Development of A Dodecacopter using Pixhawk 2.4.8 Autopilot Flight Controller

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2022 IEEE 5th International Symposium in Robotics and Manufacturing Automation (ROMA) | 978-1-6654-5932-7/22/$31.00 ©2022 IEEE | DOI: 10.1109/ROMA55875.2022.9915674

Abstract—**This research focused on the development of unmanned aerial vehicle (UAV) of a dodecacopter system. The dodecacopter is controlled through a Pixhawk 2.4.8 firmware-based flight controller. The communication between the dodecacopter and flight controller is connected through wireless communication system. The dodecacopter is well equipped with latest technology from Pixhawk flight controller for efficient and smooth controlling system. The dodecacopter balancing system is using the technology of barometer MS5611 and magnetometer IST8310 sensors. The developed dodecacopter is equipped with 12 Tarot 4006 brushless motors to increase the payload capability. Based on the results, the experiment shows that the dodecacopter can hover and maintain its position with optimum stability. Observation shows that the dodecacopter performances can be increased by using high-powered motors, lighter batteries.**

Keywords— flight controller, dodecacopter, unmanned aerial vehicle

I. Introduction

Nowadays, unmanned aerial vehicle (UAV) research and development have been popular and allow approaches for numerous uses including tactical flights, search and rescue activities topography mapping. A dodecacopter is a VTOL (vertical take-off and landing) which belongs in the multicopter type. It is features with 12 brushless rotors that generate the lifting force and enable the dodecacopter to improve its workload functionality.

To stabilise itself, this type of multicopter requires a continuous real-time control operation. Thus, this case of analysis poses difficulty in the field of control engineering. In essence, a dodecacopter consists of coaxial rotors where a pair of rotors are mounted one above the other with the same axis of rotation but turning in opposite direction. This design of dodecacopter with applied concept of coaxial rotors has two motors on each arm that rotates in opposite directions to neutralize rotational torque.

Dodecacopter has advantages than the previous drone technology where the mechanical design of the type of drone can sustain more payload. Besides that, the stability when hovering also become the main advantages because of the individual motor's speed manipulated the changes of direction.

The main issue in previous research on quadcopter is the balancing and stability system. Most of quadcopter designs will be unbalance and lost stability in case there are disturbances directed on it such as wind [1]. In this project, to solve the above problem, a comprehensive system of a dodecacopter is proposed. Generally, a dodecacopter is a more stable and powerful version of a multicopter design. The 12 propellers configuration provides substantial ability to hover and fly with solid maneuverability in the air.

II. Related Work

In the development of a dodecacopter using PixHawk Autopilot Flight Controller, several theoretical and methods are in need of a review through past related researches. Such reviews are detailed in this chapter which includes previous design, development and control of a multicopter. [2] studied rotor-cylindrical wing configuration and evaluation for a multicopter. This research is aimed at developing an efficient magnus wing rotor for multicopter and applying the same principle in the tracking industry. The span-disks attached at the ends reduced the risk and function as a temporary mechanism for storing power, thus providing the industry wide choices for application.

Later, [3] conducted research based regulation of quadcopter attitude at cascade in the face of motor asymmetery. In this analysis the UAV attitude control problem was analyzed as the characteristics of the 4 actuators differed. To achieve stabilization, a cascade control system was introduced with a PD controller to the inner loop, and a PI controller in the outer loop to ensure destructive exclusion.

[4] worked on experimentally tested software Hexacopter Predictive Controller. In a custom-made laboratory rig and with outdoor flight testing, the control technique presented in this paper was tested with experiments on a hexacopter. The UAV has been reported to be able to obey the evasive maneuvering commands.

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[5] studied on digital representation in multicopter design along the life cycle of the product. The unique technique consists of the novel visual, graph-based design languages framework reflected in UML (Unified Modeling Language), which permits both the development of new engineering models and the reuse of pre-existing engineering models. The paper discuss the approach, modeling process and computational methods, including specifications design, simulation, cost, energy analysis and their integration along the product life-cycle.

[6] carried research on systematic modeling approach for the development of a variable pitch quadrotor biplane VTOL UAV for payload transmission and flight test. This paper discusses the conceptual design and flight proof of concept in a new variable pitch quadrotor biplane UAV prototype system for payload delivery. The presented methodology was chosen by taking an example of a VTOL UAV for a mission requirement of handle and execute 6 kg payload at 16km from the point of origin to a destination. The Linux version of open-source QGroundControl ground station software is used to track and record telemetry data in real-time.

