AUTOMATIC TAKE-OFF AND LANDING (ATOL) IN SWARM-IOT FOR AIR QUALITY MEASUREMENT

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Abstract

The main problem of the conventional air quality measurement system is it sometime gives inaccurate result due to the pollution nearby the sensor. To solve this problem, this research builds a prototype of Unmanned Aerial Vehicle (UAV) as part of Swarm-IoT (Internet of Things) to measure the air quality. Since a Swarm-IoT is a distributed autonomous IoT devices, we have to make sure that the UAV has the ability to identify the take-off position to know where it should return autonomously without the help of remote control. Thus, the purpose of this research is to create an Automatic Take Off and Landing (ATOL) functionality on the air quality measurement UAV. For air quality measurement purposes, as an additional of the ATOL functionality, we program the UAV to operate autonomously from take-off, hover at the altitude of 3 and 5 m for measuring the air quality, and finally landing on the same position from take-off without any human intervention. In general, the components used to do the ATOL functionality for the UAV are Pixhawk, Mission Planner, Global Positioning System (GPS), Telemetry, and a personal computer. The results obtained after creating the system are the UAV can successfully take-off and land automatically to the take-off place with the precision of average distance from the takeoff and landing position is 45 cm. The average data error for take off coordinate is 2.95 m and the average data error for landing coordinate is 2.95 m. The precision of the altitude at 3 m is 9.5 cm and at 5 m is 6.9 cm.
Keywords: UAV, Swarm-IoT, ATOL,GPS.

1. Introduction

The air quality level changes continuously, this happen due to various reasons such as vehicle emissions, environment and climate changes [1]. To overcome this, creating an effective system to measure the quality of the air of the environment around us is a great solution. The current air quality measurement system is considered to be inaccurate, because it only measure at a certain points on the ground so it give inaccurate result that affected by various reasons.

Since the ground access is usually hindered and full of obstacles, the most feasible way to implement a mobile air quality monitoring robots is via Unmanned Aerial Vehicles (UAV) . For that reason, we propose to create a Swarm-Internet of Things (IoT)-based Quadcopter UAV that consists of a group of small UAV that can work altogether. This UAV is expected to help us measure the level of air quality by flying it.

In addition to that, to make the work easier and efficient, this research propose an Automatic Take Off and Landing (ATOL) system for this UAV. The basic UAV have to remotedly piloted by an operator that requires a routine training to fly and land it because it controlled by a human. This basic system can cause an accidents which make a failure for the flight. As mentioned in, [2] the principal cause of the failure were classified as human error, technical failure, weather and sabotage.

Nowadays, several companies produce ATOL systems for UAV with developed ground station software that being as a commercial use. One of the company that produce this is The UAS Europe. They provide a flight control system. This system fully allow autonomous flights, from take-off, mission to landing. The limitation of this solution is the cost. However with the recent increase in development of UAV development, there are now many devoloped system that can be afford at a low budget.

Several papers have been published that propose the method of ATOL system for the UAV. In 2007, KARI (Korea Aerospace Research Institute) developed an autopilot design of a tilt-rotor UAV as a Smart UAV Development Program in Korea. This system using Particle Swarm

Optimization (PSO) method. The objective was to create an automatic tool for control system design using the PSO method that being developed and applied to autopilot design of tilt-rotor. This project achieved a whole autopilot system includes several parts like state observer, state estimator, and flight controller [3] .

By looking at all of the problem, this research proposes to make an ATOL system that capable perform a fully autonomous mission, from the take-off to the landing process. This system use Pixhawk as the autopilot system, Mission Planner as the Ground Control Station (GCS) software, Global Positioning System (GPS) as the receiver, Telemetry as a two way datastream, and a computer as the control unit.

2. Basic Theory

A. Navigation System in Quadcopter

Navigation system in quadcopter is a technique for reading the position and direction of objects against the surrounding conditions.

