Autonomous Quadcopter for Product Home Delivery

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***Abstract*— This paper represents Quadcopter (QC) as a low-weight and low-cost autonomous flight capable Unmanned Aerial Vehicle (UAV) for delivering parcel ordered by online by using an android device as its core on-board processing unit. This QC by following Google map can locate and navigate destination. This paper demonstrates the QCs capability of delivering parcel ordered by online and coming back to the starting place. The promising result of this method enables future research on using QC for delivering parcel.**

Keywords—Quadcopter; Autonomous Flight; Home Delivery; Android Device;

I. INTRODUCTION

An Unmanned Aerial Vehicle (UAV) is an air-craft without a human pilot aboard. Its flight is controlled either autonomously by onboard computers or by the remote control of a pilot on the ground or in another vehicle. The QC an emerging UAV is lifted and propelled by four rotors. It has good maneuverability with limitless applications. Departing from a century old design, modern QCs are evolving into small and agile vehicles. After already proving their usefulness as aerial imaging tools, new research is allowing QC to communicate perceptively with other autonomous vehicles, to explore unknown environments and to maneuver in dense surroundings with speed and precision. Individually, these advances will allow QC to complete missions such as long-term surveillance and search and rescue. However, if all of these developing technologies are combined, quad rotors will be capable of advanced autonomous missions that are currently not possible with any other vehicle. This paper shows details and usages of a QC as weight lifter which is capable of making a path using Global Positioning System (GPS) for delivering parcel ordered by online.

II. INDUCEMENT

Use of autonomous QC will enable faster transport of goods which will ensure timely delivery. It will also reduce the fuel cost of vehicles and human labor of home delivery. Besides, it will improve transportation management. Generally, home delivery requires vehicle and manpower. This process consumes fuel of vehicle and time of service delivery boy. If the vehicle get stucked to traffic jam then it will waste more time and fuel. Using an autonomous QC for home delivery can overcome this problem. Company's operational efficiencies and productivity will increase as a result of improving supply chain management. It will help to increase customers' satisfaction. Revenue growth is directly impacted by better supply chain management. Profitability and capital utilization also impacted by better supply chain management. Needless to say better supply chain management ultimately helps one's company to create a competitive advantage in market place. The effect of reducing fuel cost and labor cost will reduce production cost and increase consumer surplus and raise profit of the producer.

III. PRINCIPLE OF QC OPERATION

The basic QC design consists of four complete rotor assemblies attached at equal distances from each other and a central hub. All the rotors are located within the same plane and oriented such that the thrust generated by each rotor is perpendicular to the vehicle as shown in Fig. 1. If the rotors are comprised of parts with the same specifications and expected performance, each will produce the same amount of thrust given a specific power input. The angular momentum of any of the four rotors generates a torque about the inertial center of mass of the vehicle which can be effectively counter balanced by the torque created from the opposing rotor [1]. This configuration requires that opposite rotors spin in the same direction while adjacent rotors spin in opposite directions. An immediate advantage to the quad rotor design is that, it is not necessary to implement additional equipment such as control moment gyroscopes with the sole purpose of negating extraneous torques on the vehicle [2].

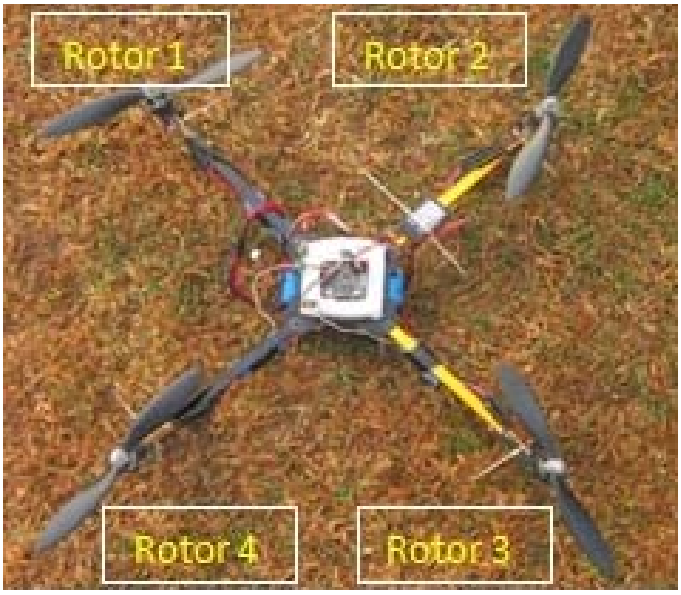


Fig. 1: A prototype QC.

