera used to capture the images in hexacopter. Before the flight take off the camera setting must be done and cross verified such as camera switch, output frequency range must be set, to gain the control over the hexacopter automatic and manual control gain must be set with respect to the speed range and a travel servo limit must be specified to gain the immediate control over the drone when it is in air along with position hold accuracy with vertical and horizontal range values.

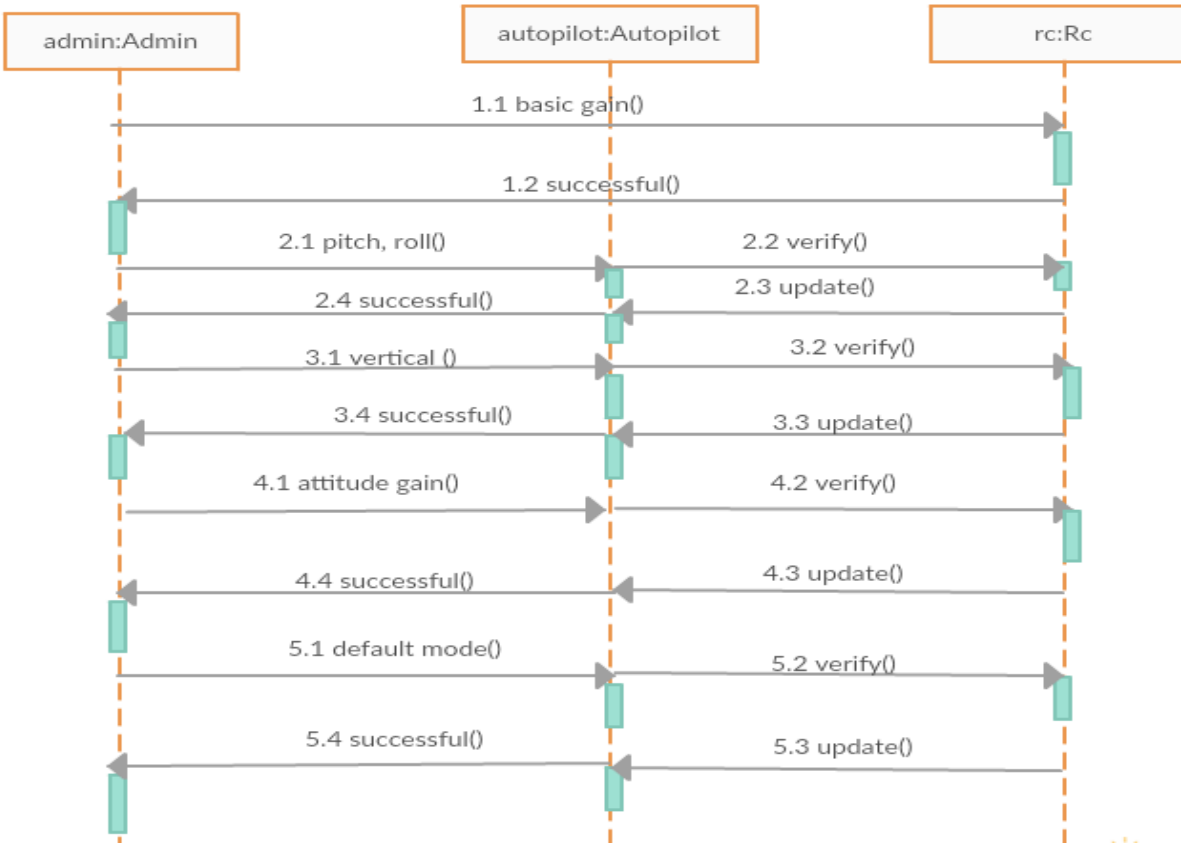

Figure 5.6: Sequence diagram of autopilot mode

The Figure 5.6 shows the auto pilot mode of the hexacopter, it helps the user to get control over hexacopter in the air when the multirotor is out of control due obstructs in the air or high speed.

5.4 Activity Diagram

The progressions of a movement are operations, specifically activities from the state model. Few activities run everlastingly until an external event interrupts them; however many activities eventually finish their work and terminate. The end of associate activity is ending of event and frequently point outs the successive activity to be started. The operations and events carried out in multithreaded software system are described in the given figure below [39].

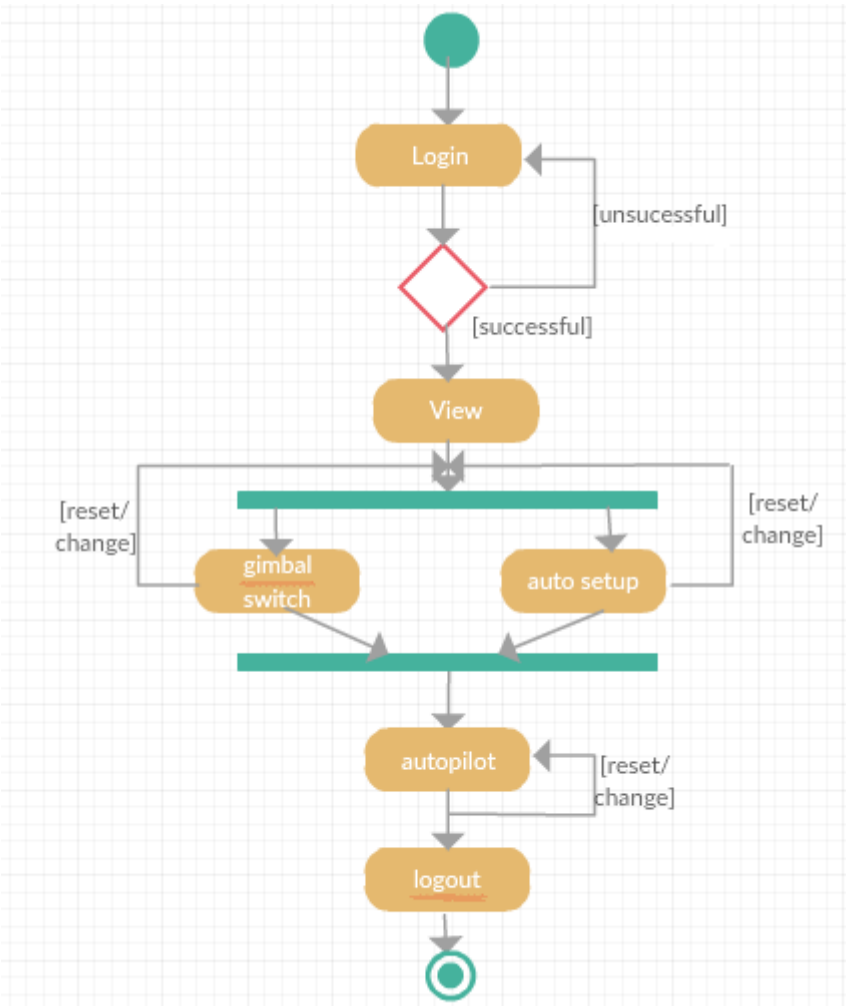

Figure 5.7: Activity Diagram of autonomous hexacopter

The Figure 5.7 represents the activity diagram that describes the set of activities that takes place in development of the application. The activities are represented module wise which describes the actions at each stage.