1. Global Positioning System (GPS)
   GPS is a satellite naviagiatoin system that used to determine the position of an object on the earth surface. GPS uses a one-way ranging technique from the GPS satellites, which are also broadcasts a message that infrom its current position, direction and exact time [4]. In general, GPS receivers can be classified as three. Its consist of GPS Control Segment, GPS Space Segment (space section), and GPS User Segment (user section). GPS receive signals transmitted by GPS satellites. In order for a GPS to work correctly, it must establish a connection to the required number of satellites. For determining the position, 3 satellites are used for 2-dimensional positioning (latitude and longitude) and 4 satellites are used for 3-dimensional positioning (latitude, longitude and altitude)[4]. The more satellites obtained, the higher our position accuracy will be.
2. Pixhawk
   Pixhawk is specifically designed to be a research platform for computer vision based flight control and autonomous flight using computer vision. It is a designed hardware in Quadcopter UAV that can flight automatically/autonomously using onboard computer vision. The hardware and software presented in an open source platform which allows fully automatic flight on the quadcopter without external processing device. Pixhawk designed by the open hardware PX4 project and produced by 3D Robotics. It features an advanced processor which provides outstanding performance, flexibility and reliability to control each quadcopter automatically. Pixhawk provides standards hardware specifications and guidelines for drone systems development. The overall navigation setup on the pixhawk will be carried on microcontroller or computer and laser vision. The on-board processing for localization and maneuvers currently using GPS.
3. Inertial Measurement Unit (IMU)
   IMU is a unit in an electronic module that typically consists of gyroscopes, accelerometers, and pressure sensors. Basically its combine input from several different sensor types in order to accurately output movement. It can measure a variety of factors, including speed, direction, acceleration, specific force, angular rate then sent the data to the main processing unit. IMU are typically used to maneuver aircraft including UAV. IMU can be used in GPS positioning systems that allowing the navigational device to continue with an estimated position and heading if it loses the satellite connection [5].

B. Telemetry

Telemetry is a device that can processes the measure a physical characteristic of an object and the results can then be transmitted electronically to where the measurement data is displayed by using cable or wireless media [6]. In this research, telemetry is used to retrieve flight information of the quadcopter on the personal computer in order to follow several parameters of your aircraft on the ground. The telemetry that being used in ths thesis is Radio Telemetry 433 MHz 100 mW. This telemetry used radio signals, which are made up of invisible and silent electromagnetic waves, to determine location. A radio telemetry system is made up of three parts: a radio transmitter, a radio antenna and a radio receiver.

C. Dilution of Precision (DOP)

DOP is a standard that used in satellite navigation to define the error propagation navigation satellite geometry on positional measurement precision [7]. In this thesis, we use Horizontal Dilution of precison (HDOP) parameter used for measuring the quadcopter position precision/accuration. The HDOP value that displayed is describe the current strength of the satellite configuration (geometry) and the certainty of the data that the quadcopter can collect at that moment. The smaller the DOP value the better the satellite geometry to perform position calculations and more visible satellites low in the sky, the better the HDOP and the horizontal position (Latitude and Longitude). In selecting satellites to obtain most accurate positional accuracy, then the DOP value should be as small as possible.

D. Ground Control Station (GCS)

GCS are a set of hardware or a software application that enable the vehicle operator to communicate and control the connected vehicle. GCS enable the user to adjust the vehicle parameter and receive the real time data throughout the mission flight of the vehicle. The GCS has complete features for control and data transmission. In general, it provides the virtual cockpit and live map that indicates the vehicle position. GCS also allow the user to do the autonomous flight that was pre-planned and and provides two-way communication for the vehicle during flight.

E. Mission Planner

Mission Planner is a full-featured GCS application for the open source for unmanned vehicle autopilot software that supported by ArduPilot. It can help users to control several types of vehicles such as Aircraft, Copter and Rover. This software is compatible with Windows only. Mission Planner can also be used as a configuration or as a station control for your autonomous vehicle.

3. Research Method and Simulation

A. Design System

In this research, an ATOL system for the Quadcopter UAV is developed which allows the users to use a Personal Computer (PC) to control the quadcopter automatically. This research uses the Pixhawk 2.4.8 as a flight controller, which determines the trajectory of its moving movement based on the longitude and longitude coordinate points, and the altitude selected in the Mission Planner that being used as the Ground Control Station (GCS). The coordinates displayed on the mission planner are generated by the GPS on the Quadcopter. Then the data from the GPS transmit to the mission planner software via Telemetry which is connected to the quadcopter and the PC. As for the altitude of the quadcopter, it is obtained from the barometer sensor on the Pixhawk 2.4.8. The quadcopter will send data via telemetry periodically so that the position of the quadcopter always be monitored, so that the flying process from take off to landing can run well.

Fig.1 - Design System.

B. Mission Path

The flight succesfully doing the mission if all of the path from take off, go to the waypoint 1 (WP1) at the altitude of 3 m, go to the waypoint 2 (WP2) at altitude of 5 m, and landing the quadcopter to the home location (return to launch) is obtained.

