Multipoint Navigation for Quadcopter

BY

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A PROPOSAL

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Universiti Tunku Abdul Rahman

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for the degree of

BACHELOR OF INFORMATION TECHNOLOGY (HONS)

COMMUNICATION AND NETWORKING

Faculty of Information and Communication Technology

(Perak Campus)

JAN 2015

DECLARATION OF ORIGINALITY

I declare that this report entitled "**Multipoint Navigation for Quadcopter**" is my own work except as cited in the references. The report has not been accepted for any degree and is not being submitted concurrently in candidature for any degree or other award.

Signature : _____

Name : THOMAS CHAU GUAN LIANG

Date : 15 MARCH 20215

UNIVERSITI TUNKU ABDUL RAHMAN

REPORT STATUS DECLARATION FORM

Title: Multipoint Navigation for Quadcopter

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Academic Session: JAN 2015

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Perak._____ Dr. GOH HOCK GUAN

Date: 15 MARCH 2015 **Date**:16 MARCH 2015

Abstract

The main purpose of this project is to develop a system which able to set multiple longitude and latitude into a drone (quadcopter) and allow it to move to these locations automatically. Information gathering is an important role in military operations or rescue operations, even in city or border patrol as reported by Federal Aviation Administration (2014) and Coxworth, B. (2013). Unmanned aerial vehicles (UAVs) (quadcopter) have become an effective tool due to their mobility and observation capabilities. The early state of this subject is to build a fully functional quadcopter with Global Positioning System (GPS) chipset. Quadcopter with GPS chipset able to receive satellite signal so that the route of the quadcopter can be calculate before flight and readjust during flight. To enter coordinate of location into quadcopter, a program which can establish a connection to Arduino base flight controller by Universal Serial Bus (USB) is needed. Thus, to create such a program is also part of this project. At the final state of this project, the quadcopter should be able to receive coordinate of multiple location from a personal computer by using USB, and the move to these location automatically. The final product of this project will allow user to scout rural area where hard to enter.

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LIST OF ABBREVIATIONS

AI	Artificial Intelligent
ESC	Electric Speed Controller
GPS	Global Positioning System
UAVs	Unmanned Aerial Vehicles
USB	Universal Serial Bus

Chapter 1: Introduction

1.1.0 Introduction and Limitation of Quadcopter

1.1.1 Quadcopter Is Effective Tool

Information gathering is an important role in military operations or rescue operations, even in city or border patrol as reported by Federal Aviation Administration (2014) and Coxworth, B. (2013). Unmanned aerial vehicles (UAVs) (quadcopter) have become an effective tool due to their mobility and observation capabilities. The development of quadcopter (multi-rotor) has stalled until very recently, because that is extremely difficult and nearly impossible to control four independent rotors without electronic assistance. The decreasing cost of modern microprocessors has made electronic control of quadcopter feasible for commercial, military or even rescue mission [3].

1.1.2 Limitation of Quadcopter

However, the use of quadcopter is limited in short range, because quadcopter are normally using 2.4G Hz wireless signal to receive command from controller, getting away from signal source might cause crash to be happen. This paper describes the development of multipoint navigation system for quadcopter.

	Advantage	Disadvantage
Current Solution	Fast respond	Short distance. Need human control in flight
New Solution from this Project	Slow respond. No need human control after depart	Long distance

1.2.0 Project Scope

1.2.1 Main Functions need to be added in This Navigation System

The main goal of this system is to enable a quadcopter receives multiple locations from a user end device, then move to patrol these locations with the duration or number of patrol decided by the user. Thus mean for a fix distance patrol, user can decide the time taken for one round patrol and when to end mission. The system also needs to handle simple accident like rotor malfunction. User can decide to cancel route at any time, even in the middle of patrolling.

1.2.2 Design of Navigation System

This navigation system is aim to be design into two parts, user end terminal part and quadcopter part. User end terminal is software on computer or phone that used to allow user to enter the details for patrol mission and send to quadcopter using wireless adapter on the device. This navigation system on quadcopter part is aim to be develop in flight controller. Thus mean, by only editing the coding inside flight controller board, no additional hardware needed. Then flight controller will collect data from sensors to complete the flight.

1.2.3 Future Trend of Navigation System for Quadcopter

The future of UAV (quadcopter) could be helpful in many fields, thus the navigation system need to be more complex and intelligence. The quadcopter might have artificial intelligent (AI) built-in; AI can get data of environment from camera and sensor, and then analyse it and take appropriate action. This could enable UAV to work indoor for dangerous mission like nuclear plant monitor and battlefield building scout.

1.3.0 Project Objective

1.3.1 Navigation System for Quadcopter

The objective of the following project is to develop an offline multipoint navigation system for quadcopter to patrol between multiple point in different purposes like forest fire detection, border patrol and, traffic monitor. The system consists of a quadcopter with wireless and Global Positioning Satellites microcontroller to receive command from user and positioning information from satellites signal. The success of this project is measured by the system accuracy to reach these locations given.

There are several objectives to be archive in this project:

- The quadcopter has to be able to receive command from computer.