5.5 State Machine Diagram

The state diagram nodes in graph are states and directed arcs are movement between states. It indicates sequences states that cause events. State names should be distinctive within the degree of a state diagram. All the objects in a class executes the diagram for that class, this modules their essential behavior [40][41].

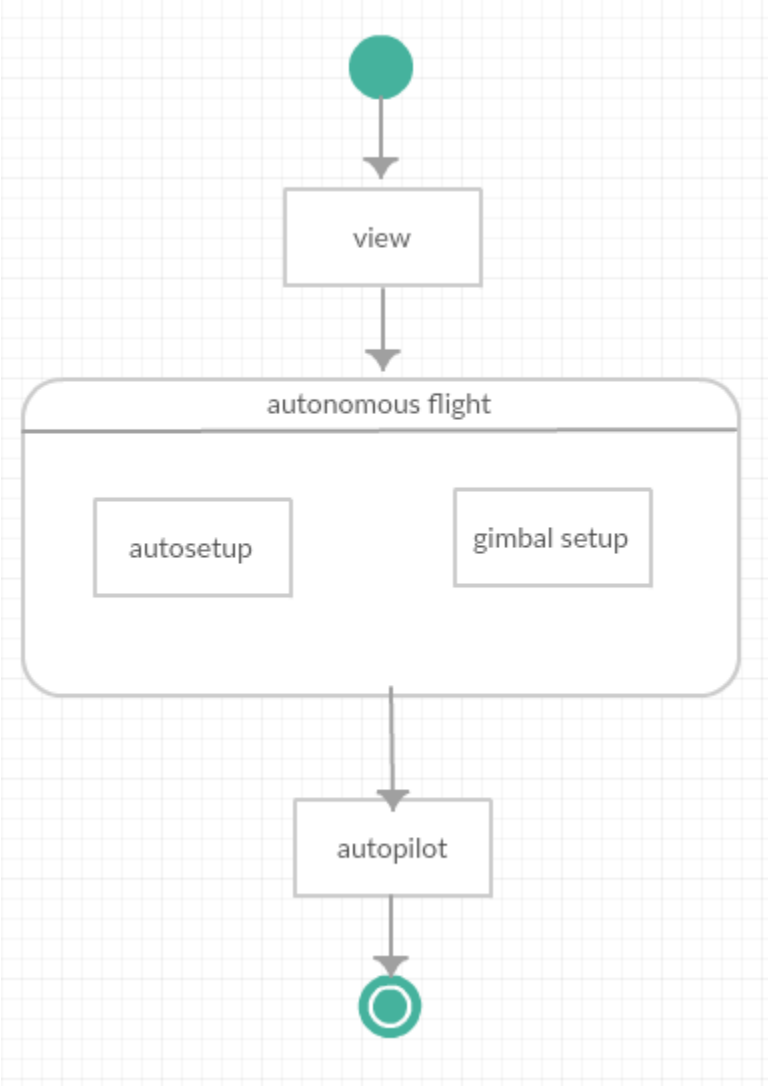

Figure 5.8: State machine diagram of autonomous hexacopter

The Figure 5.8 depicts the states associated in designing the chat application, identifying the chat application as a state; consider the modules as various sub states associated within the main state.

5.6 Functional Modeling

Data Flow Diagram shows the flow of information among the different progressions in a system. It is a pictorial representation that depicts the flow of data and transformations that are applied as data moving from source to destination. It describes in a simple and easy way without concentrating on the facts of the system [42].

Level 0

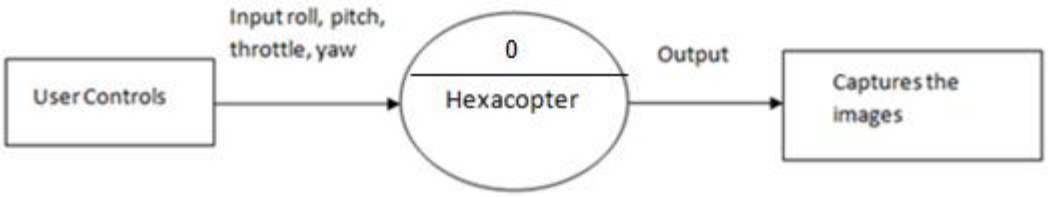

Figure 5.9: DFD of multithreaded software system for an autonomous hexacopter

The Figure 5.9 shows complete flow of data at a minute level starting from user controlling the hexacopter and capturing the images during the fly. The inputs are pitch, roll, throttle, yaw as basic gain values to control the drone during the hover to capture the images.

Level 1

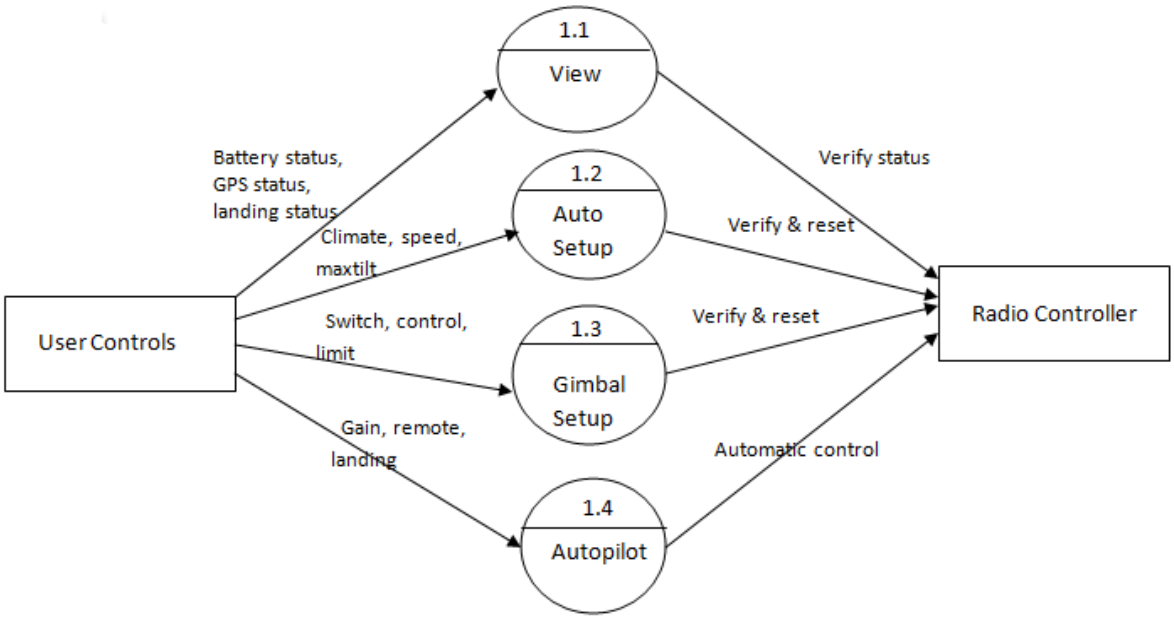

Figure 5.10: DFD of a multithreaded software system for an autonomous hexacopter

The Figure 5.10 shows the data flow of application detailed view indicating each flow of process at every point and how the modules work according to user control. It depicts the inputs given for the individual modules and the output generated.