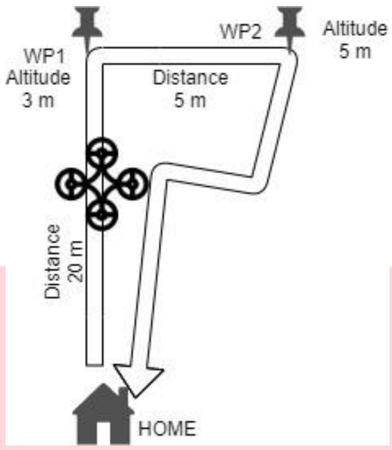

Fig. 2 – Mission Path.

C. Preflight Parameter Check

Before doing the mission flight, the Quadcopter need to fullfilled this requirements to safely doing the mission flight. The parameter that need to be checked before flight are:

1. HDOP Value

   Before the flight, the operator need to check the HDOP value to be less than 1 (the lower value the better). When HDOP value is lower, the certainty that the horizontal (latitude and longitude) position are better.
2. GPS Satellite Check

   Other parameter that need to be checked before the flight by the operator is verify the GPS value to bigger than 3 and make sure the GPS Satellite counts to bigger than 7. If the GPS satellite is smaller than 7, the GPS cant be locked, and the quadcopter cant be in armed mode. Bigger value will be better to locked the GPS accurately. If the GPS satellite is smaller than 7 there is more potential for a GPS glitch. Because it cant precisely knowing the current position and the waypoint position to the mission flight. This can result a crash in the quadcopter flight.

D. Preflight Flowchart

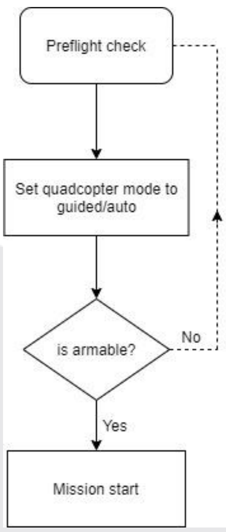

Fig.3 – Preflight Flowchart.

Before conducting a flight mission, a preflight check must be carried out based on the preflight parameter check. After checking the parameters that must be required before flying, the operator must set the quadcopter to guided/auto mode. Then activated the armed mode on the quadcopter. If all of the parameter is fulfilled, then the operator can start the flight mission for the quadcopter.

