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AUTONOMOUS AERIAL DELIVERY SYSTEM

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ABSTRACT

It is rightly said that Robots are next generation citizen of the modern world. Advancements in robotics technology is increasing leaps and bounds which is making them flexible to do human like works more effectively without any rest. In this project we develop a autonomous aerial drone for delivery of products which will reduce manpower and also improve the quality of delivery. An autonomous aerial drone will be made, which is GPS linked and navigation enabled, which will fly off from the factory and deliver the product at the doorstep of the customer. The drone is made with commercially available low cost materials and software so that further research could be carried out with ease.

INTRODUCTION

The Autonomous Aerial Delivery System is a small lightweight hover-capable vehicle that can be controlled over a custom wireless system. Here in this paper the Autonomous Aerial Delivery System is an Octa-Copter. The Octa-Copter has a robust sensor suite so that can also operate in a more autonomous mode. The autonomous mode includes subsystems such as a GPS module so that the Octa-Copter, once given a GPS target location, can make its own way to the target coordinates without further human control. This flight mode requires additional subsystems such as ultrasonic proximity sensors, so that the robot can detect and avoid obstacles including the ground) and a digital compass, so that its direction can be detected and corrected. All of these sensors send a lot of data to the MCU, the brain of the Octacopter, which must process the information according to its algorithms and prompt the appropriate subsystems to action. An especially complex task assigned to the MCU is to maintain level flight by varying the speed of individual motors based upon the calculation of data received from the IMU (Inertial Measurement Unit).The IMU combines data from a triple-axis accelerometer and a dual-axis gyroscope using a sensor fusion algorithm. The subsystems of the Octacopter are interdependent, linked by the MCU, the physical frame, and the power system. Power comes at a premium in an aerial vehicle where flight duration varies directly with its total weight. The frame must be designed strong and rigid enough to support all the other systems yet, light enough to so as to prolong flight duration to acceptable levels. The Octacopter consists of several subsystems some of which are more interwoven into the design, such as the MCU, and some that are more isolated, for example the video system. The block diagram in figure 1 below provides an overview of the Octa-Copter subsystems (Black, Kliffton *et al*., 1992).

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Sensor Subsystems

The Quad-Copter requires several sensors to perform tasks that range from critical, such as flight stability, to optional, such as the high altitude sensor. Additionally, sensors are an important part of the Octa-Copter autonomous functions such as altitude maintenance, path finding, and object avoidance. The different sensor subsystems can be organized into the following categories: flight stability sensors, proximity sensors, yaw or direction sensor, and the navigation sensor (GPS).

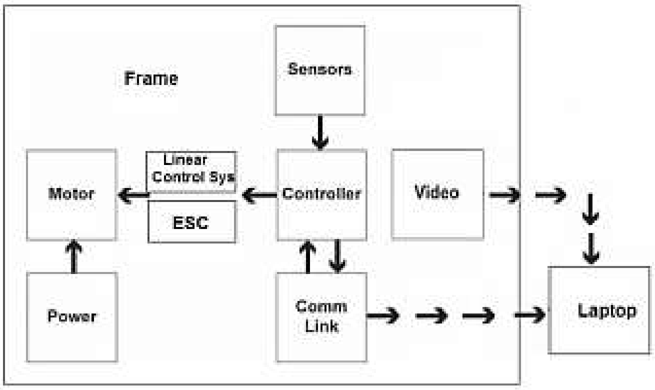

Fig. 1. Block diagram of Octa-Copter subsystems.

Flight Stability Sensors

The flight stability sensors are a critical system for the Octa-Copter to remain in flight. The system consists of a triple axis accelerometer and a dual axis gyroscope combined into a 5 Degree of Freedom IMU. The accelerometer is the ADXL335 from Analog Devices, and the gyroscope is the IDG500 from Inven Sense. The outputs from the sensors will be combined using a sensor fusion algorithm, which outputs an improved estimate of the angular state. The output of the sensor fusion algorithm is the input to the linear control system which adjusts the speed of each motor to maintain a level hover. The sensor fusion algorithm used is based on an adaption that uses the gyroscope to monitor and correct for angular velocity about the Quad-Copter axes.