Level 2: Data Flow Diagram of View Module

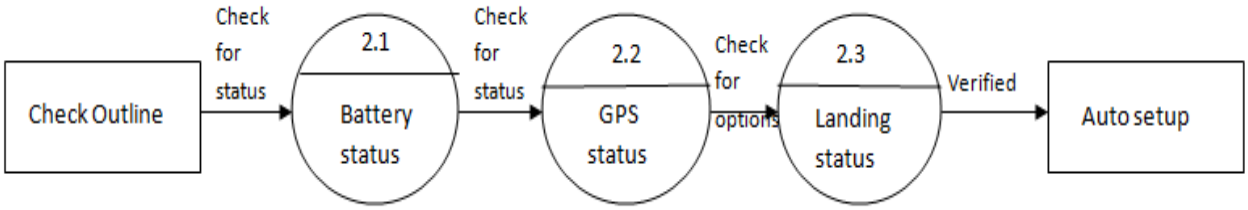

Figure 5.11: View Module

The Figure 5.11 indicated data flow diagram of view module with battery status, GPS status with X axis, Y axis and Z axis values, options is given for landing the hexacopter; this module mainly depicts the initial status of the drone when it is switched on.

Level 2: Data Flow Diagram of Auto setup Module

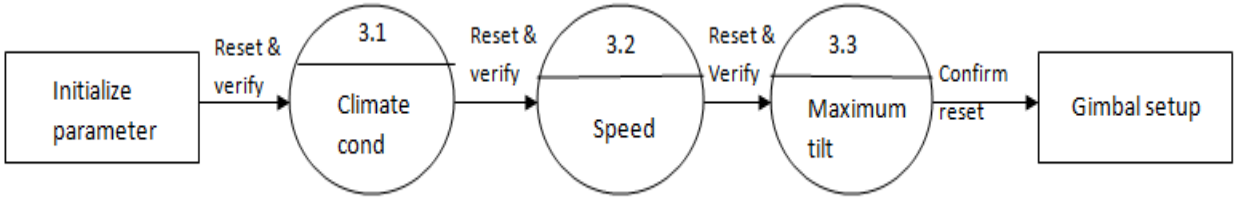

Figure 5.12: Auto setup Module

The Figure 5.12 indicated data flow diagram of auto setup module with the climate conditions has to be set according to different seasons like summer, winter and rainy, the speed of the drone has to be reset and verify with respect to different range so that it should be capable of flying in air without any problem, the maximum tilt of the multirotor is set in order to avoid the collision in the air.

Level 2: Data Flow Diagram of Gimbal setup Module

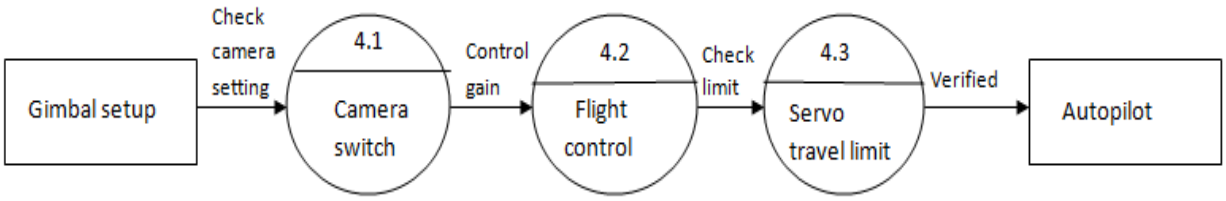

Figure 5.13: Gimbal setup Module

The Figure 5.13 indicated data flow diagram of gimbal module with camera settings with camera switch, output frequency range and flight control gain and travel servo limit is set to check and verify the control over the speed while capturing the image.

Level 2: Data Flow Diagram of Autopilot Module

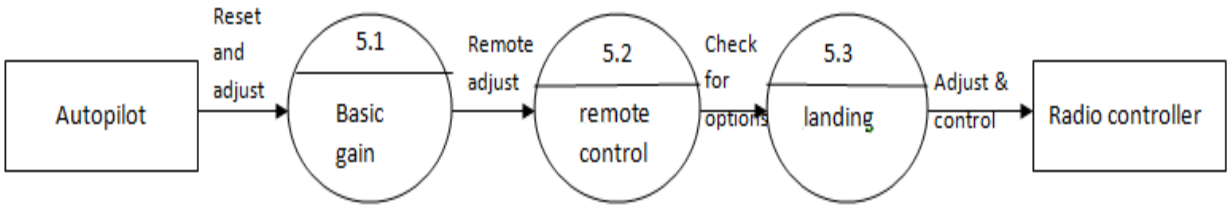

Figure 5.14: Autopilot Module

The Figure 5.14 indicated data flow diagram of autopilot module with basic gain of the hexacopter speed using remote control to land the multirotor safely. The input is given to reset and adjust the basic gain values i.e. pitch, yaw, roll and throttle along with remote control with landing options at starting point and current position.

Design Decisions: The implementation of multithreaded software system for autonomous hexacopter includes Object Oriented Modeling Approach as it allows the developers to measure the performance of various modules individually. The unique feature associated with this approach allows enables the developers to add objects to the system without any risk or effect. This feature of adding and creating new objects and modules with less effort and the newly created object inherits many of its features from prevailing objects this makes OO approach easier and makes its difference from procedure oriented approach.

Chapter 6: Implementation

This chapter 6 defines the implementation of the project along with the screen shots of each module to depict the working of each module.

6.1 PDL for Multithreaded Software System

PDL for Auto Setup Module

Input: Enter the user inputs for Climate conditions

Read the user input for climate conditions

Categorize the climate conditions and speed.

If the input is invalid

Display the error/ warning message

Else

Accept the user input

End if

Output: Inputs are verified and connectivity is established between the forms

PDL for Gimbal Module

Input: Enable the camera with speed limit

Read the user inputs

If the speed limit is invalid

Display the error/warning message

Else

Accept the speed limit range

Endif

Output: Connectivity is established between the forms

PDL for Auto pilot Module

Input: Enter the automatic and manual speed range

Read the user input

If the automatic and manual speed range is invalid

Display the error /warning message

Else

Accept the automatic and manual range speed

End if

Output: Connectivity between the forms are established

6.2 Implementation: The implementation section includes the screen shots of the autonomous hexacopter with detailed description of each and every module.

Figure 6.1: Main form

Figure 6.1 depicts the main form of the multithreaded application for an autonomous hexacopter with different menu options to access the application; it includes mainly login page, instructions and components page with instructions and specification kit of the drone, view module, auto setup, gimbal setup, auto pilot options.