[7] studied simulation of a non-commercial UAV for experimental control and robotics. This paper presents the modeling of the black box and the simulator of a non-commercial hex-rotor platform for teaching control and automation subjects. The platform is equipped with an open source, Ardupilot 2.6 controller board that is compatible with Arduino [8].

III. Methodology

This chapter is divided into two parts. The first part is understanding the dodecacopter structure design and hardware. The second part deals with software design in order to develop the dodecacopter configuration and system.

A. Hardware Design

Dodecacopter can be portrayed as a vehicle with 12 propellers joined to rotors situated at the cross casing. Fixed pitch rotors are applied to control the vehicle movement. The paces of these 12 rotors are free. By free, pitch, roll and yaw orientation of the vehicle can be controlled effectively. ZD850 full carbon frame kit is used for the scale model of this project as illustrated in Fig. 1. Fig. 2 shows the rotation of every rotor in the dodecacopter configuration.

Fig. 1. ZD850 full carbon frane kit

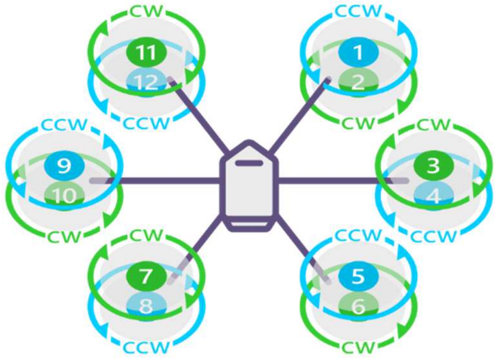


Fig. 2. Rotation of every rotor in dodecacopter configuration

Pixhawk is an advanced autopilot designed and suitable for new users to involve in the world of autonomous vehicles. It is optimized to run PX4 version 1.7, suitable for academic and commercial developers. Based on Fig.3, the Pixhawk-project FMUv2 open hardware design and runs PX4 on the NuttX OS. The onboard sensors are both accelerometer LSM303D, MPU 600, Barometer MS5611 and magnetometer IST8310.

Fig. 3. Pixhawk 2.4.8 with onboard sensors

As shown in Fig. 4, the connection between the power management board (Holybro PM07), ESC, motor and the flight controller are wired together. The motors are wired with ESC first and soldered at the power management board before connect to the flight controller. There are 2 type of input which is the Main input and Aux input. The telemetry, receiver and GPS module are externally connected to the flight controller.

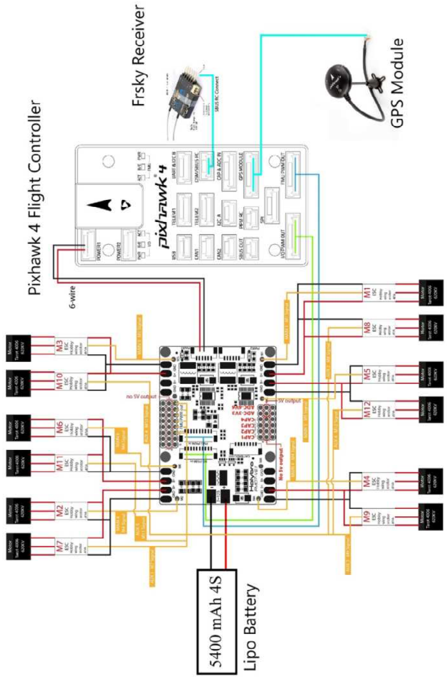


Fig. 4. Wiring connection between power management board and flight controller

B. *Software Configuration*

Mission Planner (MP) provides full flight control and mission planning for any MAVLink enabled drone. Its primary goal is ease of use for professional users and developers. As presented in Fig. 5, Mission Planner runs on Windows, OS X, Linux, iOS and Android. It supports multiple autopilot such as PX4 Pro, ArduPilot or any vehicle that communicates using the MAVLink protocol. It works with all vehicle types supported by PX4 Pro and ArduPilot (multi-rotor, fixed-wing, VTOL, etc.).

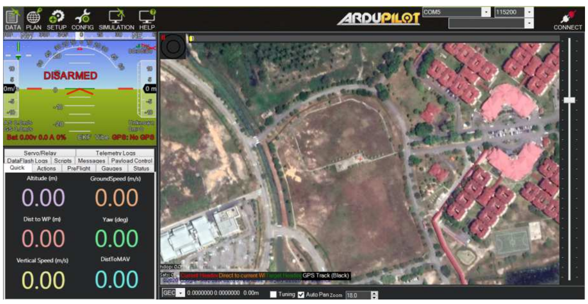


Fig. 5. Main page in Mission Planner Ardupilot Software

The most important in board configuration parameter is the board PWM count which is the control number of FMU outputs which are setup for PWM. BRD_PWM_COUNT set to value of 4 because dodecacopter motor uses 12 outputs which 8 outputs from the main output and 4 from the fmu output as shown in Fig. 6.