Proximity Sensors

Proximity sensors will be used for two distinct purposes on the Octa-Copter: a downward oriented sensor to detect the distance to the ground, and a forward oriented sensor to detect obstacles such as trees and walls. Both sensors will be ultrasonic range finders, specifically, the MaxSonar LV-EZ2s from MaxBotix. Both sensors are necessary for any sort of autonomous flight protocols such as object avoidance or automatic altitude control. The FS-CT6B shave a maximum range of about 20 ft. for a large object such as a wall, however; this range diminishes significantly when detecting smaller targets. Both of the FS-CT6B ultrasonic sensors will be remote from the main PCB and connected with 6-12 inch of wire to header pins (Nieuwenhuisen *et al*., 2014).

Yaw/Direction Sensor

Yaw is the movement about the vertical axis of the Octa-Copter. Yaw must be stabilized as a requirement for attaining a stable hover. Yaw can be manipulated by increasing the speed of two motors along a single axis while simultaneously decreasing the speed of the motors on the other axis. This will rotate the Octa-Copter in place while maintaining a net equilibrium on the vertical axis. This change to the yaw can be initiated either directly by the user giving a wireless command or autonomously by the microcontroller using sensor data from a digital compass. The digital compass used for this purpose will be HMC6352 two-axis magnetometer from Honeywell, which communicates with the microcontroller via a two-wire serial interface. The compass heading can be used as a component input of the stabilization loop to maintain a stable heading. Furthermore, the compass can be used in conjunction with the GPS module to autonomously plot movement to a GPS coordinate (Wang Fu *et al*., 2013).

Navigation/Position Sensor (GPS)

A GPS module will be integrated into the design of the Octa-Copter which will be a central component of the autonomous mode of operation. The GPS system will allow the Octa-Copter to hover in place by repeatedly returning to a point of origin, or to move towards a given coordinate. The MediaTek MT3329 GPS module will be used. The MT3329 has an antenna integrated into the casing of the chip which is an optimal design for the Octa-Copter. It has a positional accuracy of within 3 meters and a sensitivity of up to -165 dBm. The MT3329 also has coding and firmware support available from the DIY drones website. Originally, the plan was to mount the chip directly onto the main PCB, subsequently; the design has changed to the GPS module being mounted on a breakout board and wired to the main PCB with header (Ozalp *et al*., 2013).

Power

Power has been divided into two separate parts: the motors and the main components for operation and control. This was found as the best solution to minimize noise and to protect the main board from unforeseen problems based on in experience with PCB design. Since the majority of the required power needed to be drawn is consume by the motors, the best solution is to directly connect the lithium polymer (LiPo) batteries to the motors. Since the biggest concerns regarding the LiPo batteries are mass and cost, the best route to minimize both of these issues was to select either one very large battery or two smaller ones. This design will implement the latter. The Esprit EM-35 3-cell 35C 4000mAH are an excellent source in terms of mass, balance, and charge capacitance. The batteries will be directly connected to the ESC, which are rated at 30A per ESC & also connected to other subsystems as shown in figure 2 below.

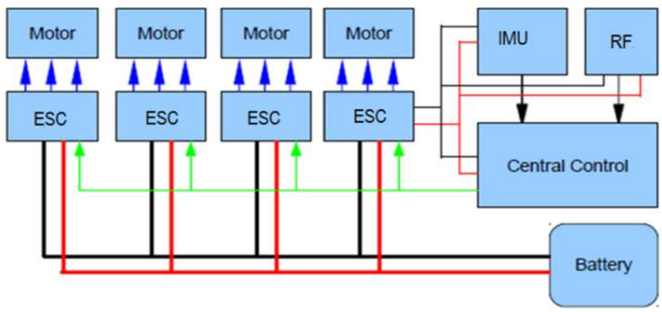

Fig. 2. Block diagram of Power Distribution on Drone (Quad-Copter)

Linear Control System

The linear control system will be responsible for stabilizing the Octa-Copter. This will be the most crucial system of Octa-