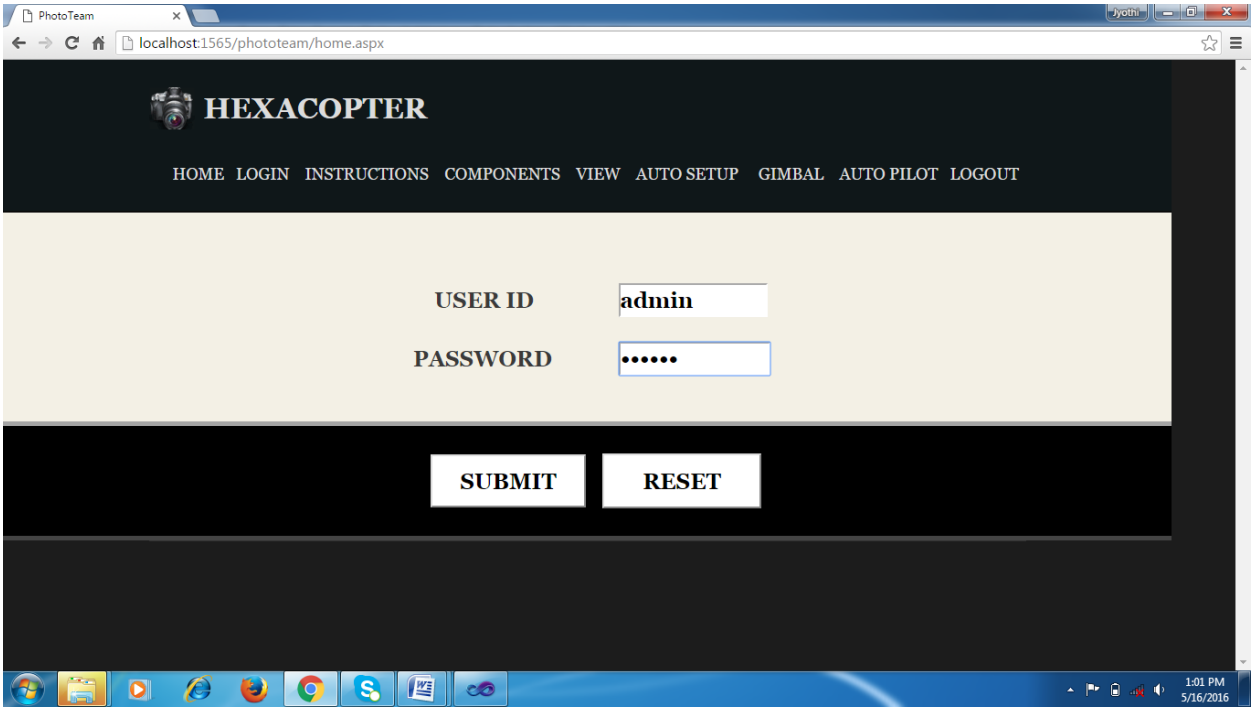

Figure 6.2: Login page

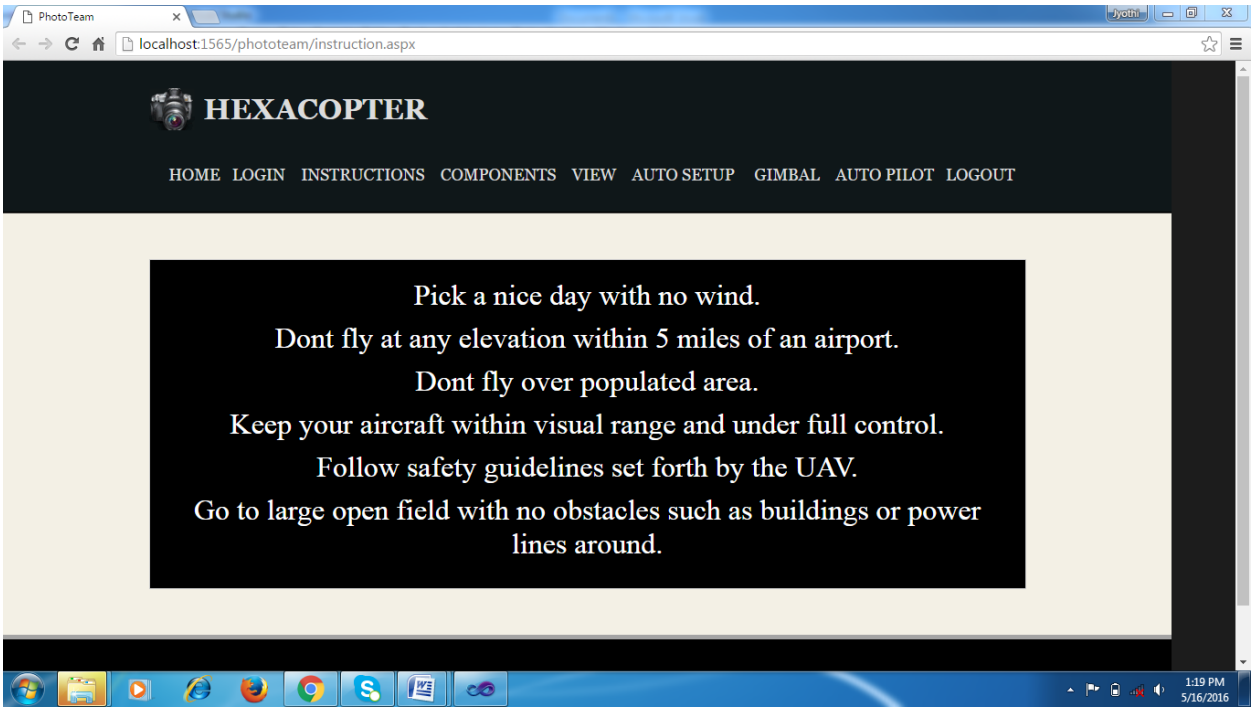

Figure 6.3: Instruction page

The Figure 6.2 shows the user login with appropriate login id and password to access the multithreaded software system; the login module is associated with authentication.

Figure 6.3 shows the instruction to be followed before flying any multirotor in the air, the users has to follow the instruction given.