BRD_ALT_CONFIG	0		0 10
BRD_BOOT_DELAY	0	ms	0 10000
BRD_IMU_TARGTEMP	-1	degC	-1 80
BRD_IMUHEAT_I	0.3		0 1
BRD_IMUHEAT_IMAX	70		0 100
BRD_IMUHEAT_P	200		1 500
BRD_IO_ENABLE	1		0:Disabled 1:Enabled
BRD_OPTIONS	1		
BRD_PWM_COUNT	4		0:No PWMs 1:One PWMs 2:Two PW...
BRD_RTC_TYPES	1		
BRD_RTC_TZ_MIN	0		-720 +840
BRD_SAFETY_MASK	12288		0:Disabled 1:Enabled
BRD_SAFETYENABLE	1		0:Disabled 1:Enabled
BRD_SAFETYOPTION	3		
BRD_SBUS_OUT	0		0:Disabled 1:50Hz 2:75Hz 3:100Hz 4...
BRD_SD_SLOWDOWN	0		0 32
BRD_SER1_RTSCTS	2		0:Disabled 1:Enabled 2:Auto
BRD_SER2_RTSCTS	2		0:Disabled 1:Enabled 2:Auto
BRD_SERIAL_NUM	0		-32768 32767
BRD_TYPE	2		0:AUTO 1:PX4V1 2:Pixhawk 3:Cube...
BRD_VBUS_MIN	4.3	V	4.0 5.5

Fig. 6. Board configuration parameters

Referring to Fig. 7, the configuration for FRAME_CLASS is sets to value of 12 based on the dodecacopter configuration. This controls the major frame class for the multicopter component. There are 2 types of frames for frame class 12 which is type X and type +. For this dodecacopter, it uses configuration type +.

FRAME		
FRAME_CLASS	12	0:Undefined 1:Quad 2:Hexa 3...
FRAME_TYPE	1	0:Plus 1:X 2:V 3:H 4:V-Tail 5:A-...

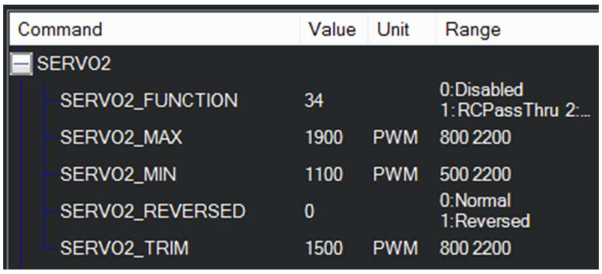
Fig. 7. Frane configuration parameters

Motors act as servos in this configuration. All servos need to be defined for each motor. Based on Table 1, SERVO 2 are sets to value 34 which acts as motor 2. Each servo are defined to every motors.

TABLE I. SERVOS VALUE

Servo	Value
1	33
2	34
3	35
4	36
5	37
6	38
7	39
8	40
9	82
10	83
11	84
12	85

From Fig. 8, SERVOx_MAX and SERVOx_MIN are sets to default which is typically value 1000 is lower limit, 1500 is neutral and 2000 is upper limit



Command	Value	Unit	Range
SERVO2			
SERVO2_FUNCTION	34		0:Disabled 1:RCPassThru 2:...
SERVO2_MAX	1900	PWM	800 2200
SERVO2_MIN	1100	PWM	500 2200
SERVO2_REVERSED	0		0:Normal 1:Reversed
SERVO2_TRIM	1500	PWM	800 2200

Fig. 8. Servo 2 configuration

IV. Results and Discussion

Dodecacopter consists of 12 motors that uses independent signals. For safety measures, propellers are uninstalled when testing the output signal from the motors. This test was performed by using BitScope micro oscilloscope. The achieved output signal is shown in Fig. 9. The signal shown are in pulse modulating width (PWM) signal. Typically, the output distribution power produces voltage of 1.36V – 4.00V based on the motors used for the multicopter.