E. Mission Flight Flowchart

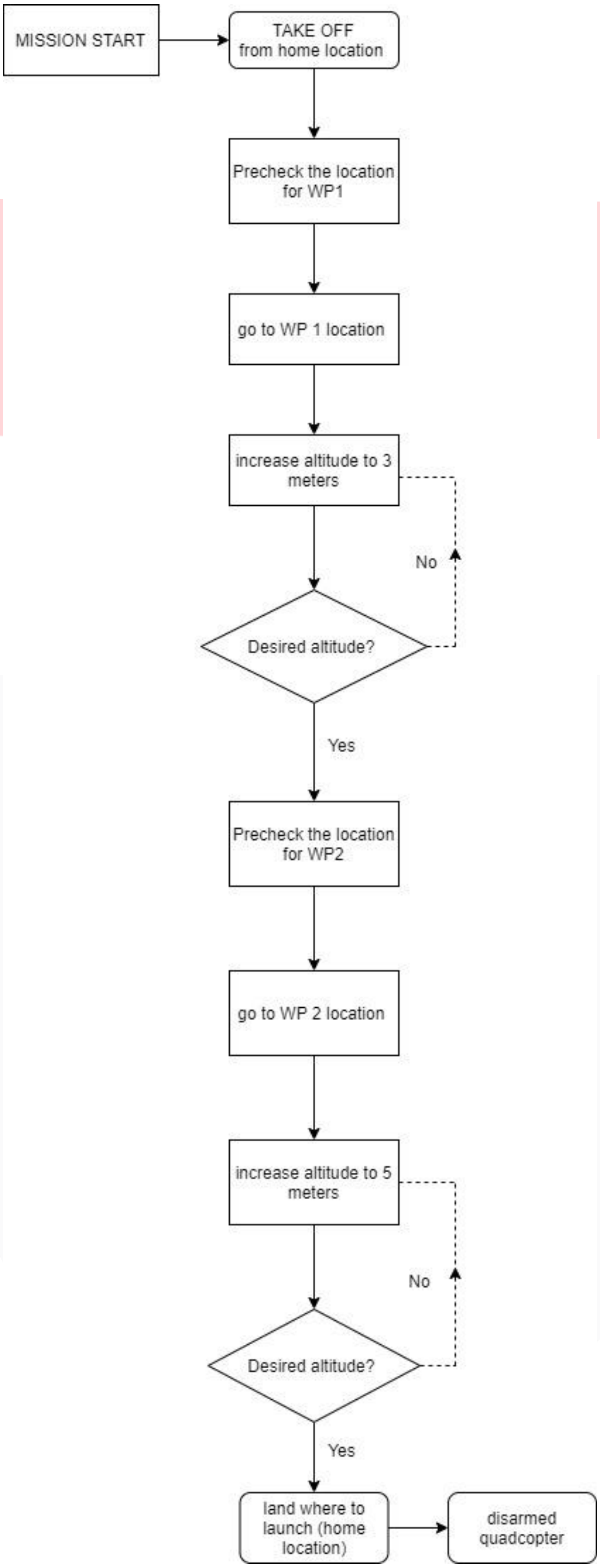

Fig.4 – Mission Flight Flowchart.

The flight consists of 4 mission, the following are the mission that need to be carried out :

- The first mission for the quadcopter is to take off from the home location to altitude of 3 m.
- The second mission for the quadcopter is to go the WP1. After reaching the WP1, the quadcopter will adjust the altitude according to the input which is 3 m.
- The third mission for the quadcopter is to headed to WP2. Then the quadcopter will increase the altitude according to the input which is 5 m.
- The last mission for the quadcopter is land to where its launch (the home location). When it succesfully landed, the quadcopter will return to disarmed mode.

F. Testing Scenarios

In this thesis, to analyzed the ATOL system two parameters that need to measure are the positioning accuracy and altitude accuracy

1. Positioning Accuracy

The positioning accuracy calculated by comparing the take off and landing location according to the GPS in quadcopter, comparing between the GPS in quadcopter and google maps for the take off location, and comparing between the GPS in quadcopter and google maps for the landing location.

2. Altitude Accuracy

The altitude accuracy calculated by comparing the altitude measurement in barometer with the manual measurement in WP1 and WP2 and analyzed the result with the given input 3 and 5 m.

4. Result

A. GPS Precision on The Take Off and Landing Coordinate

This test is conducted to determine whether the take off and landing locations for the quadcopter are located pricesly. In this research, the ATOL system on the quadcopter is expected to land and take off at the same coordinate point.

Table 1 : Takeoff and Landing Coordinate Point.

Take Off Latitude	Take Off Longitude	Landing Latitude	Landing Longitude	Shifting (cm)
-6.9761062	107.6303296	-6.9760833	107.6303554	50
-6.9760543	107.6303371	-6.9760985	107.6303372	44
-6.9760711	107.6303402	-6.9760721	107.6303371	47
-6.9761032	107.6303545	-6.9761097	107.6303298	36
-6.9760165	107.6303457	-6.9760332	107.6303478	47
-6.9760793	107.6303352	-6.9760786	107.6303369	42
-6.9760782	107.6303367	-6.9760782	107.6303367	38
-6.9760988	107.6303249	-6.9760892	107.6303234	62
-6.9760848	107.6303388	-6.9760936	107.6303433	43
-6.9760512	107.6303276	-6.9760826	107.6303548	41
			Average	45

From the table above, it can be seen that although each mission is expected to take off and land at the same coordinate point, however the GPS reading different results. 32 GPS readings depend on the value of locked satellite, weather, air pressure and test location. The average distance precision in takeoff and landing is 45 cm.

B. Take Off Coordinate on Quadcopter

This test is conducted to find out the accuracy value of the GPS on the Quadcopter. The coordinates point from the GPS Ublox M8N compared with the results of the coordinates point the Google Maps. At each experiment, the coordinate take off point of the quadcopter was measured using the GPS Ublox M8N that displayed on the mission planner and comparing with the quadcopter take off coordinates point that obtained manually via google maps.

Table 2 : Take Off Coordinate on Quadcopter.

Google Maps Coordinate	GPS Ublox M8N Coordinate	Shifting (m)
-6.976108,107.630349	-6.9761062,107.6303296	2.29
-6.976089,107.630310	-6.9760711,107.6303402	4.32
-6.976034,107.630347	-6.9760165,107.6303457	2.07
-6.976070,107.630315	-6.9760793,107.6303352	2.52
-6.976074,107.630369	-6.9760782,107.6303367	3.64
-6.976125,107.630330	-6.9760988,107.6303249	2.87
	Average	2.95
	Deviation	0.86

The Table above show the take off coordinate measurement results via GPS and Google Maps. Then the data from the 2 measurements are inputted back on google 33 maps to get the distance between the two coordinate point. From the table above, it can be seen that the coordinate reading between Google Maps and GPS has an average data error of 2.95 m with deviation of 0.86.