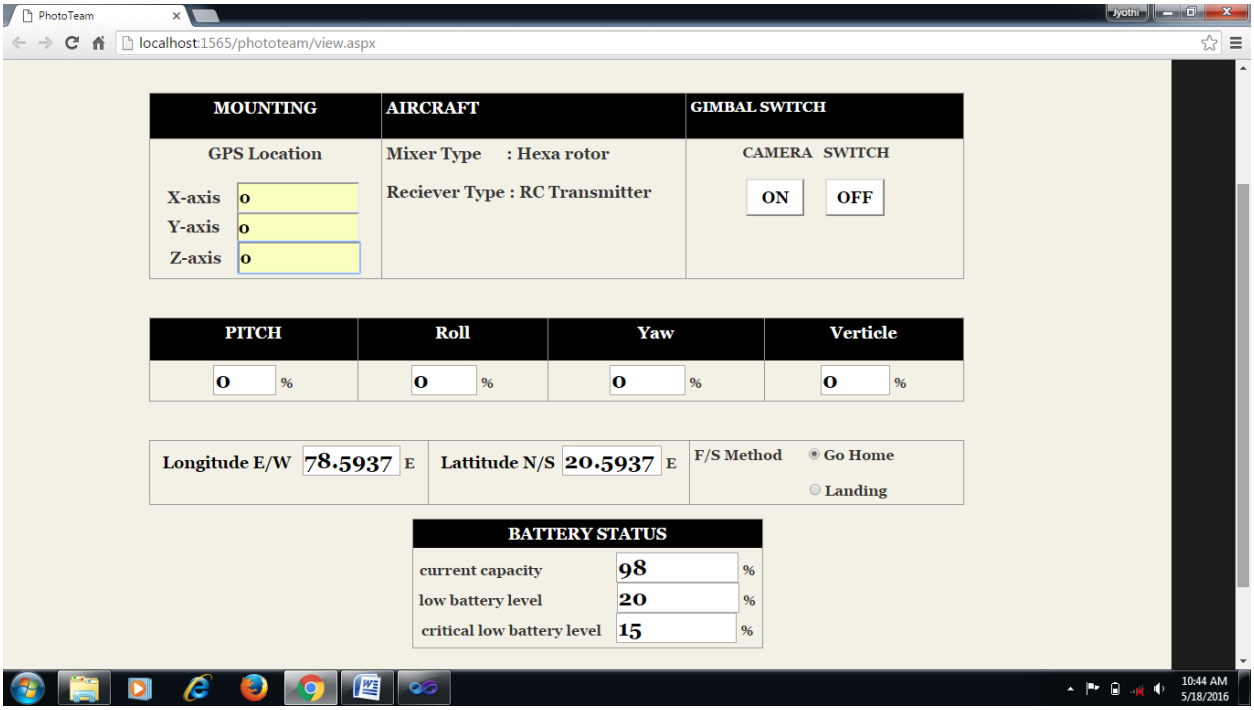

Figure 6.4: View Module

Figure 6.4 shows the complete outline of the hexacopter with aircraft type and RC type, when the hexacopter is initially switched on to fly, it consist of battery status with current capacity, low battery level and critical low battery level values, the longitude and latitude values are pre-entered with respect to the location, flight landing safe modes are given with Go Home and Landing options, GPS Location basic gain with X, Y, Z axis values are specified to gain the control over the flight in air along with camera switch on and off options.

