Design and Fabrication of Voice Controlled Unmanned Aerial Vehicle

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***Abstract*—Unmanned Aerial Vehicles have gained well known attention in recent years for a numerous applications such as military, civilian surveillance operations as well as search and rescue missions. The UAVs are not controlled by professional pilots and users have less aviation experience. Therefore it seems to be purposeful to simplify the process of aircraft controlling. The objective is to design, fabricate and implement an unmanned aerial vehicle which is controlled by means of voice recognition. In the proposed system, voice commands are given to the quadcopter to control it autonomously. This system is navigated by the voice input. The control system responds to the voice input by voice recognition process and corresponding algorithms make the motors to run at specified speeds which controls the direction of the quadcopter.**

Keywords—Quadcopter; voice recognition; arduino; thrust calculation; RF module; voice commands

I. INTRODUCTION

In recent days, Quadcopter has become one of the popular models in UAV systems research. They are made in various sizes for specific applications such as indoors and outdoors. The small-scale unmanned aerial vehicles find a variety of applications. For smaller UAV's, quadcopter becomes suitable for safety, stability and manoeuvrability. The need for greater manoeuvrability and hovering ability of helicopter headed a rise in quadcopter research. The design became simple but they are highly reliable and manoeuvrable. Research is being done to increase the abilities of quadcopters by making advancements and innovations in multi-craft communication, environment exploration, and manoeuvrability. If these developing abilities are combined, quadcopters would be capable of carrying out advanced autonomous missions that are currently not possible with other vehicles.

The Quadcopter is an emerging Unmanned Aerial Vehicle which is lifted and propelled by four rotors. A quadcopter uses four motors and propellers to create thrust and give the total lift. The lift and torque is controlled by varying the RPM of the four motors. Two motors rotate in counter clockwise direction and the other two motors rotate in clockwise direction. This configuration causes the torque from each motor to cancel by the corresponding motor rotating in the opposite direction. The difference of quadcopters from helicopters is that for controlling pitch, yaw, and roll movements the pilot uses variable thrust between the four motors. There is no single large collective pitch rotor or tail rotor that is used to manoeuvre a conventional helicopter. By precisely spinning these four propellers of quadcopter at different speeds, all the common directional movements of a quadcopter are attainable - Hover, forward, backward, left, right, and yaw or turning movement.

Voice Technology has become a wide area of research which is being done in many critical avionic and aeronautical communication systems. Research has been carried out by aeronautical companies such as Euro control and AENA which is in collaboration with some Voice Technology expert groups. In that, voice and text databases were created and new voice and text processing models was developed for specific requirements. These technological improvements have been supported by the hardware that executes these algorithms as well as the improvements within the algorithms that demonstrates the properties of intelligent search for the best solution. The Speech Processing and Data Analysis Lab at FAMU-FSU College of Engineering is presently working on research projects which involve building intelligent autonomous systems that supports multimodal human-computer interactions[19]. The key intention of this research is to develop a platform for advancing knowledge and discovery in HCI research and also to have a research in intelligent autonomous systems.

II. METHODOLOGY

A. Working of Voice controlled Quadcopter

Quadcopters are commonly controlled by RC method. The vehicle is navigated according to the input from the transmitter by giving appropriate throttle, pitch, yaw and roll values manually. In such cases there is a loss in transmission and so the quadcopter takes some time to respond to the signal. Apart from this conventional method, it can be controlled by interfacing voice commands and transmitting using RF module. There are two stages in this construction. They are designing and assembling the quadcopter vehicle and interfacing quadcopter with speech recognition module and programming the actuators speed for each input commands. The balancing and levelling condition during flight is sensed using sensors namely accelerometers and gyroscopes, and its output of the sensors is used in hovering and smooth levelling.

B. Block diagram for Voice control System of UAV

Fig. 1 and Fig. 2 show the block diagram for transmitting and receiving module respectively. Transmitting module comprises the user voice commands which are the input to the vehicle. The user voice commands are converted into signals by means of voice recognition module

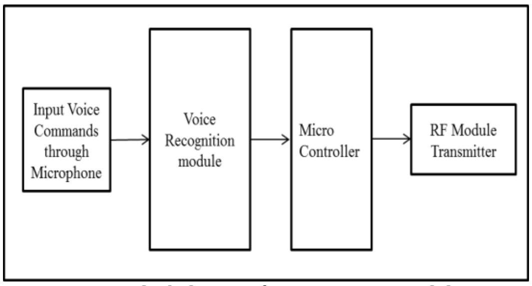

Fig. 1. Block diagram for transmitting module.