There are two types of QC working principle [3]. They are-

- "+" configuration: In this configuration, two motors of QC rotate clockwise and other two motors rotate anti-clockwise. Opposite motors will rotate in same direction. QC operating motherboard's front will be pointing rotor-1, shown in Fig. 2

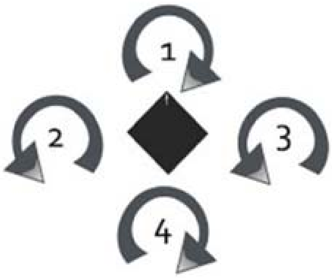


Fig. 2: "+" configuration

- "x" configuration: It is almost same to "+" configuration. Difference is QC operating motherboard's front will be pointing to the direction between rotor-1 and rotor-2, shown in Fig. 3.

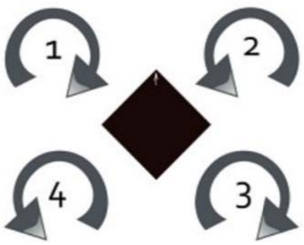


Fig. 3: "x" configuration

IV. OVERVIEW OF OPERATION

QC will start autonomously with the product for the consumers. Before flying GPS co-ordinates input is given by computer. QC will fly to its given direction by following Google map. After reaching its desired location it will confirm its customer and drop the parcel and get back to the starting point through the same route.

Complete operation of delivery service via QC can be categorized by following phases shown in Fig. 4.

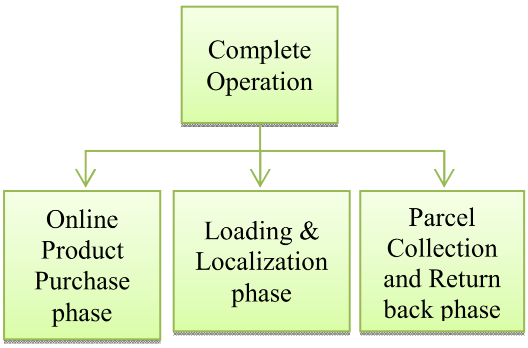


Fig. 4: Tree diagram of complete operation.

A. *Online Product Purchase phase*

At first customer will order for product through online using payment gateway. During online order placement, the customer will provide cell number. Customer will also inform about the required time of delivering the product as per schedule of the provider. Then online shop will send a confirmation SMS with a product identification (ID) to the customer. Later on, this product id will be used for verification.

B. *Loading and Localization phase*

At local office the QC will be armed and before that location of the place that is the co-ordinate will be provided to GPRS and product ID will be provided to the memory of motherboard of the QC with the help of computer. The parcel will be loaded the QC with the help of rolling machine. Then the QC will start to fly for destination by following the GPRS from where it has started flying.

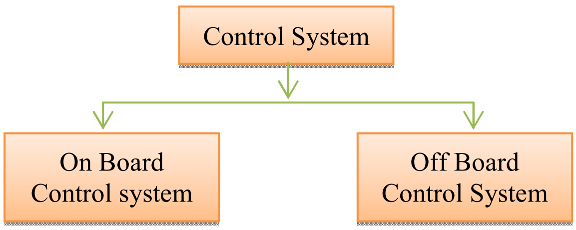
C. *Parcel Collection and Return back phase*

Local monitoring office will notify the customer before ten minutes of delivery. The QC will be remained stabilized for one minute after reaching the destination. After receiving the SMS (for verification) the QC will drop the parcel and come back to the starting point following the GPRS.

V. STRUCTURAL, POWER AND ELECTRICAL COMPONENTS

QC is designed to have four arms which provide the body a stable balance. Each arm is associated with one motor of 3350 rpm/volt, comprising of total four motors. Each motor is associated with one propeller of APC electronic E series of 14 inch diameter and 10 pitch. Each motor is connected with one Electronic Speed Controller (ESC).