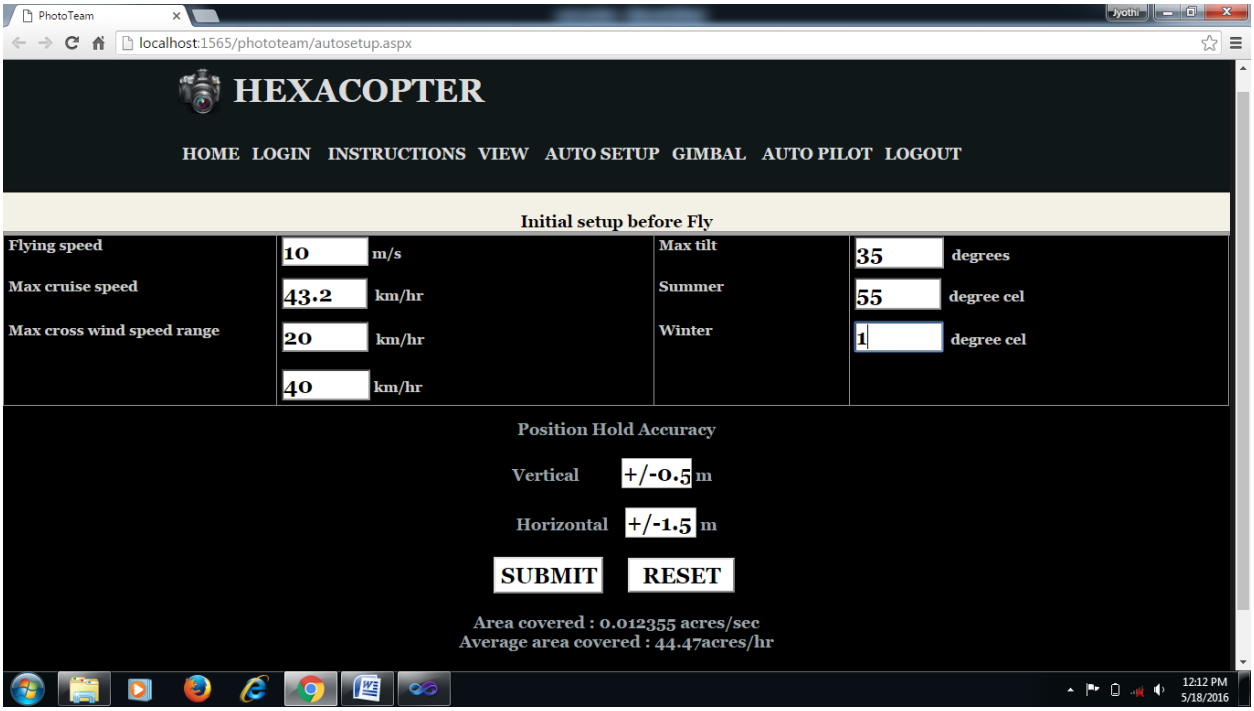

Figure 6.5: Auto setup Module

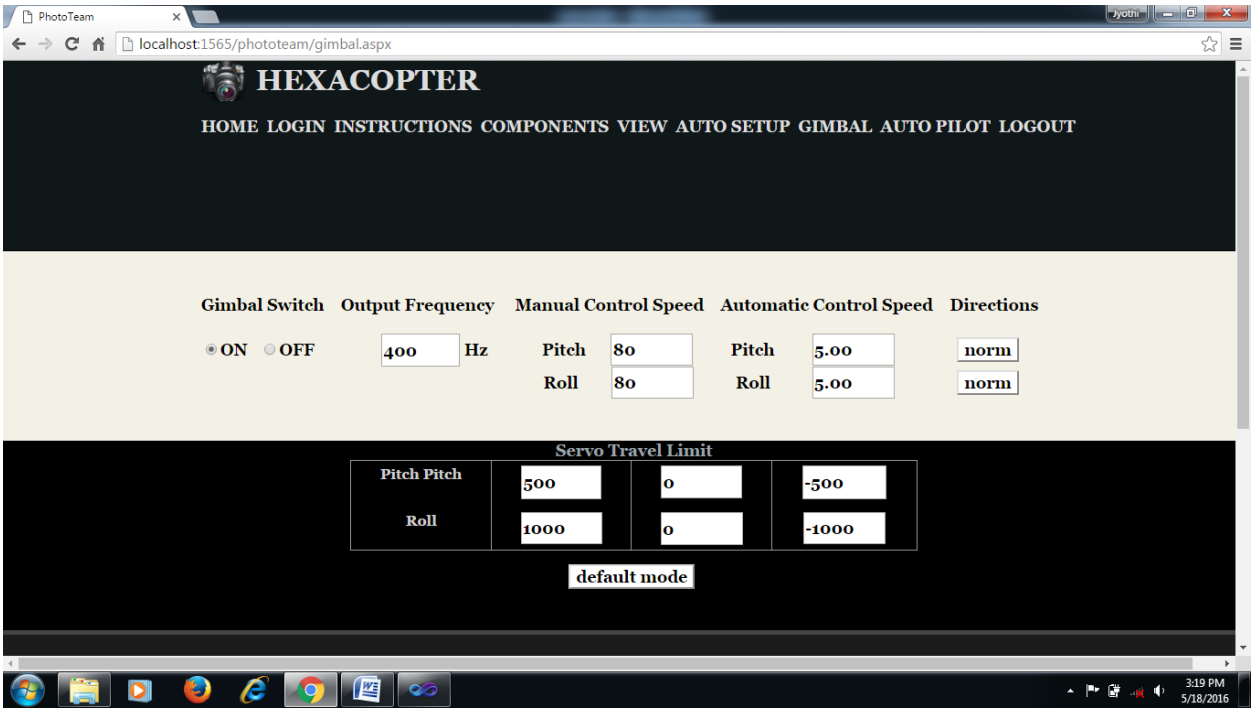

Figure 6.6: Gimbal Module

Figure 6.5 shows the initial conditions setup for hexacopter before flying in the air based on the climate changes now and then, along with it; it also includes position hold accuracy range. The distance covered by drone is calculated with respect to the seconds and minutes to estimate overall time taken to cover the entire area.

Figure 6.6 shows the camera setting during the fly in the air based on manual and automatic control gain speed, it mainly consist of servo travel limit to control the speed of hexacopter in air in order to capture the images properly.

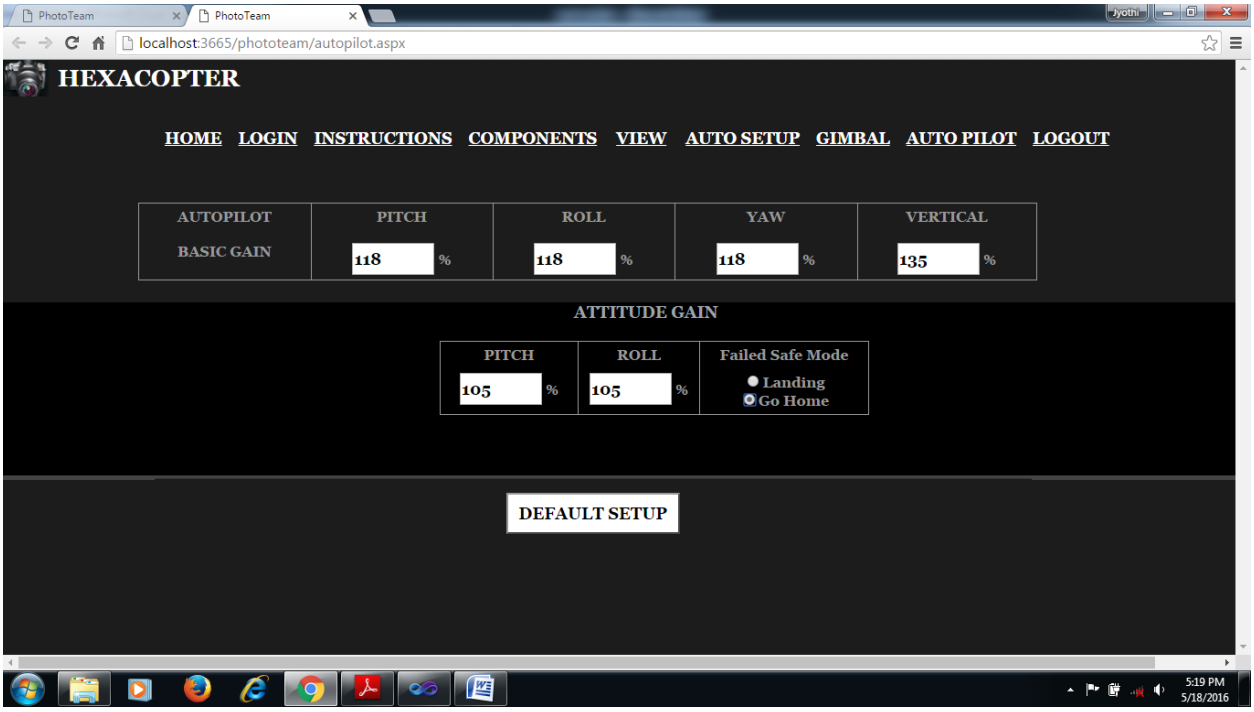

Figure 6.7: Auto Pilot Module

Figure 6.7 shows the auto pilot mode setting i.e. default setting mode when hexacopter goes out of control during the hover in the air then the entire multirotor can be controlled by switching to auto pilot mode which includes basic gain pitch, roll, yaw, vertical gain with default values pre-defined along with failed safe mode options. When user clicks on the default setup mode button then automatic control will be gained over the drone immediately and multirotor can be landed safely.

Chapter 7: Software Testing

This chapter involves the different testing techniques carried out on the product. It conjointly depicts the screen shots in conjunction with the various attainable test cases.

The software development cycle does not restrict to software development but also includes testing portion too, in order to ensure the standards of the work. It is one of the critical section of any product improvement. Basically it is carried out by a team of testers the results and actions are recorded in a test document which will be kept for future reference. While performing the testing in case if any hug bugs are found then the product is sent back to the development team to rectify the same and rebuilt. The test cases are performed in multiple ways just to ensure the developed product is bug free and works according to user requirements [43].

The process of testing mainly eliminates the minor issues such as undesirable lines in the code and includes the remarks as per requirement and optimizes the code as indicated by the commercial standards.

- **Test plan** – It is a document which showcases the details like reason for testing, scope of testing, risks involved, environment, timeframes, objective of testing and in charge person of testing team along with scheduled time and date [44].
- **Test case** – It generally shows the details of product to be tested such as test case id, summary, procedure, inputs used and outputs generated [45].

Automation testing and manual testing are the two major techniques used in software testing in today's work culture. Manual testing is done without using any testing tools while automation testing is done with some automated testing tools using test scripts. Cost involved in manual testing is comparatively less to the automated testing techniques. And time consumption in automation testing is less compared to manual testing due to the usage of automated testing tools [46].