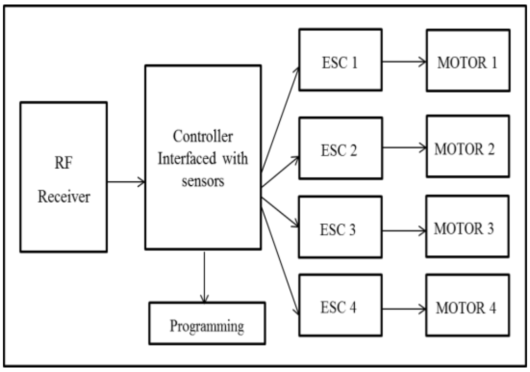

Fig. 2. Block diagram for receiving module.

III. DESIGN OF QUADCOPTER MODEL

The X type frame used in the quadcopter should be thin, light weight and strong enough to withstand deformation and loads. Usually the frames are indicated as motor to motor distance or the diameter of the circle of frame area. The diameter of the circle of frame area for mini aerial vehicle ranges between ¼ metre and 1 metre. For the mini aerial vehicle ½ metre area is chosen for application. The diagonal distance from motor hub to motor hub is this project is therefore 450mm. At the centre of the frame, a plate or bed is attached for resting of on-board controllers, battery and other electronic components. When the frame is subjected to bending or twisting load, the amount of deformation is proportional to the cross-sectional shape section. The stiffness of the solid structure is lesser than the hollow structure. The torsional stiffness of a closed square cross-section is greater than the closed circular section. Therefore closed square cross sectional hollow frame is used. This reduces overall weight. The stiffness can be varied by changing cross-sectional profile dimensions and wall thickness. Therefore box type frame or truss type frame can be chosen.

The quadcopter virtual model with motors and propellers assembly is designed using CATIA 3D modeling software which is shown in Fig. 3

Fig. 3. Quadcopter Virtual model.

The parameters of the quadcopter frame are shown in Table I.

TABLE I. QUADCOPTER FRAME PARAMETERS

S.No	Parameters	Specification
1.	Arm Length (Four arms)	205 mm
2.	Arm dimensions (width, height and thickness)	12 × 12 × 0.5mm
3.	Central frame Plate dimensions (length, breadth and thickness)	110 × 110 × 1mm
4.	Motor to motor distance	450 mm
5.	Fastening Screw and nut dimensions	2mm diameter, 15 mm length.
6.	Drill size	2 mm hole size (all holes)
7.	Total weight	216

A. Propulsion System

The propulsion system consists of motors, propellers, Electronic Speed Controllers (ESCs), batteries and propellers. Both the motor and propeller combination produces thrust and moves the vehicle upwards. As the estimated all up weight is considered to be 1.5 kg, the thrust requirement from four motors should be double that of 1.5 kg. Therefore each motor should be able to produce 850g of thrust force. Motors are selected based on their Kv rating. It is calculated by the equation as follows

$$\text{RPM} = \text{Kv rating} \times \text{Voltage input} \qquad (1)$$

Substituting the values of RPM and Voltage input,

$$\text{Kv rating} = 10378/11.1 \approx 935 \text{ Kv}.$$

Propeller is a type of fan which transmits power by converting rotational motion into thrust. The APC brand propellers are good in quality and are used in many quadcopters. Propellers are generally twisted along the length of the blades. This is to ensure whether the angle of attack of the blades is kept relatively constant along their length. The twisted portion of the propeller is generally termed as pitch. The propeller is specified on the basis of its pitch and diameter in inches.

Power (Watts) = $Kp \times D^4 \times P \times RPM^3$ (2)

Where Kp is the propeller constant (1.11 for APC propellers), D is the propeller diameter in feet, P is the propeller pitch in feet and RPM is the rotations per minute in thousands. The propeller diameter is to be chosen as that absorbs power of 200Watts at 10378 RPM.

Substituting the values, we get

$$D = 0.439 = 10 \text{ inch.}$$

Static Thrust Calculator software is used to calculate Static Thrust values and power required from the battery source. It is indicated in Fig. 4.