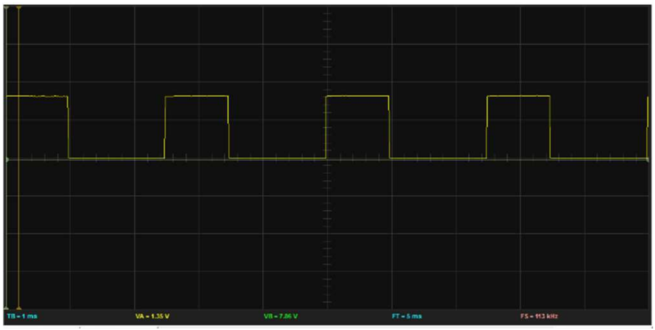


Fig. 9. Motor signal output

Manual flight tests have been performed to investigate the manual operation mode, flight altitude and position locking as shown in Fig. 10 and Fig. 11. Two types of manual flight mode are used in this test which is PosHold and Stabilize. Meanwhile, flight data is acquired from the Flight Log in the ground control station.

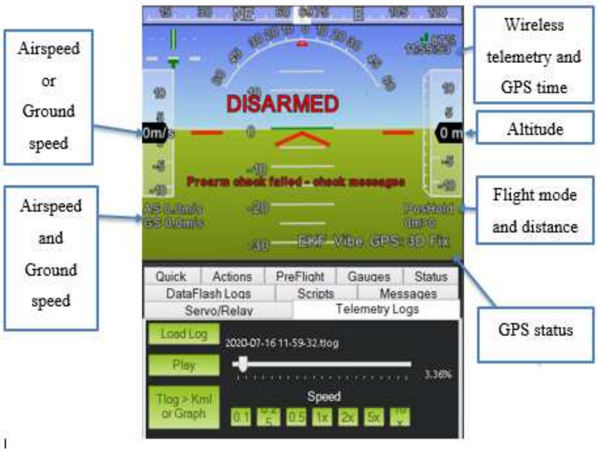


Fig. 10. Flight data before arm

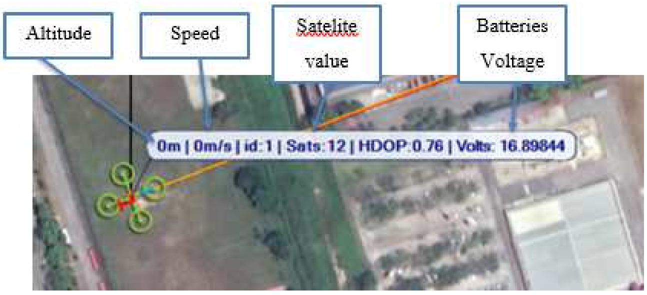
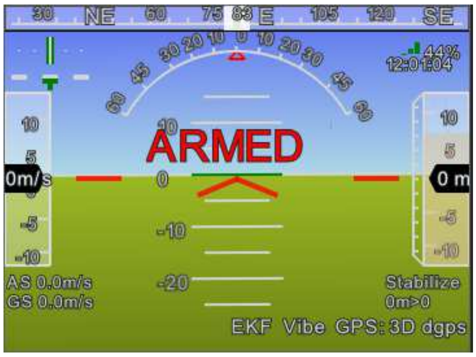
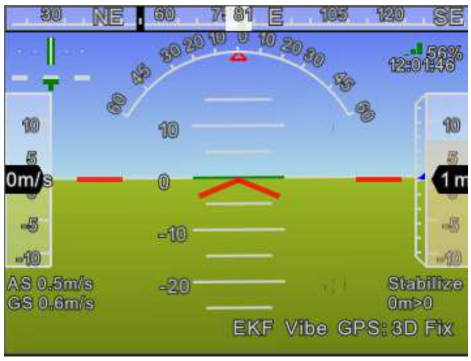
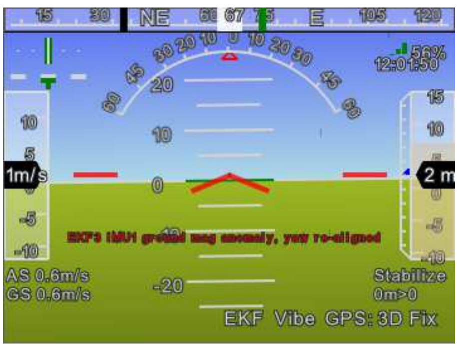
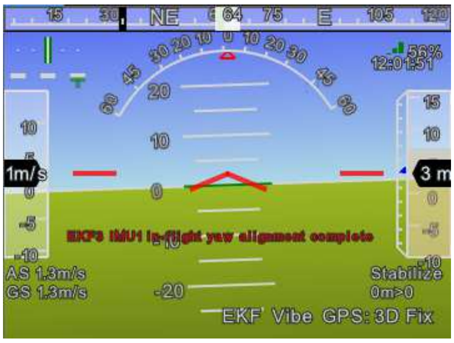
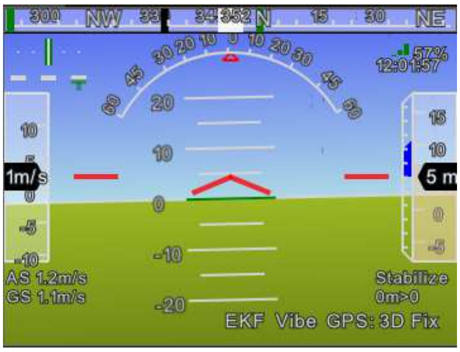
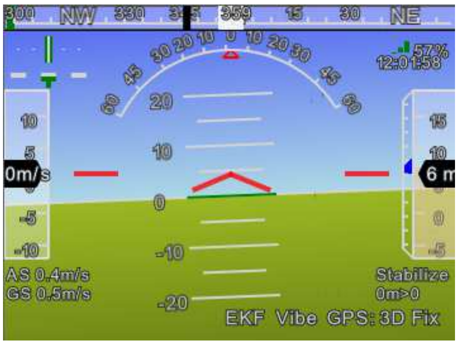