7.1 Test Cases

- **Unit testing:** Unit testing is defined as preparation to perform testing on units of implemented code. It clearly helps is identifying the faults in the logic associated or algorithms in individual units [47]. Once unit testing is done then the function is said to be error free or else the function part has to be recorded and tested again and again. Stubs and Drivers are most associated part of unit testing, where drivers basically work on calling unit and stubs works on called units. They both allows the reuse of functions so that the constant changes in the application can be tested repeatedly without incorporating complex coding lines in test code [48].

➢ **Unit Test Case Summary for Alert/Notification module**

Table – 7.1: Unit Testing For Alert / Notifications

Tc_Id	Feature Tested	Sample Input	Expected Output	Observed Output	Results
Tc_H101	Null/no input	No data should be entered	Message should be displayed as no user input	Alert message displayed with error	Pass
Tc_H102	Wrong/invalid Input data	Erroneous data to be submitted/entered	Message to be displayed is invalid user input	Alert message displayed with error	Pass
Tc_H103	Notifying the users	Request to fetch the data	Appropriate notifications to end users in response	Notification displays appropriate action	Pass

Tc_Id	Feature Tested	Sample Input	Expected Output	Observed Output	Results
Tc_H104	Appropriate action, on click submit	Click the button	On click of submit button redirect the control to same page	Redirect back to the same page	Fail
Tc_H105	Appropriate action on click submit	Click the button	On click submit redirect the control to same page	Redirect to same page	Pass

- **Unit Test case summary for navigations**

Table – 7.2: Unit Testing For Navigations

Tc_Id	Feature Tested	Sample Input	Expected Output	Observed Output	Results
Tc_H201	Forms links	Click on link to move to next form	Proper connections	Link to appropriate form on every mouse click	Fail
Tc_H202	Form links	Click on link to move to next form	Proper connections	Link to appropriate form on every mouse click	Pass

Tc_Id	Feature Tested	Sample Input	Expected Output	Observed Output	Results
Tc_H203	Connection failure/error	Click on link to move to next form	Appropriate message showing the failure/error	Alert the users by displaying the reason for the failure	Pass
Tc_H204	Data Movement	Appropriate data to be moved from one form to another	Data consistency b/w the interacting forms	Consistency in data update at the backend	Pass
Tc_H205	Connection Termination/end	Click on button to move to next form	Do not return to login page once logged in same page	no reestablishment of such connection	Pass

- **Integration testing:** It is the extended procedure of unit testing. The individual units tested are combined and integrated into single system and its performance is tested. It mainly concentrates on identifying the problems that occur within the system when all the units are integrated into single system [49] [50]. Integrated testing primarily exposes and deals with problems among the interfaces before problem occurs in real-world execution. It is a constituent of extreme programming [51][52].

➢ **Integration Test Case Summary Auto setup mode with Auto pilot mode**

Table – 7.3: Integration Testing for Auto setup mode application with Auto pilot phase**.**

Tc_Id	Feature Tested	Sample Input	Expected Output	Observed Output	Results
Tc_H101	Working of Multithreaded software Application	Application should executes with necessary input data	Application Should work as expected by the users	Link to the appropriate form on mouse click	Pass
Tc_H102	Working of Auto setup Application	Application runs with necessary input data	Application Should work as expected by the users	Correct working of application	Pass
Tc_H103	Connectivity between the form	Navigate form one form to another form	Control Transfer from one form to another without time delay	Connection is Established without any error or delay	Fail
Tc_H104	Redirect back to Auto setup and Gimbal mode from auto pilot mode	Exits and redirect to application home page	Exit the application with an alert/notification message to the user	Redirects to the home page	Pass
Tc_H105	Connectivity between each and every forms	Navigate form one form to another form	Control transfers from one form to another without time delay	Connection is established without any errors or delay	Pass