  To control or pre-set the movement or the behaviour of quadcopter, command from computer is necessary.

- The quadcopter must able to receive multiple coordinates of location.

  Normally a patrol route will not only contain only two coordinates which will only form a straight line, but multiple coordinates.

- The quadcopter should be able to travel from point to point.

  Since the quadcopter will receive multiple point from user, so to complete the patrol mission, the quadcopter should be able to travel from point to point which pre-set by user.

- The quadcopter need to return to starting point while finished the mission.

  The return function is necessary for provide maintenance to quadcopter and avoid unnecessary accident.

1.4.0 Impact, Significance and Contribution

1.4.1 Application of Completed Navigation System

The final product can help in several fields that need constant patrol unit. With camera added on the quadcopter which installed the navigation system, the quadcopter will able to help to monitor traffic condition instead of using helicopter, then the cost for traffic monitoring can be reduced. The quadcopter can also help in monitor forest fire or illegal activities at border with infrared ray and heat sensor, since there are too many areas in the forest are hard to enter for most of the vehicles.

1.4.2 Low Cost and Safe

According to AVAITOR MEDIA (a Web Development and Aviation Research/Promotion Company), a light helicopter will cost more than 1 million USD which is much higher than quadcopter. Thus using quadcopter is much cheaper instead of using helicopter in patrol mission. So if use quadcopter as a solution for long term patrol mission can reduce the cost significantly. Other than that, using quadcopter in military scout mission can ensure the safety of soldier since quadcopter may not need to control by soldier and can be sacrifice at any time.

1.5 Chapter Organization

Inside this report, chapter 1 is an introduction about quadcopter and this project. Other than the information about quadcopter, chapter 1 contains the project scope and objective which is important about this project. Last sub chapter is a briefing about impact and contribution by this project.

Chapter 2 is literature review which contains technology involved in hardware or software using in this project. Information about the hardware and software can help to understand the theory better.

Chapter 3 is talking about system methodology. Three types of system development model will be discussed and the most suitable model will be used in this project. The milestone of this project also contained in chapter 3. At last in chapter 3, the cost for this project and cost for this product to be commercialized will be stated too.

Information about system design will be inside chapter 4. Information about system flow, system design and hardware overview stated in chapter 4.

Chapter 5 is conclusion which about the summary of all chapter.

Chapter 2: Literature Review

2.0 Technology Involved in Quadcopter

2.1 Basic Idea of Quadcopter

A quadcopter is a multi-rotor flying vehicles which having four rotor. Usually arranged in "X" shape or "+" shape. Two rotors rotate clockwise and the other two rotate anti-clockwise in order to balance the torques exerted. Flight controller in quadcopter will keep collect measurement from inertial measurement unit to maintain the balance of the quadcopter.

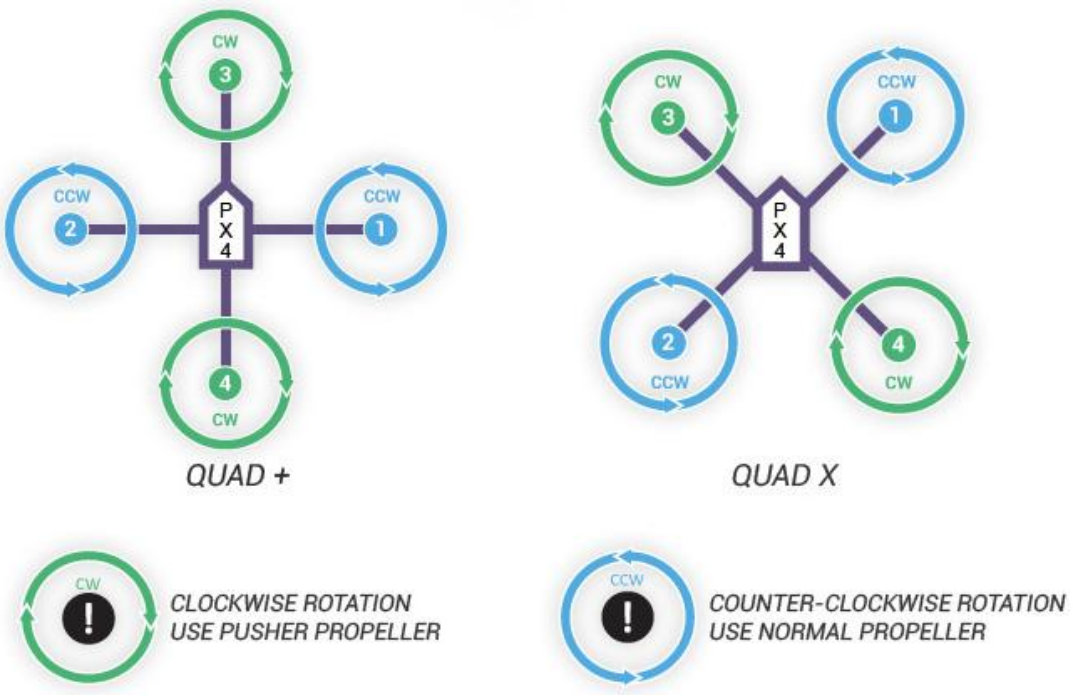

Fig. 2.1: Propeller direction of quadcopter.