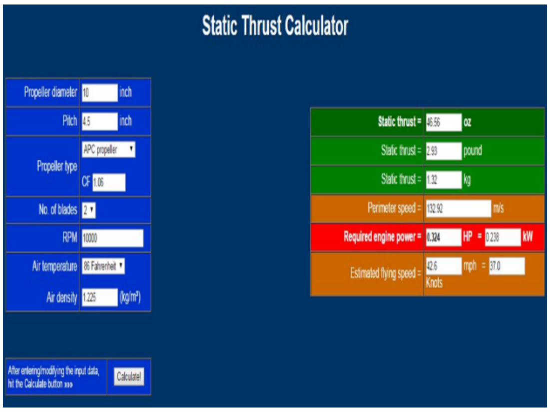

Fig. 4. Static Thrust Calculator.

The motor and propeller of the above configuration will be able to produce static thrust of 1.32 Kg and required power is 238 watts. Also the estimated flying speed is 37 miles per hour.

A. Electronic Speed Controllers

The function of the electronic speed controllers is to get the output signal from the flight controller and precisely control the speed of the motor. It supplies power from battery and it varies according to the input signal. It also has Battery Eliminated Circuit. BEC supplies 5V output from ESC that powers up receiver and Flight controller. Each motor is connected to an electronic speed controller. They give a smooth linear throttle control and a fast response to the throttle input. The electronic speed controller is selected based on its Ampere rating. This should be greater than ampere rating of the motor.

ESC rating = (1.2 to 1.5) × max. Ampere rating of motor

By the above equation, ESC rating is found to be 22.5 A.

B. Battery

Lithium Polymer batteries are used in quadcopter. These cells can produce an enormous amount of current, needed for the brushless motors. These batteries are rechargeable, can last longer, have low weight and high voltage capacity compared to other type of batteries. These batteries are available as 3.7V per cell. These batteries are rated based hon their C-rating. C-rating specifies how fast a battery can discharge. A 2000mAh battery with 12C rating would discharge 12 times its capacity i.e. 24000mAh for 1/12th of an hour. These batteries provide burst current and C-ratings are specified as per burst currents.

Maximum current withdrawn by motors = no. of motors × maximum current withdrawn by single motor. So the maximum current withdrawn is 60A.

C. Flight Controller

A flight controller is a microcontroller in which suitable sensors and RF module are interfaced in order to control the speeds of the motor by receiving the commands from transmitter and feedback from sensors. The Arduino Uno is based on the ATmega328, which is used as flight controller because of sufficient input and output pins, high performance and light weight. It has 14 digital input output pins, of which 6 pins are used as PWM outputs, 6 pins are used as analog inputs, and a 16 MHz crystal oscillator for faster performance. It occupies less weight around 20g.

D. Inertial Measurement Unit

An inertial measurement unit works by checking the rate of acceleration using one accelerometer in each axes. It also checks the changes in rotational attributes in each axis for pitch, roll and yaw using one gyroscope each.

The MPU 6050 is a 6 DOF or a six axis IMU sensor, which means that it gives six values as output. Three values are given from the accelerometer and three are given from the gyroscope. This chip uses Inter Integrated Circuit protocol that is for communication. Its purpose is to stabilize the aircraft during flight. To do this process, it takes the signals from the three gyros (each for roll, pitch and yaw axis) and feeds the information to the Integrated Circuit. This then processes the information according to the program embedded and sends out a control signal to the Electronic Speed Controllers which are plugged onto the board and also connected to the motors. In accordance with the signal from the IC the ESC's will either speed up or slow down the in order to maintain level flight.

E. RF module

The RF module consists of an RF Transmitter and an RF Receiver. The transmitter and receiver (Tx/Rx) pair operates at a frequency range of 434 MHz. An RF transmitter receives serial data and transmits it through Radio Frequency through its antenna that is connected at pin4, wirelessly. The transmission occurs at the rate of 1Kbps - 10Kbps.The transmitted data is received by an RF receiver operating at the same frequency as that of the transmitter. The RF module is encrypted with a pair of encoder or decoder. The encoder is used for encoding parallel data for transmission feed and reception of data is decoded by a decoder.

F. Electronic Components Connection

The assembly and connections of the various electronic components of the Quadcopter is shown in Fig. 5. The four motors are controlled by Arduino controller through four ESCs. As two motors should spin in clockwise and other two should spin in anticlockwise direction, the positive and negative wiring from motor to ESC is checked for its direction, and if it is in opposite direction, the wiring is changed and the direction of the spin of motors are verified. The four motors pins are connected to PWM pins of Arduino board which is already interfaced with MPU6050 sensor.