VI. CONTROL SYSTEM



A. *On Board Control System*

Android device is interfaced with ArduPilot Master (APM) of QC [4] for two purposes:

1) SMS Control: After reaching destination, the QC will remain stabilized there for one minute. If the QC receives the correct product ID in the test SMS send by the customer for verification, it will drop the parcel and then come back to the starting point of flying following the GPRS. If it does not receive the correct product Id. then the QC will come back to the first place without dropping the product.

SMS will be sending to the android mobile phone which will be interfaced with the APM of QC via three signals of interfacing TxD, RxD and GND. It works as follows:

-Configuring the Global System for Mobile (GSM) modem of android for text mode by the following command [4].

AT +CMGF command sets the GSM modem in text mode. Text or Protocol Data Unit (PDU) mode can be selected by assigned 1 or 0 commands. “1” is used for text mode and “0” is used for PDU mode. For example,

AT +CMGF =1

-For sending SMS in text mode, the text SMS along with the mobile number of the recipient to the MCU of the QC by following

AT command:

AT +CMGS command sets the GSM modem in text sending mode along with the text.

AT +CMGS=1

GSM modem sends the command to the Microcontroller Unit (MCU) through MAX232. MAX232 is a device which enables serial communication between GSM modem and MCU.

2) Following Google Map via GPRS and GPS

a) GPS: The on board control system contains a Motorola Droid phone of Android Operating System, has both GPRS (WL1271) and GPS (QSC6085) capabilities interfaced with APM [5]. On board GPS will locate the current location of QC. Once, location information of destination is provided to GPS, it will get direction from the Google map. GPS interfacing with MCU enables QC automatically following the path to reach destination as well as to return back. Fig.3 shows walking mode in Google map. The QC will follow this walking mode direction for determining the airpath by maintaining a certain altitude to ensure shortest possible airpath without any obstacle.

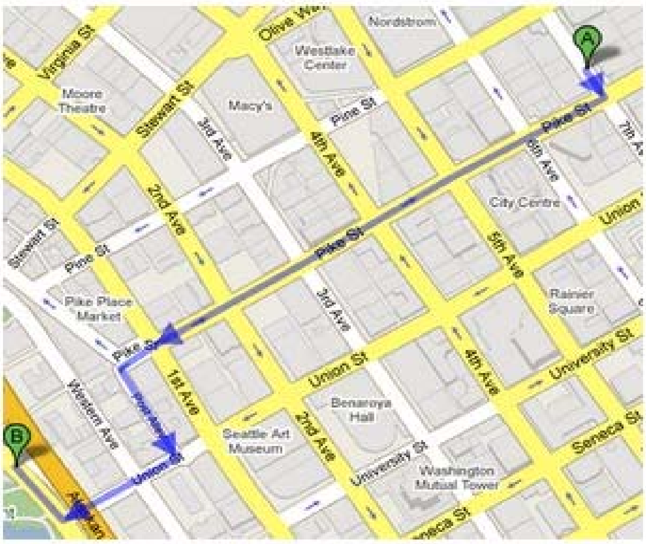


Fig. 6: Walking mode in Google map.

Fig. 7 demonstrates the working of GPS to find out the current location of QC.

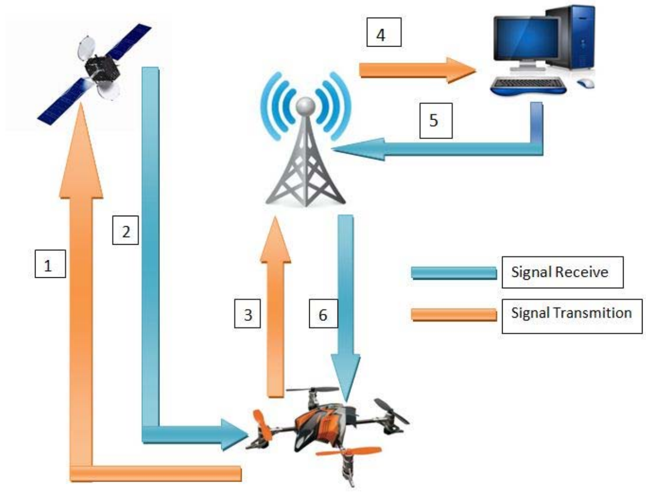


Fig. 7: Working of GPS to find out the current location of QC.