PS: PX4 in Figure 4 is a model of flight controller.

(Wiring your Motors for X or + mode configuration 2014)

2.2 Movement of Quadcopter

A quadcopter is a flying vehicle with 6 degree of freedom (DOF) but only controlled by four inputs. A movement of a quadcopter is controlling by changing the speed of rotation of every rotors. Result in changing of torques and make the quadcopter move. Fig 2 show Movement of a quadcopter where direction of arrow represents the direction of propeller but thickness of arrow represents the speed of propeller in aerial view.

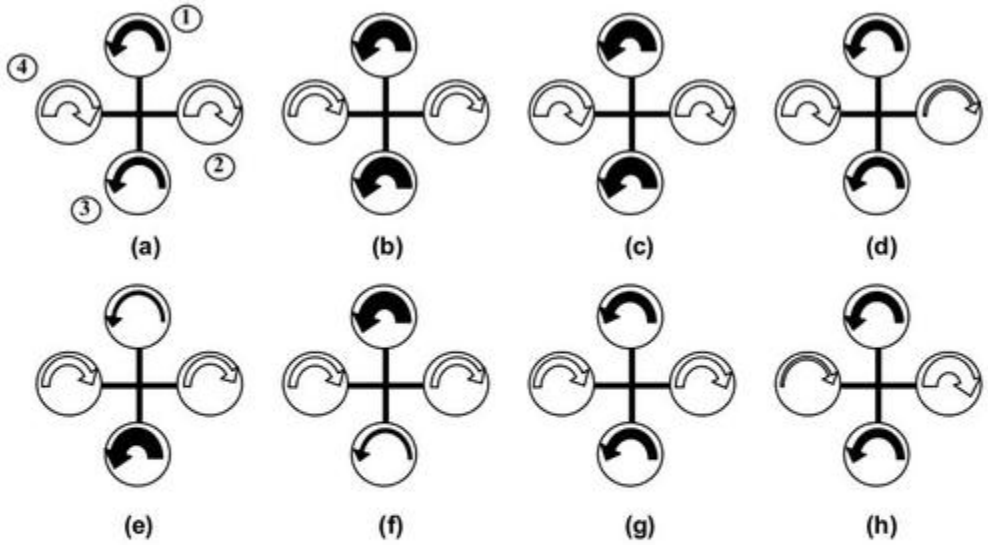

Fig. 2.2: Movement of Quadcopter in aerial view.

(MULTI-PURPOSE UNMANNED AREIAL VECHICLE WITH TEMPERATURE SENSING ALGORITHM AND AERIAL VIDEO FEEDING. 2014).

2.3 Navigation with Global Positioning System (GPS)

According to Polytechnic of Milan, the global positioning is the most accurate method so far. The system use signals from satellites that known position to locate the position of receiver. This system began in 1978 and fully operational in 1995 which have totally 24 satellites. All satellites transmit a non-directional signal in UHF and the signal contains details about identifier, satellite position and starting time of transmission. The receiver can read these signals and calculate distance from lapsed time with the equation below.

$$(x - x_i)^2 + (y - y_i)^2 + (z - z_i)^2 = d_i^2 = c^2 \cdot t_i^2$$

Where:

x,y,z = position of receiver;

x*i*,y*i*,z*i* = position of *i*-th satellite;

d*i* = distance of receiver from *i*-th satellite;

c = speed of electromagnetic radiation;

t*i* = time elapsed between transmission from *i*-th satellite and reception.

By using GPS, the navigation system should be able calculate the best path, and locate the quadcopter if crash happened. By using technology mention above, a navigation system which smart enough to handle simple action like move to charging location and able to provide accurate flight path can be produce at last.

2.3 Electric Speed Controllers (ESC)

An electronic speed controller is a special electronic circuit that purposely made for control a speed and direction of electric motor. ESCs used widely in a lot of application including brakes and various start-up safety features, but most often using in radio controlled model which is using brushless motor. In simple words, the function of ESCs is to control the speed of motor by changing switching on and off.