7.2 Testing Screen shots

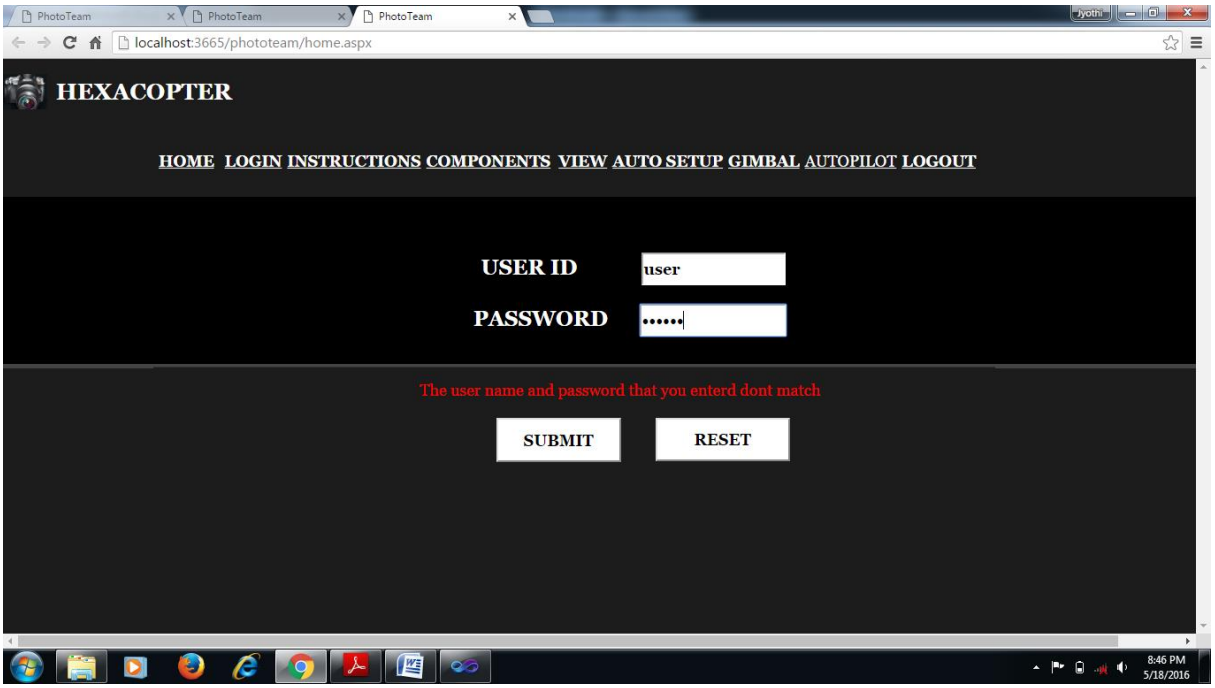

Figure 7.4 Login Page with appropriate alert Message

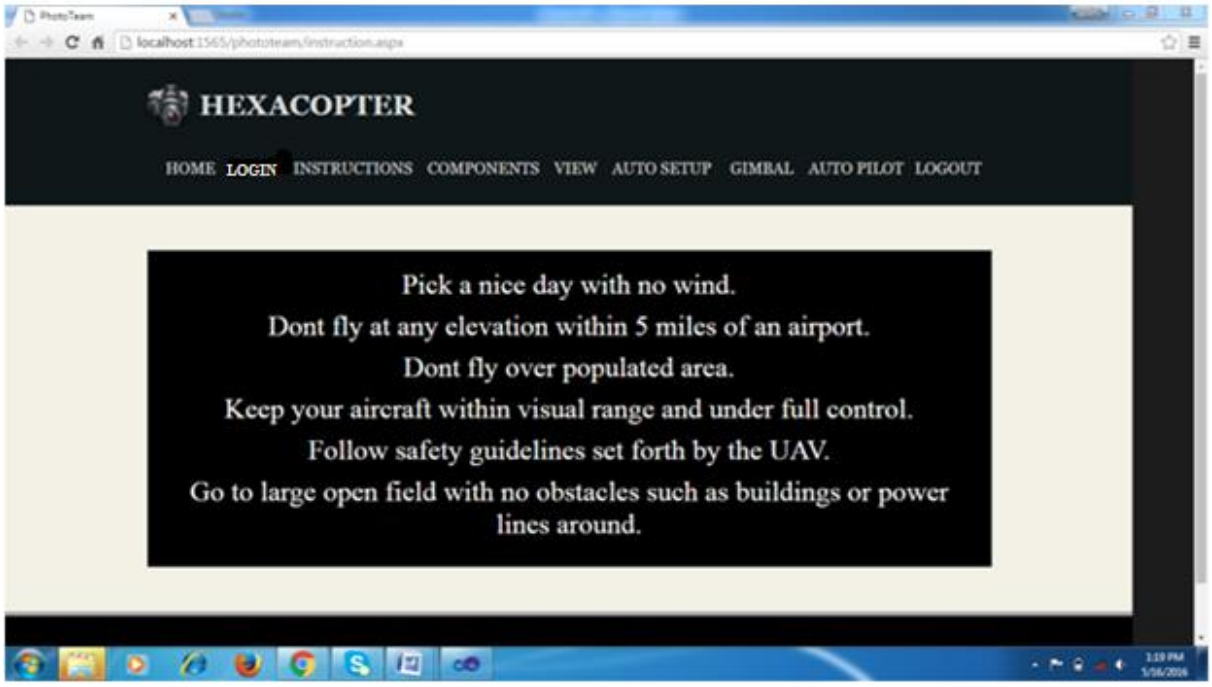

Figure 7.5 Home page representing form connection establishments

The above Figure 7.3 represents the appropriate alert message on every action taken by the users. And various test cases are performed in testing Table 7.1 to ensure that the appropriate alert messages are popped up without any flaws. The Figure 7.4 describes the connectivity between the forms, how each and every form in the system is interconnected with other and they are tested so that the connections are appropriate and no forms are left without connectivity.

Chapter 7: CONCLUSION

The application is implemented in the span of 6 months, the required information is collected based on the specifications given by the clients and application is developed and tested as per the schedule given.

The developed multithreaded software system holds light weight user interface along with the enhanced security feature to enable interaction between various entities, the applications hold light graphical user interface in order to make the user to feel convenient to work with it. The interaction with user inputs with respect to the sensors and GPS input with the radio controller is recorded and maintained in the database.

Each module is designed and deployed based on the client's requirements, each module is interrelated to each other in terms of sensors and actuators, GPS, camera, auto pilot mode values to gain the control over the drone at any point of time in the air.

View module displays the initial status of the autonomous hexacopter when switched on; the auto setup module is developed to verify the temperature and speed of the drone within the given range; gimbal setup mode is implemented with thermal cameras to capture the photos of plantations; auto pilot mode is deployed with default control settings to get the control over the drone; the components module is designed to specify the hardware tools required to build the hexacopter.

The multithreaded software application developed is successfully installed and integrated with the user system to enable its working within a single platform and since the user requirement is agricultural based, the integration of multirotor application adds the additional advantages to the system by enabling the fast and easy means of accessing the multirotor in the field of agriculture in order to capture the images to identify the infected region in the plantations. Thus the product developed for agricultural purpose is 70% more efficient compared to the existing system.

Chapter 9: FUTURE ENHANCEMENT

The multithreaded software application developed meets the basic requirements of the multirotor, with the given time span almost all the features are covered and implemented as per the user requirements.

Upon the added extension of time one can add some of the additional features to the existing system. Multirotor can be built with Crop Duster Sprayer which is more accessible tool that could be used eventually by delivering groceries to revolutionizing the way managing their crops. They can be used in inspecting the highway overpasses without shutting down the lanes of traffic tracking jobs. Commercialization of drones, it can be used in movies to get the perfect shot. Drones are used in journals for transforming the videos and images captured for news coverage and also used to assist the fire department to get the real-time video of the fire occurred. The defense department can use the drones at the borders of the country in order to detect the people who cross the border in dark without any knowledge of restrictions and can be used as lifeguards during adventure swimming in oceans in order to save the swimmers about sharks or heavy waves occurring in their way. People doing adventures and nature documentary can make use of these kinds of drones to get the sky view to take up the next step. Drones can be used to locate the lost people or vehicle in the forest with GPS trackers.

APPENDIX A

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APPENDIX B

USER MANUAL

Safety Notes: Do fly just in safe zones and constantly far from other individuals! Try not to work RC airplane inside the region of homes or hordes of individuals. RC machine are inclined to mishaps, disappointments, and accidents due to an assortment of reasons including pilot blunder, radio impedance, and absence of support.

Pilot is in charge of their activities and harm or damage occurring amid the operation of RC air ship machine. At the point when flying the aircraft, the quick pivoting props of Streak 800 may bring about genuine wounds with any mischance happened. In this manner please remember that wellbeing at first amid the flight.

Ensure you have introduced your own particular Hexacopter Controller and the Props in the right course as indicated by the industrial facility's manual of the Controller.

Specification Kit

Frame	:	332gm
Motor	:	108gm
Propellor	:	81gm
ESC	:	48gm
Battery	:	168gm
PDB	:	7.6gm
IMU	:	10gm
GPS	:	12gm
Bluetooth	:	2gm
Battery alarm	:	7gm
Additional	:	50gm

The total weight of Hexacopter is **838.6 gms**.

The weight of any multirotor drone must less in order to fly high in the air with maximum and minimum speed, when the payload weight more than the motor weight then the drone cannot maintain the constant speed and level in the air.

HOW TO BEGIN

Step 1: Switch on the Radio Controller (RC) to make the drone to fly in air.

Step 2: Once the RC is switched on it will give the current status of the hexacopter with battery status, GPS enable and Flight Landing options, Camera Status.

Step 3: Verify the auto setup mode and reset the climate conditions, wind speed, speed of hexacopter before the hover.

Step 4: Check the camera setup with speed limit, set the speed limit according to the requirement to capture the images correctly.

Step 5: Once both auto setup mode and gimbal setup is completed and verified you can choose the auto pilot mode to get control over the drone by clicking on the default mode button.

Step 6: With the controlled hovering of the drone either you can make the drone to land at the starting position or make the drone to land at current position based on the convenience.