Copter as it will enable the Octa-Copter to fly stable. The linear control system will consist of a discrete PID controller that will be design in software with integer math. The PID will receive an output from the sensors and determine if the Octa-Copter needs to be stabilized or not. The design of the system is as follow. In order to make the PID controller equation a discrete the integral term and the derivative term has to be in discrete form. For the derivative term a backward finite difference form will be used. For the integral term a summation of all previous error will be used. The error signal will be a discrete function where each error will be sampled and stored in an array. The derivative term will calculate the difference between two consecutive error samples and divide it by the sampling period, while, the integral term will do a summation of the array and multiply it by the sampling frequency. Discrete equation (1) is shown below along with the Ki term (2) and the Kd term (3).

$$x(n) = K_p e(n) + K_i \sum_{K=0}^{n} e(k) + K_d[e(n) - e(n-1)] \quad (1)$$

$$K_i = \frac{K_p T}{T_i} \quad (2)$$

$$k_d = \frac{K_p T_d}{T} \quad (3)$$

Where, T will be the sampling period and Ti the integral time constant. The PID controller will use 3 functions in order to initialize, calculate the PID controller, and reset the PID controller. The MCU will use PWM to control the motors. The PWM signal will be generated by using the MCU's 16-bit timers and the output compare registers. The main software will be interrupt driven. The reason for this is to keep MCU running and not waiting for an event to happen. While the MCU is calculating the PID equations it can still receive data through UART and I2C as shown below.

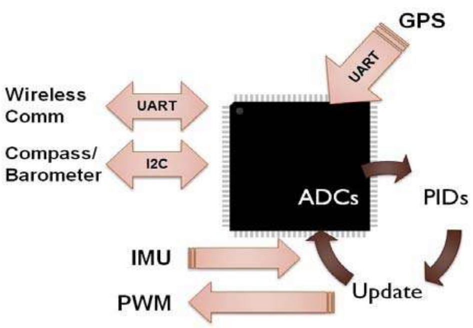

Fig. 3. Overview of MCU interfaces

Software

The software will be responsible for controlling all aspect of the Octa-Copter. These include the action perception loop, polling of the sensors, and controlling movement. The code is yet to be written as we haven't yet selected Microcontroller for the same.

Frame

The best way to keep the copter from spinning is to have the propellers move the propellers in opposition to each other. The top and bottom propellers will be used to spin counter-clockwise, while left and right propellers are used to spin clockwise. The object-detecting ultrasonic sensor will be pointing towards this front end, while the ground detector will be facing below it. A light weight frame must be designed to support all the Octa-Copter subsystems. The frame will be either entirely aluminum or a combination of aluminum and carbon fiber tubing. Carbon fiber tubing has a slight strength to weight ratio advantage over aluminum but is more expensive, Hence we will be using Aluminium for the same. Frame structure is shown in figure 4.

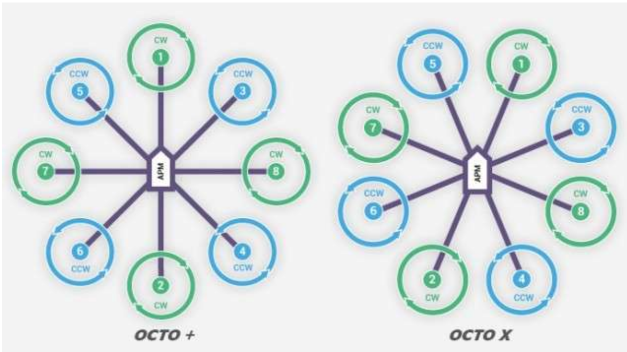

Fig. 4. Basic Octa-copter Design

Wireless

ZigBee is a protocol used normally on sensors networks. This protocol uses a mesh networking topology, where each device can talk to each other without a central routing device. ZigBee is based on the IEEE committee standard 802.15.4. ZigBee is considered a PWAN(Personal Wireless Area Network.) ZigBee can work in the ISM bands of 915 MHz and 2.4 GHz. The maximum data rate that ZigBee can achieve is 250 Kbits/s. ZigBee can operate at different maximum distances depending on the environment and components used. [1]

Features

1. Load carrying capability (upto 1200 grams)
2. Autonomous delivery and return to pick up point
3. GPS tracker

Conclusion

The Octa-Copter is an ambitious engineering project that is challenging all members of the group in several different areas of learning. The fight stability algorithm in particular caused a development bottleneck as the group explored different options to optimize the system. A custom wireless communication system is to be designed and many more technical difficulties yet to come in achieving a successful project. The difficulties, however, are an important aspect of the learning process.

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