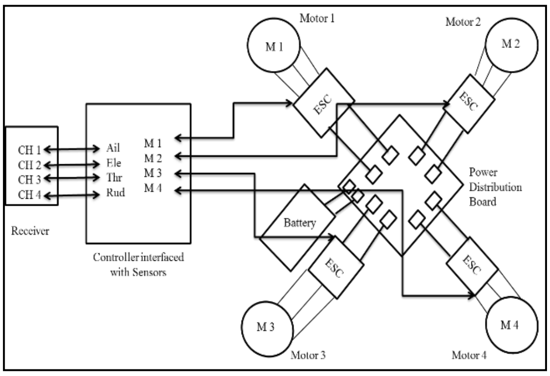

Fig. 5. Electronic Components Connection.

The fabricated quadcopter model assembly is shown in the Fig. 6.

Fig. 6. Fabricated Quadcopter model.

IV. THRUST CALCULATION

The total mass of the quadcopter is estimated in Table 2.

TABLE II. MASS OF THE COMPONENTS

S.No.	Parts	Weight (g)
1.	Central Frame and arms	216
2.	Motors (4)	220
3.	Propellers (4)	40
4.	Electronic Speed Controllers (4)	95
5.	Flight Controller	40
6.	Battery	190
7.	Receiver and other sensors	100
	TOTAL	901

The total empty mass estimated from the above table is about 901 grams. As the expected payload capacity is considered as 300 grams, the quadcopter should be able to fly with a total mass of around 1200 grams.

The thrust of the quadcopter [3] is given by the equation

$$T = \pi D^2 \rho v \Delta v/4 \quad (3)$$

Where T is Thrust in N, D is Propeller diameter in m, ρ is Density of the air – 1.22 kg/m^3
Also

$$V = \Delta V/2 \quad (4)$$

Where V is the velocity of air at the propeller, ΔV is the velocity of the air accelerated by propeller.
Substituting, we get,

$$T = \pi D^2 \rho (\Delta v)^2/8 \quad (5)$$

But power

$$P = T(\Delta V)/2 \quad (6)$$

Substituting the value of ΔV,

$$T = [\pi/2D^2 \rho (P^2)]^{1/3} \quad (7)$$

Therefore, total mass lifted by the quadcopter vehicle is calculated as

$$m = \text{Thrust/ acceleration due to gravity} = T/g \quad (8)$$
$$m = [\pi/2D^2 \rho (P^2)]^{1/3}/g \quad (9)$$

Substituting the values, we get

$$m = 1.739 \text{ kg} \quad (10)$$

The total mass comprises of empty mass of Quadcopter of 1.100 kg and payload of 639 grams.
The results of the thrust calculation of the Quadcopter show that it would be capable of flying with a minimum payload of 539 grams safely.

V. INTERFACING VOICE RECOGNITION MODULE

The aim of voice recognition is to analyze a word that is picked up by a microphone as user input command and convert it into text to microcontroller so that it can be identified as a signal.
This method of process takes place in two stages.

1) The acoustic signal from the microphone is extracted and cracked down into 30microsecond segments each for analysis. For each segments, an acoustic image is extracted. This is a vector of the signal.
2) Corresponding to this signal, phoneme for each segment is determined which is the smallest unit of spoken language. English language is considered as the mode of input command and the English language is made of 45 phonemes. For each segment of signal, the program determines the matching probability with every phoneme and combines those probabilities with its pronunciation and the possibility of a word occurring in the target language. This type of recognition is more accurate than

other voice recognition methods, as it fetches over predefined trained set of words only.

EasyVR 3 is a multi-purpose speech recognition module which is designed for robust and cost effective speech recognition competencies to any application. The EasyVR 3 module is used with any host with an UART interface powered at 3.3V – 5V, like PIC and Arduino boards. This module is connected to Arduino Uno microcontroller that is connected to a computer to program voice commands and sound outputs into an EasyVR module and quickly test it from the PC as shown in Fig. 7.

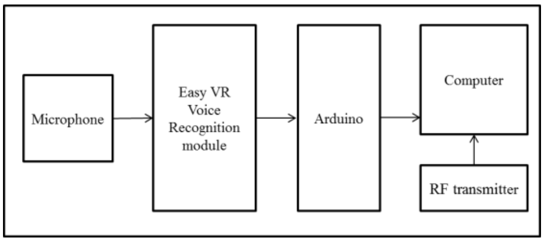

Fig. 7. Interfacing Voice Recognition Module on the transmitter.