In fig. 7,
1= Beacon Starts
2= Receives a wave form corresponding satellites
3 and 4= Through GPRS and GPS module encode the wave,
5= Computer gives a co-ordinate to tower
6= Tower gives the co-ordinate to QC from GPS to show the path.

b) GPRS: This QC consists of a sim-900 GPRS (General Packet Radio System) module used to connect to the internet. Through internet GPS module gets the data. With this data, QC will follow the path.

3) APM: APM is used as main operating board. It can be used in both fixed and rotary wing. It has pxIMUv2.5 and LPC2148 ARM 7 (up to 60MHz) microcontroller to run all the operation on board [6]. This QC motherboard consumes only 360mW of power and can be run in voltage supply of 3.7V to 5.5V. It has 32 KB RAM and 512 KB flash memory.

APM has some on-board sensors. They are-

a) Gyro: for XY directions here IDG500 is installed and for XY directions IX500 is installed.

b) Accelerometer: QC can be expected to fly maneuvers below 2g acceleration. APM has on board SCA310-D04 installed that has resolution of 900 counts/g, 0.0109 m/s^2 maximum acceleration.

- APM sensing capabilities:
- 3D Linear Acceleration
- 3D Angular Velocity
- 3D Earth magnetic field
- 1D Barometric Pressure
- 4D ultrasound / IR
- 1D Temperature

The following figure describes the total on-board control system:

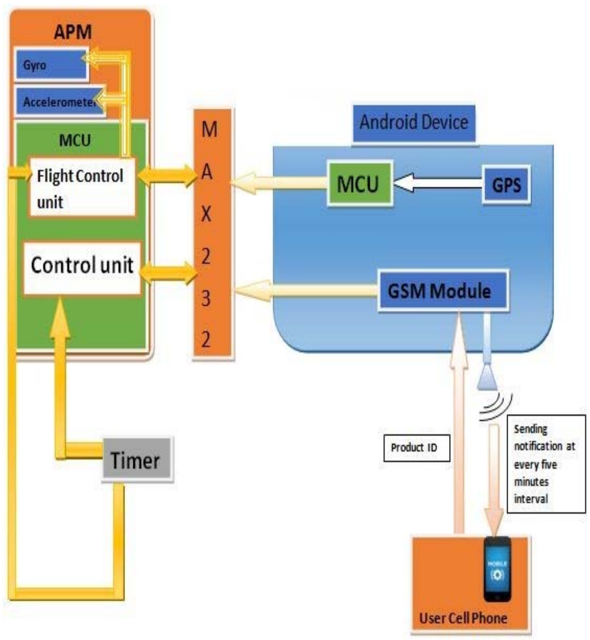


Fig. 8: On board control system

B. *Off board control System*

Off board control system consists of a computer of the control room of the local office and receiving message from mobile of the user. The computer of the control room provides necessary data to the GPS in the QC after arming the QC. Computer of the control room will also monitor the position of the QC during transportation via GPS with the help of internet. The android device interfaced with MCU of the QC will send continuous notification to the user mobile after every five minute interval. After reaching the destination, customer will send the product ID as confirmation SMS to the android device of the QC.

VII. LOAD CALCULATION

The total mass of the QC has been estimated in Table-I

TABLE I. EMPTY MASS ESTIMATION

Components	**Number of quantity**	**Mass of one quantity (gram)**	**Total mass (gram)**
Motor	4	60	240
Battery	1	400	400
Structure and other components	1	1	260
Total Empty Mass			800

Total empty mass estimated from Table-I, is 800 gram. As the expected maximum payload capacity of the QC has considered as 300 grams, so the QC must be capable of flying with total mass of 1100 grams.