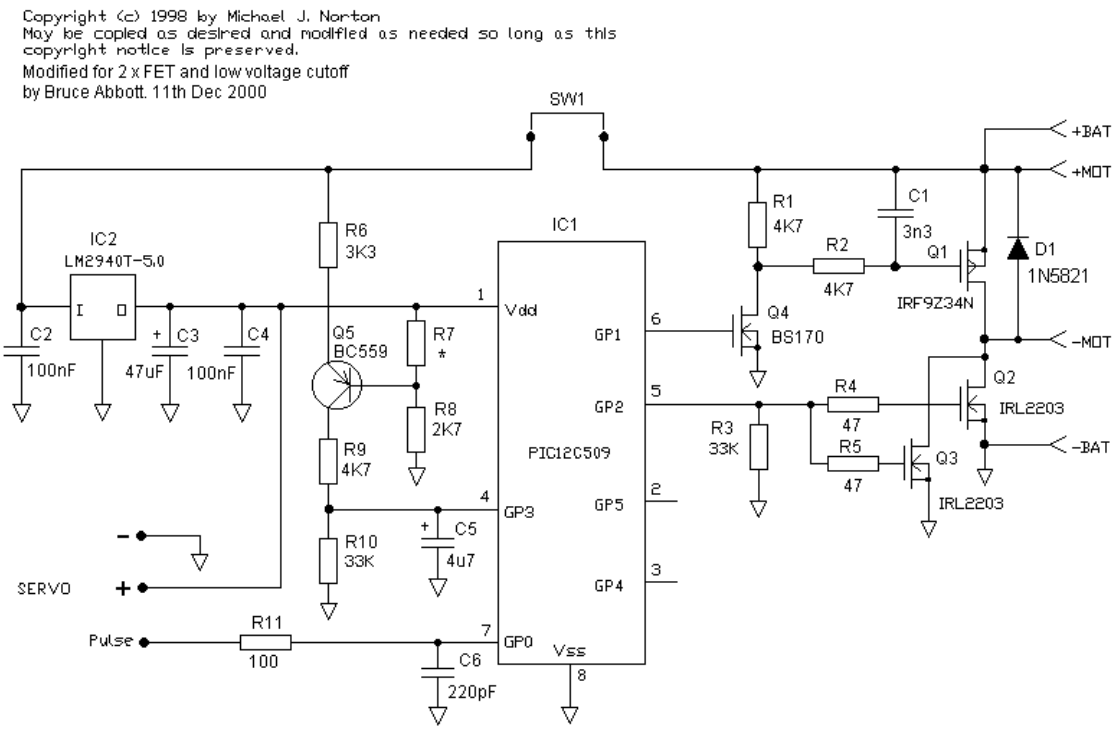

Fig. 2.3: Circuit Design of an ESC for Brushless Motor.

(http://homepages.paradise.net.nz 2015)

2.5 C Programming language for Board Configuration

C programming language is a structured and procedural high-level programming language develops by Dennis Ritchie. Although C was designed as a system programming language, but C has used in variety of application because it consumes lesser flash memory and good processing speed while compare to others language.

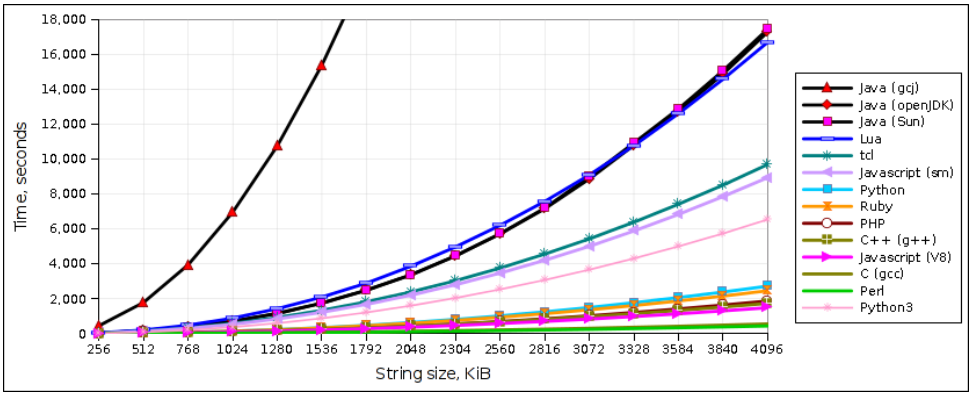

Fig. 2.4: Processing Speed Graph

Fastest: Python; Ruby; PHP; C++; Javascript V8; C; Perl5

(raid6.com.au/ 2015)

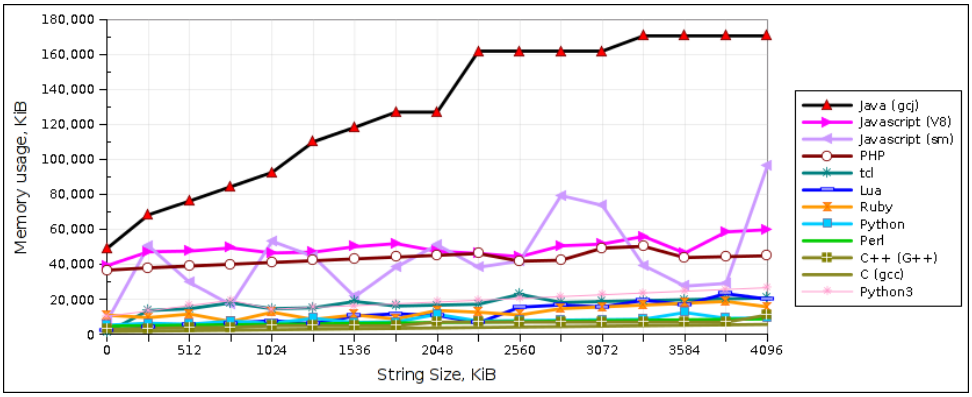

Fig. 2.5: Memory Usage Graph

Lowest: Python, Perl5, C++, C

(raid6.com.au/ 2015)

Chapter 3: System Methodology

3.1 System Development Models

3.1.1 Waterfall model

Waterfall model is a basic model for software engineer. This is one of the most basic models which widely used in many projects. This model ensures design flaw before the product was developed by emphasizes planning at the beginning. This model is suitable for those projects which concern about quality control by intensive document and planning.