A. Voice Command Recogntion

After interfacing Voice recognition module to the Arduino, Easy VR commander software is downloaded and the application is to be installed. The recognition function of the EasyVR works on one single group at a particular time and so all the commands that are to be used at the same time are to grouped together. When EasyVR Commander gets connected to the module, it reads all the user-defined commands and groups, that are stored into the EasyVR module non-volatile memory. The main application window is shown in Fig. 8

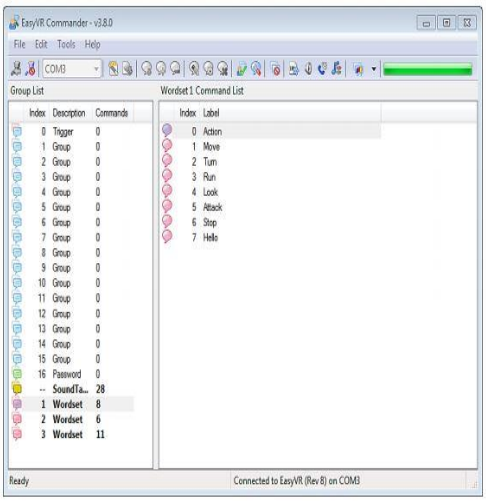

Fig. 8. Easy VR Commander Window.

A new command is to be added by first selecting the group in which the set of commands are to be created. After selecting a particular group, Edit menu is clicked and a Command List is generated as shown in Fig. 8. A command is given a label and it is first trained to the label. It should be trained twice with the user's voice. When the voice is spoken within the given time of 5 seconds, it is recorded and appears on the Commands List with the default name TEST_CMD_ZERO. It can be renamed and a group of commands that are needed for the navigation of the quadcopter is trained and recorded.

After a group of commands are trained, the commands can be tested, by using the “Tools” menu, in order to make sure that the trained commands are recognized successfully.
If a command is to be re-trained, previous trained command is to be erased and trained once again by pressing the Phase 1 button as show in Fig. 9

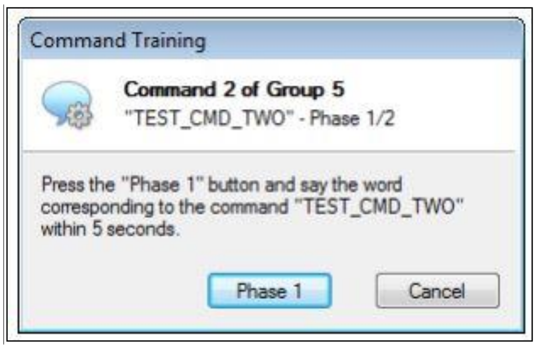

Fig. 9. Voice Command training.

B. Software design for Voice commands

The module is connected to the Arduino which sends signals to the RF transmitter. Based on each command, the speed of the motors is programmed, i.e. how much roll, pitch yaw and throttle values are to be given for each input signal command. For taking off, using the voice recognition function, the quadcopter can respond to the voice command and fly up to a certain height and start hovering. Thus four motors speed up for 5 seconds, which gives lift, and after it hovers in the air. The speed of the motors are controlled by varying the values after analogWrite command function in Arduino. Timer function can also be used for advanced programming for running all motors a certain speed for a particular time and changes its speed of individual motors for better navigation. Ten basic commands are used in a set of Group Command List in order to maneuver the quadcopter vehicle as shown in Table. III

TABLE III. VOICE COMMANDS FOR QUADCOPTER AND THEIR ACTIONS

S.No	Voice Commands	Actions
1	Start Motors	Motors start spinning, maintaining middle speed
2	Fly Low	Speed of motors decrease and vehicle comes lower
3	Fly High	Speed of motors increase and vehicle goes up faster
4	Go Left	Right portion of motors increases speed
5	Go Right	Left portion of motors increases speed
6	Go Forward	Left portion of motors increases speed
7	Go Backward	Left portion of motors increases speed
8	Turn Left	Counter clockwise motors increases speed
9	Turn Right	Clockwise motors increases speed
10	Hover	Speed of all motors is uniform and thrust is equal to the total weight

Thus the flight controller is programmed for takeoff, Up, down, Move left, move right, Turn left, and Turn right commands. For each command, the motor speed values are programmed after practically testing its stability and speed.

VI. CONCLUSION

The core intention of the project is to control the quadcopter entirely by Human Voice input. The quadcopter model is designed and interfaced with Voice recognition module and programmed for its flight. Accuracy of voice commands is achieved by training the words within a calm environment. In case of failure of a command, it can also be controlled alternatively by remote control. The project can be extended by implementing some advanced functionalities like "Return to User" which make the vehicle to return way back to the User. Also GPS module can be embedded within the circuit so that the quadcopter can be controlled from very long distance.

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