Thrust of QC can be expressed,

$$T = \frac{\pi}{4} D^2 \rho v \Delta v \quad (1)$$

Where,

T = Thrust

D = Propeller diameter (m) = 0.3556 m

ρ = Density of air (1.225m kg/cubic meter)

Now,

$$v = 1/2 \Delta v$$

Here,

v = Velocity of air at the propeller (m/s)

Δv = Velocity of air accelerated by propeller (m/s)

Putting the value of v in (1),

$$T = \frac{\pi}{8} D^2 \rho x (\Delta v)^2 \quad (2)$$

But power,

$$P = \frac{T(\Delta v)}{2}$$

Putting the value of Δv in (2),

$$T = \frac{\pi}{8} D^2 \rho \left(\frac{2P}{T}\right)^2$$

$$\text{Or, } T = \left[\frac{\pi}{2} D^2 \rho P^2\right]^{\frac{1}{3}} \quad (3)$$

Now, total mass lifted by QC,

$$m = \frac{thrust}{acceleration\ due\ to\ gravity} = \frac{T}{g}$$

$$m = \frac{\left[\frac{\pi}{2} D^2 \rho P^2\right]^{\frac{1}{3}}}{g}$$

Again,

$$P = propeller\ constant\ x\ \left(\frac{rpm}{1000}\right)^{power\ factor}$$

For, APC Electric "E" Series propeller (14" diameter × 10 Pitch), propeller constant is 1.118 and power factor is 3.2.

Here, rpm of the motor = 3350.

$$\text{Hence, } P = 1.118\ x\ 3.35^{3.2}$$

$$= 76.931 \text{ W}$$

Therefore,

$$m = \frac{\left[\frac{\pi}{2} x 0.3556 x 1.225 x 76.931\right]^{\frac{1}{3}}}{9.81}$$

=1 .15113 kg

= Empty mass of QC (800 gram) + Payload (351.13 gram)

The results of the calculation of the QC clearly showed that it would be capable of flying with a 300 gram payload safely.

VIII. PERFORMANCE TESTING

To estimate the flight time of the QC with various loads, actual flight test has been done with loads ranging from 0 grams to 300 grams [7]. The results of the test are shown in Table-II. During the test the QC was flown at approximately fifty feet off the ground performing stabilize flight. A plot of this information provides a relationship between the payload and the flight time and can be seen in fig. 9.

TABLE II. FLIGHT TEST RESULTS

Payload (grams)	Flight Duration (min)
0	25
100	20.80
150	18.03
200	15.80
250	14.37
300	13.30

From this figure a linear relationship can be found between the load and the duration of flight.

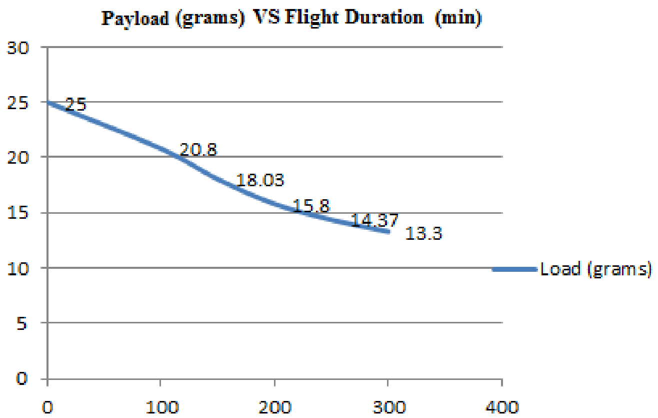


Fig. 9: Payload VS Flight Duration plot

IX. LIMITATION AND SCOPE FOR FUTURE RESEARCH

The QC is unable to perform at long distance range due to limited amount of power supply from Lithium polymer battery. Increment of power source will increase the range. But at the same time it will raise the empty mass resulting low payload capacity. Besides, it may exceed the maximum mass limit; the QC is capable of flying. For this reason, the paper is proposing to serve only one customer at a time. Furthermore, a lot of QCs deployed in a single area needs an air traffic management system which requires further research.

X. CONCLUSION

This paper deals with a systematic process of online delivery with an autonomous QC using an interfaced android device as its core processing unit. QC will deliver the parcel to the customer by following Google map which will reduce both time and manpower using for delivery. Battery power will be replaced by solar system as a power source in future. This process will be continued to optimize the cost of delivering products through QC so that poor people can use these systems more easily.

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