Fig. 11. Google map live view

TABLE II. Inflight Data

Flight Data	Description
	Dodecacopter armed and ready to take off.
	Dodecacopter take off at 1 meter with airspeed of 0.5 meter per second and 0.6 meter per second.
	Dodecacopter take off at 2 meter with airspeed of 0.6 meter per second and 0.6 meter per second.

	Dodecacopter take off at 3 meter with airspeed of 1.3 meter per second and 1.3 meter per second.
	Dodecacopter take off at 5 meter with airspeed of 1.2 meter per second and 1.1 meter per second.
	Dodecacopter take off at 6 meter with airspeed of 0.4 meter per second and 0.5 meter per second.

In waypoint flight test, the dodecacopter used auto flight mode which receive flight planning from the ground station. Based on Table 2, 4 waypoints were mapped out into the mission to investigate the stability and positioning during flight. For this test, the waypoint was set in a circular waypoint with a radius of 10m from the arming point while the altitude was set to just 1m for safety measure.

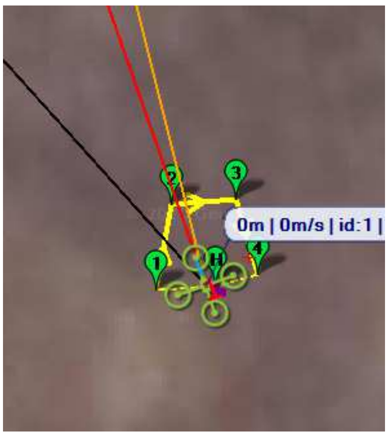


Fig. 12. Waypoint of Autoflight mode

Dodecacopter switched flight mode from auto to RTL (Return to Launch) to land safely. In RTL mode, the altitude are sets to 2m before it fly to the home position which it first arming point before slowly landing safely at the arming point location earlier. When the dodecacopter reach the home point, it descend slowly with a speed of 0.2m/s and land safely to the ground.

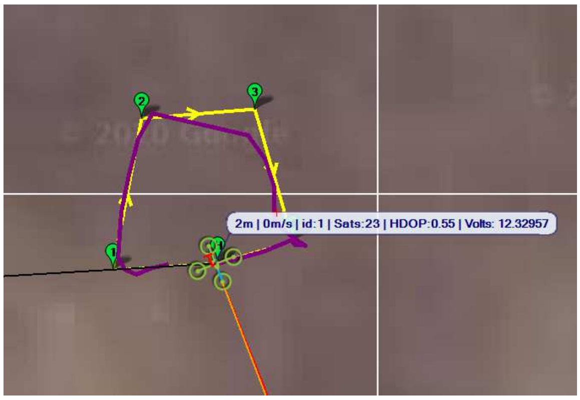


Fig. 13. Dodecacopter location reached at arming point

Fig. 14. Dodecacopter landed safely

V. Conclusion

In this paper, a dodecacopter development has been developed by using Pixhawk 2.4.8 autopilot flight controller to improve stability of a multicopter. Past multicopter designs have been reviewed over the time to investigate on the stability and performances of a dodecacopter configuration. Batteries and motors were tested to be suitable for operations. Moreover, the parameters of the flight controller was set to achieve the most optimum operation. The flight control algorithm for the dodecacopter were tested and achieved with minor correction. Based on the experiments, the Pixhawk autopilot flight controller has successfully managed to control all 12 motors with individual speed, thus made the dodecacopter managed to take off with more precision and stability. Larger frame design of the dodecacopter made the flight more stable and power especially in windy weather. Air pressure sensor was internally equipped in the Pixhawk flight controller which made the altitude reading and hovering more precise.

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