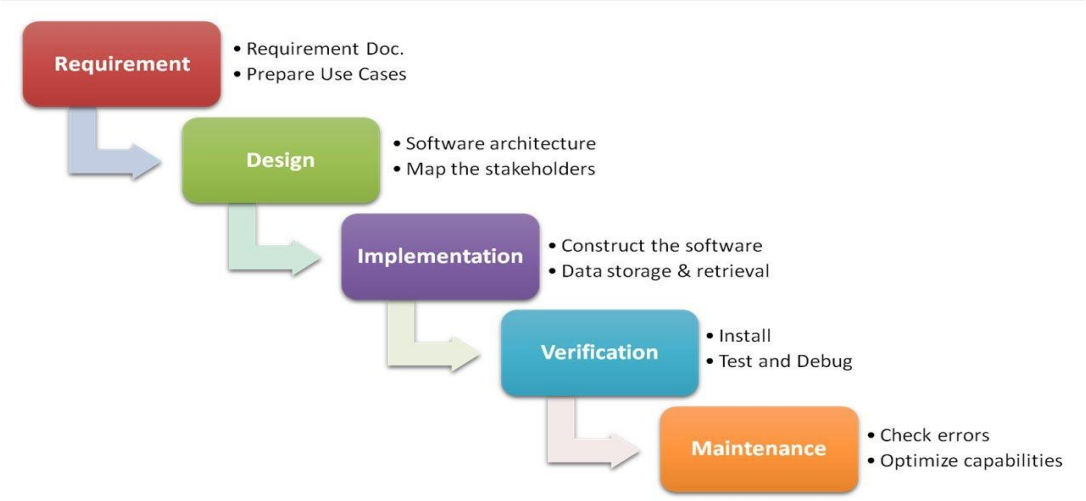

Fig. 3.1: Waterfall Model

(youtube.com 2015)

Strength	**Weakness**
Reduce planning overhead.	Inflexible.
Minimize wasted effort with structure, suitable for inexperience or technically weak people.	Difficult to address mistakes from back up.
Simple.	Only the last stage is not a paper work.

3.1.2 Spiral Model

Spiral model has four stages, which is planning, risk analysis, engineering and evaluation. The project will pass though these stages continuously. Spiral model begins with planning stages, requirements are collected and risk is evaluated. During the risk analysis stage, risk has to be identified and alternative solution need to be clarified. A prototype will be delivered at the end of risk analysis stages and software will be produce at engineering stage and debug until the end of engineering stage. During the evaluation stage, the product of the project will be tested and evaluated by customer before continues into next spiral.

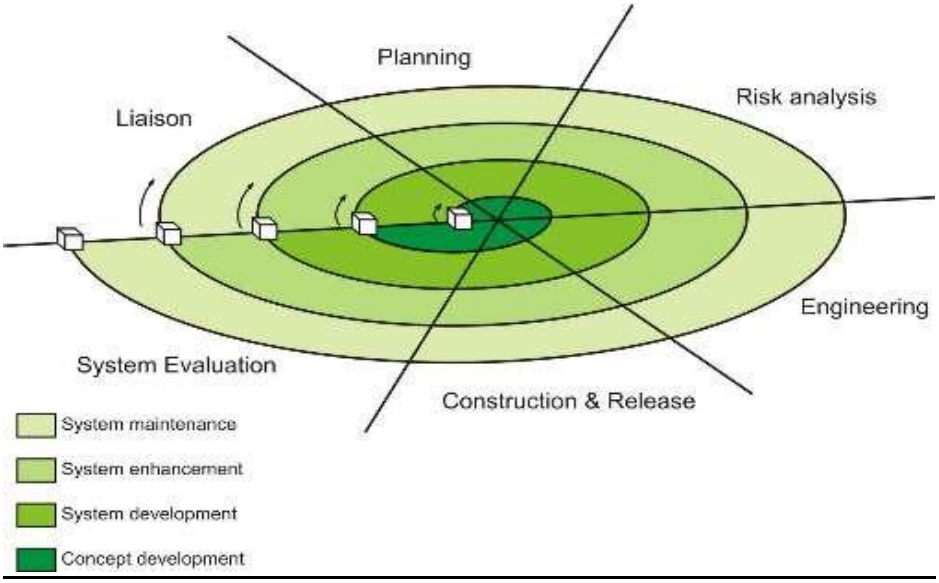

Fig. 3.2: Spiral Model

(theegeek.com 2015)

Strength	**Weakness**
A lot of risk analysis.	Expert required for risk analysis.
Suitable for large and mission-based project.	Not suitable for small project.
Prototype was created at early stage.	Can be costly.

3.1.3 Extreme Programming Model

Extreme programming relies on constant small improvement and involvement of user during the development. Every small improvement will be made after every feedback from user.