C. Landing Coordinate on Quadcopter

The coordinates point from the GPS Ublox M8N compared with the results of the coordinates point the Google Maps. At each experiment, the landing coordinate point of the quadcopter was measured using the GPS Ublox M8N that displayed on the mission planner and comparing with the quadcopter landing coordinates point that obtained manually via google maps.

Table 3 : Landing Coordinate on Quadcopter.

Google Maps Coordinate	GPS Ublox M8N Coordinate	Shifting (m)
-6.976090,107.630326	-6.9760833,107.6303554	3.31
-6.976126,107.630330	-6.9760985,107.6303372	3.21
-6.976117,107.630237	-6.9760721,107.6303371	1.21
-6.976158,107.630408	-6.9761097,107.6303298	4.08
-6.976095,107.630350	-6.9760892,107.6303234	3.01
-6.976072,107.630331	-6.9760826,107.6303548	2.91
	Average	2.95
	Deviation	0.95

Table above show the landing coordinate measurement results via GPS Ublox M8N and Google Maps. Then the data from the 2 measurements are inputted back on google maps to get the distance between the two coordinate point. From the table above, it can be seen that the coordinate reading between Google Maps and GPS has an average data error of 2.95 m with deviation of 0.95. The value is just the same with the average data error in take off coordinate point.

D. Waypoint 1 Altitude

In the WP1 mission flight, the desired altitude value is set as as 3 m. This test conducted to measure the accuracy of the Pixhawk barometer. The accuracy measurement is measured by comparing the altitude obtained from the barometer measurement with manual calculations. Manual calculation is calculated by tying a 3 m thread with a load on the quadcopter. At each WP, a delay time is given to do the manual calculation.If during the quadcopter floating on the air the thread isn't in vertical state, a mark will be given on the thread so when the mission flight is over the rest of the thread length can be measured so that the manual measurement is obtained. But, if the thread in vertical state but the load isn't on the ground, then the manual calculations are done by measuring the distance from the load to the surface of the ground.

Table 4 : Waypoint 1 Altitude.

Barometer Pixhawk (m)	Manual Calculation (m)	Differences (cm)
3.02	2.9	12
3.04	3.10	6
3.07	2.92	15
3.02	2.91	11
2.96	3.03	7
2.99	3.04	5
3.08	3.12	4
3.04	2.99	5
3.01	3.11	10
3.02	2.82	20
	Average	9.5
	Deviation	5.14

From the flight test obtained that the difference in altitude between the barometer measurement and manual measurement. The average distances of the altitude error obtained in waypoint 1 is 9.5 cm with deviation of 5.14.

E. Waypoint 2 Altitude

At Waypoint 2, the desired altitude value is set as to 5 m. By conducted the test the accuracy of the Pixhawk barometer can be obtained. The accuracy measurement is measured by comparing the altitude obtained from the barometer measurement with manual calculations.

Table 5 : Waypoint 2 Altitude.

Barometer Pixhawk (m)	Manual Calculation (m)	Differences (cm)
5.01	4.93	8
5.03	5.07	4
5.04	4.99	5
5.05	5.01	4
5.08	5.00	8
5.11	5.02	9
5.03	4.99	4
5.04	4.94	10
5.06	4.93	13
5.00	4.96	4
	Average	6.9
	Deviation	3.17

From the test, the difference in altitude between the barometer measurement and manual measurement can be obtained. The average distance of the altitude error obtained in waypoint 2 is 6.9 cm with deviation of 3.17.

5.Conclusions

This research has designed and created an Automatic Take-off and Landing system for air quality measurement drone using Pixhawk, GPS Ublox M8N, and Radio Telemtry Kit 433 Mhz, and Mission Planner. From the test results, the ATOL system that has been done, obtained a few conclusions as follows:

1. The quadcopter can take off and landing automatically with the created system.
2. The average error value of the GPS system for its takeoff and landing operation is 45 cm.
3. The average accuracy value of the GPS used in quadcopter for take off and landing is 2.95 m.
4. The average accuracy value of the altitude based on the barometer sensor in pixhawk is 9.5 cm at altitude of 3 m to 6.9 cm at altitude of 5 m.

Based on the results, this system has satisfied the success criteria for this project. Which successfully performed the autonomous flight from takeoff, doing the misson, and landing for the air quality measurement drone. Therefore, this ATOL system work effective and suitable for the IoT drone applications.

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