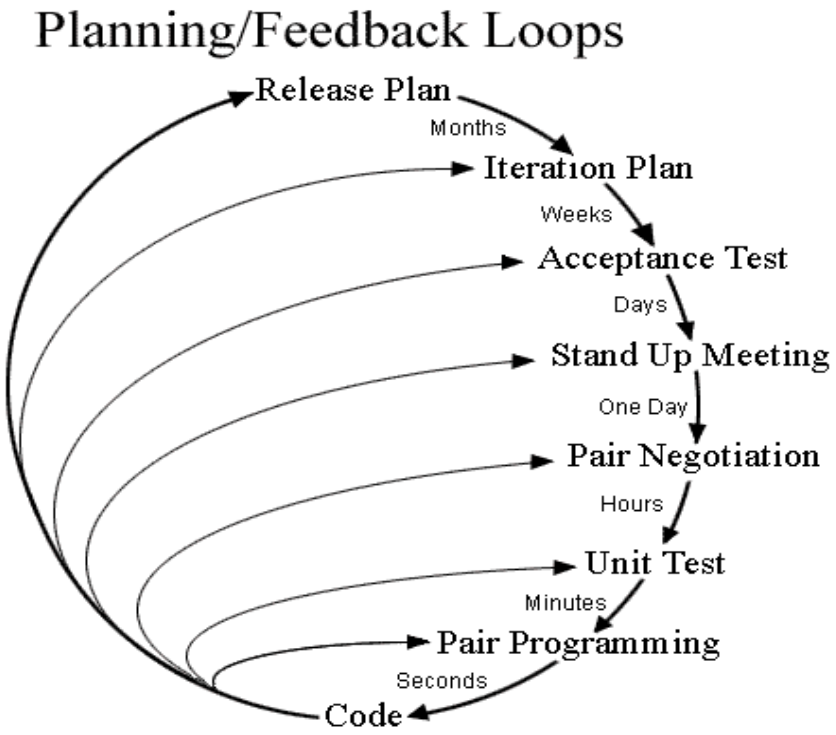

Fig. 3.3: Extreme Programming Model

(waterfall-model.com 2015)

Strength	**Weakness**
Simple method which suitable for small or medium project.	Not suitable for large project, cause lack of documentation.
Increase teamwork.	Experience and skill needed.
User requirement and quality of product can be promise.	Can be costly.
Efficient to problem solving.	

3.2 Selected Model

3.2.1 Waterfall Model Selected

Waterfall model was selected in this project because it is a simple method which is suitable for inexperience developer to start. Other than that, the flow of this model can reduce planning overhead. This model is inflexible, but it should be no problem in this project.

Strength	**Weakness**
Reduce planning overhead.	Inflexible.
Minimize wasted effort with structure, suitable for inexperience or technically weak people.	Difficult to address mistakes from back up.
Simple.	Only the last stage is not a paper work.

3.3 Project Milestone

Task	Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Paper Review														
Project: Requirement Gathered														
Project: Hardware and Software Design														
FYP Report Writing														
Project: Prototyping Software														
Project: Improving Software														

Progression		Expected Progression	

3.7 Estimated Cost

Project Development Cost

Item	Price (RM)
X230 Mini Quadcopter Combo	295.00
MultiWii PRO Flight Controller with MTK GPS Module	240.00
Turnigy nano-tech 1500mah 3S 25C Lipo Pack	50.00
2.4Ghz 4Channel Tx and Rx V2	86.00
	671.00

Commercialize Price

To sell this product on the market, a price about RM 750 will be set. This price will include all the hardware listed above and also the navigation software which creating in this project.

Chapter 4: System Design

4.0 System Design Specifications

4.1 System Flow

This project will complete a navigation system for quadcopter. To use the system, user may need a computer for coordination enter purpose and a quadcopter for flight. General work procedure describes in Figure 4.1.

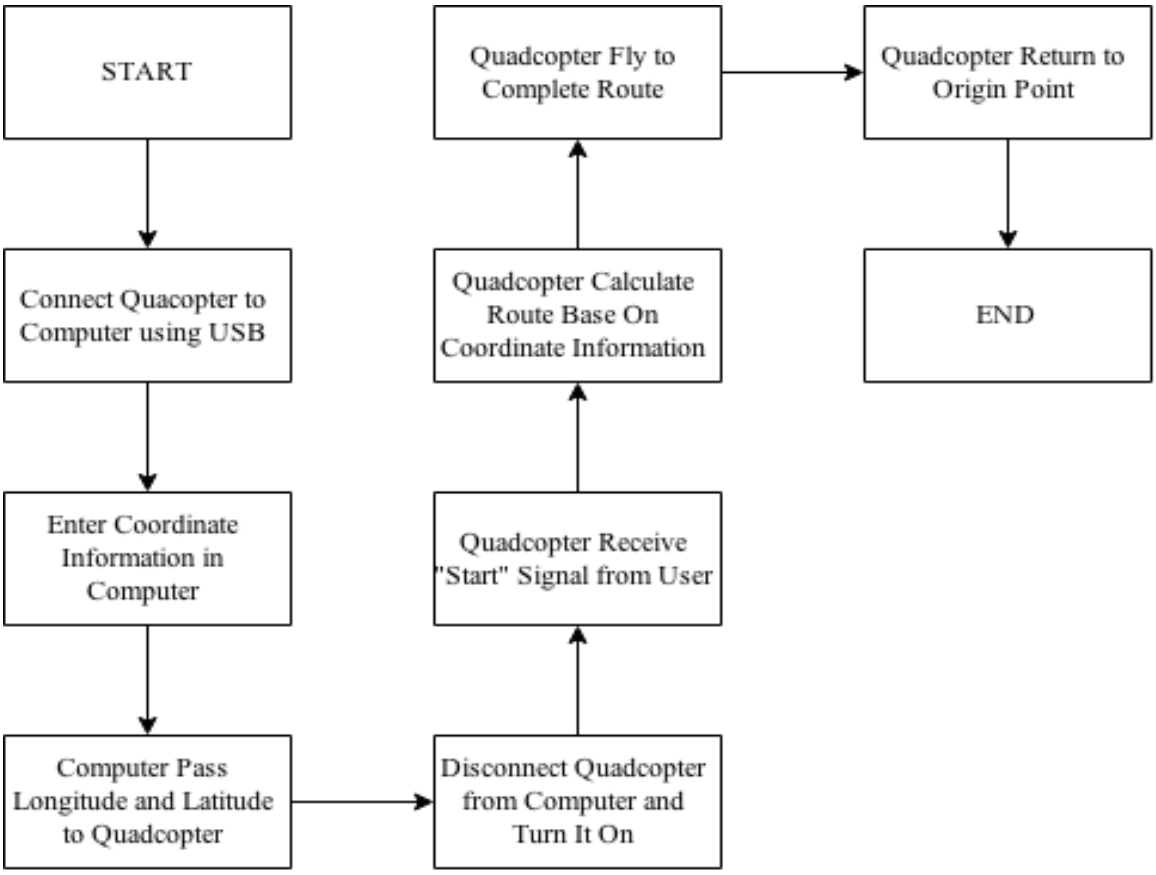

Fig. 4.1: General Work Flow for This System

4.2 System Design

In this Navigate System, need at least 3 components, which is a computer, a USB cable and a quadcopter. In the computer, a program to get coordinates information from user and pass into Quadcopter. USB cable is use to connect computer and quadcopter. And the quadcopter need to complete the flight. The general procedures are described in Figure 3.

4.3 Hardware Overview

A frame in figure 4 (HobbyKing.com 2014) is a structure that uses to hold all the components together, so it needs to be strong and lightweight.

Rotors are brushless DC motors like in upper part in figure 4.03 (HobbyKing.com 2014) that use to provide thrust to move the quadcopter.

Electronic Speed Controller (ESC) showed in bottom part of figure 5 (HobbyKing.com 2014) used to control the rotor since brushless motor normally having 3 phases and will not take direct DC power.

Propellers are used to provide force to move the quadcopter while spinning.

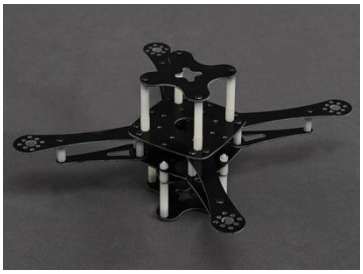

Fig. 4.2: Frame (HobbyKing.com 2014)

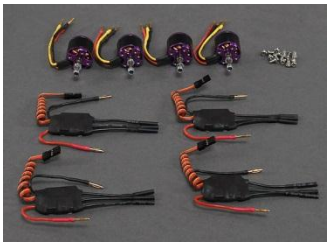

Fig. 4.3: Rotors and ESCs (HobbyKing.com 2014)

Battery is the energy sources of quadcopter. Since quadcopter having four rotors, so it needs more energy compare to helicopter in same size. Lithium poly ion (Lipo) battery are frequently using by quadcopter, from one thousand mAh to few thousands. The larger the capacity, the longer flight time will last in normal case. 1500mAh Lipo battery was used in this project which can provide reasonable flight time and also cheap in price.

Fig. 4.4: Image of battery model using in the project. (HobbyKing.com 2014)

Flight Controller is an electronic board which having Central Processing Unit (CPU). Flight controller takes reading continuously from Inertial Measurement Unit to control or stabilize the craft. Model of flight controller using in this project is MultiWii Pro 2.0 .

Inertial Measurement Unit (IMU)is an electronic sensor devices that having 3-axis accelerometer and 3-axis gyroscope, together they represent 6 degree of freedom(DOF) IMU, Sometimes there is also additional 3-axis magnetometer becomes 9DOF for better Yaw stability. IMU is embedded on flight controller in this model.

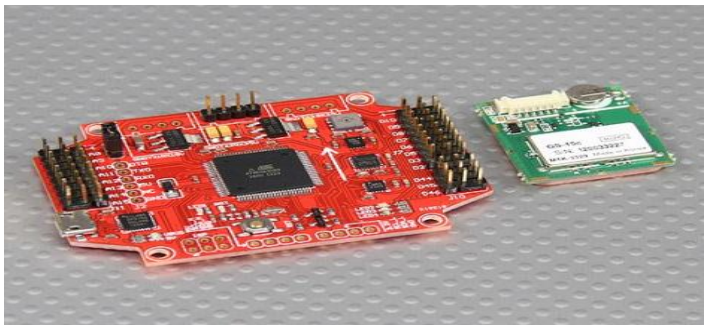
Fig. 4.5: Flight Controller (Left) and GPS module (Right) used in the project. (HobbyKing.com 2014)

Global Positioning System (GPS) module used in this project is MTK 3329. Specification as below (HobbyKing.com 2014):

Position Accuracy: **<3m CEP (50%) without SA (horizontal)**
Cold Start**: under 35 seconds (Typical)**
Warm Start: **under 34 seconds (Typical)**
Hot Start: **under 1 second (Typical)**
Power Consumption: **48mA @ acquisition, 37mA @ tracking**
Shut-down current consumption: **15uA, typical**
Dimensions: **30x26x7mm**
Weight: **8g**

Chapter 5: Conclusion

High Demand of Market

Since information gathering has becomes more and more important in multiple type of operation line military operations or rescue operations, even in city or border patrol. Unmanned aerial vehicles (UAVs) (quadcopter) have become an effective tool due to their mobility and observation capabilities, while the development of quadcopter has made a significant improvement. The decreasing cost of modern microprocessors has made electronic control of quadcopter feasible for commercial, military or even rescue mission. This navigation system able to help user gather information without control the quadcopter in real time.

Advantages and Limitation of Current Solution

Current solution for information gathering by quadcopter is real time human control. This solution able to give a fast respond since this is using real time human control. But the limitation of this solution is the distance between controller and quadcopter must not too far since the connection are using 2.4GHz.

Purpose of this Project

The final product of this project allow user to use a quadcopter in auto pilot mode. Although the quadcopter using this system may not respond fast like the current solution, but the distance limitation of current solution can be overcome. With the final product, patrol or scout mission in rural area will become easier.

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Perl, Python, Ruby, PHP, C, C++, Lua, tcl, javascript and Java comparison. (2012). [image] Available at: http://raid6.com.au/~onlyjob/posts/arena/#speed [Accessed 16 Mar. 2015].

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Appendix

FINAL YEAR PROJECT WEEKLY REPORT

Project I

Trimester, Year: T2 ,Y3	Study week no.: 2
Student Name & ID: THOMAS CHAU GUAN LIANG 1102638	
Supervisor: Dr Goh Hock Guan	
Project Title: Multipoint Navigation for Quadcopter	

WORK DONE Met with Supervisor to discuss possibility of control Quadcopter with laptop wireless network card.
WORK TO BE DONE Research about possibility of control Quadcopter with laptop wireless network card.
PROBLEMS ENCOUNTERED No way to do that.
SELF EVALUATION OF THE PROGRESS Good.

_____ _____

Dr Goh Hock Guan THOMAS CHAU GUAN LIANG

FINAL YEAR PROJECT WEEKLY REPORT

Project I

Trimester, Year: T2 ,Y3	Study week no.: 4
Student Name & ID: THOMAS CHAU GUAN LIANG 1102638	
Supervisor: Dr Goh Hock Guan	
Project Title: Multipoint Navigation for Quadcopter	

WORK DONE Research about possible ways to pass coordinate information to quadcopter.
WORK TO BE DONE Figure out how to make USB connection to quadcopter.
PROBLEMS ENCOUNTERED Too little information.
SELF EVALUATION OF THE PROGRESS Good.

_____ _____

Dr Goh Hock Guan THOMAS CHAU GUAN LIANG

FINAL YEAR PROJECT WEEKLY REPORT

Project I

Trimester, Year: T2 ,Y3	Study week no.: 6
Student Name & ID: THOMAS CHAU GUAN LIANG 1102638	
Supervisor: Dr Goh Hock Guan	
Project Title: Multipoint Navigation for Quadcopter	

WORK DONE Draft for FYP I Proposal. Study about USB connection Coding.
WORK TO BE DONE Finalize FYP I Proposal.
PROBLEMS ENCOUNTERED Too little information. about USB connection.
SELF EVALUATION OF THE PROGRESS Goob.

_____ _____

Dr Goh Hock Guan THOMAS CHAU GUAN LIANG

FINAL YEAR PROJECT WEEKLY REPORT

Project I

Trimester, Year: T2 ,Y3	Study week no.: 8
Student Name & ID: THOMAS CHAU GUAN LIANG 1102638	
Supervisor: Dr Goh Hock Guan	
Project Title: Multipoint Navigation for Quadcopter	

WORK DONE Finalize FYP I Proposal.
WORK TO BE DONE Build a prototype.
PROBLEMS ENCOUNTERED Too little information. about USB connection..
SELF EVALUATION OF THE PROGRESS Good.

_____ _____

Dr Goh Hock Guan THOMAS CHAU GUAN LIANG

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