Proceedings of First International Conference on Smart Systems and Green Energy Technologies (ICSGET 2022)

Implementation of Leader Follower Approach in Quadcopter

[1]Pandiyarajan.R, [2]Chandravadhana, [3]Vivek. T, [4]Agnishwar Jayaprakash

[1,2,3] Department of Mechanical Engineering, Agni College of Technology-OMR, Thalambur, Chennai-600130 Tamilnadu, India.
[4] Garuda Aerospace, OMR Chennai-600130, Tamil Nadu, India.
Email: pandiyan.rajan8@gmail.com

Abstract

Modern concepts and technology have the potential to address many of the problems we confront on a daily basis and in our professions. In order to demonstrate the advantages of using the control strategy (Leader-Follower) through drones and their comprehensive application-oriented functioning, the project "Implementation of Leader Follower Approach in Quadcopter" has been detailed in this article. Building and using a quadcopter has been shown to be feasible for "Autonomous flight without aid of ground pilot" as the electronic age has progressed. The topic of formation control of numerous quadcopters, which has uses in the entertainment, medical, and defence industries, has been developed in this part. Additionally, "lift-up technologies" utilise it. which today are completed with the assistance of cranes and other tools. Due to the introduction of several cutting-edge technologies, including as GPS, Bluetooth, and other new-age sensors, the design of drones is much more trustworthy and amazing by incorporating both hardware and software requirements. This project's primary objective is to enhance drone capabilities by utilising low-cost electronics and a single drone to implement the Leader-Follower strategy using GPS interfaced with Arduino, as has been extensively discussed. A variety of theoretical principles, notably those relating to mathematical modelling based on control system and dynamics, served as the foundation for the drone's design and testing.

Keywords. Leader-Follower approach, Autonomous Flying, GPS, Arduino.

1. Introduction

Future drone applications will heavily rely on the field of drone formation control. The use of artificial intelligence and machine learning technologies to control drones in formation will completely alter the tech industry. This motivated many tech experts in the field of aerial vehicle control to conduct additional study on how to get a large number of drones to cooperate in order to carry out a specified

e-ISBN: 9788770229647 https://doi.org/10.13052/rp-9788770229647.007

operation. Between drones Quadcopters have a number of benefits, including excellent reliability, low cost, and tiny size. The copters are capable of performing a variety of difficult jobs, such as search and rescue missions, risk and hidden zone inspections, aerial mapping, and military uses. In any application, using many quadcopters that can interact with one another and cooperate to achieve a task more effectively than using a single quadcopter.

A formation of multiple quadcopters, as opposed to a single quadcopter, increases room for carrying sensors and other components, provides a greater cargo capacity and surveillance range, and as a result, can accomplish more difficult and time-consuming jobs more effectively. In formation control of quadcopters, there are different kinds types of approaches which are currently in use. Some of those approaches are 1) Leader-Follower, 2) Virtual Structure, and 3) Behavior-based. Among these approaches Leader-Follower approach is considered to be the less complex one in which one of the quadcopters is assigned to be a leader and other quadcopters will be assigned as a follower. The followers are programmed in such a way that it orients and navigates to the position of leader with a predefined offset.

This paper discusses about the possibility of making an autonomous quadcopter which follows its leader (remote GPS device or predefined waypoints) based on the instructions given by the programmed microcontroller which calculates the navigation vector using the “Haversine Formula” and the “Forward Azimuth Formula” based on the location and orientation data collected from the GPS receiver and compass respectively.

1.1. PROJECT’S MAIN IDEA

This project is aimed at implementing Leader-Follower approach in quadcopter by making it fly autonomously without using any remote controller. To achieve this, we have used a microcontroller interfaced with GPS and compass which is programmed in such a way that it mimics the function of remote controller by controlling the drone autonomously by providing input commands to the Flight controller on board the quadcopter.

2. PROPOSED SYSTEM

Calculating the drone's distance from the leader's waypoint and its orientation in relation to the leader's location is important if you want the drone to follow the leader's waypoint on its own. The Haversine Formula, which derives circle lengths between two places on a sphere from their longitudes and latitudes, was used to determine the distance to the target. The heading was determined using the forward azimuth formula. The leader's GPS position, the drone's coordinate acquired from the GPS receiver, and the drone's heading in relation to North

e-ISBN: 9788770229647 https://doi.org/10.13052/rp-9788770229647.007

obtained from the digital compass may all be used to determine both parameters. In order to approach the leader's location with a certain offset, the quadcopter's microcontroller (Arduino UNO) continuously recalculates the navigation vector and utilises the obtained distance and direction to regulate the input commands of the flight controller onboard.

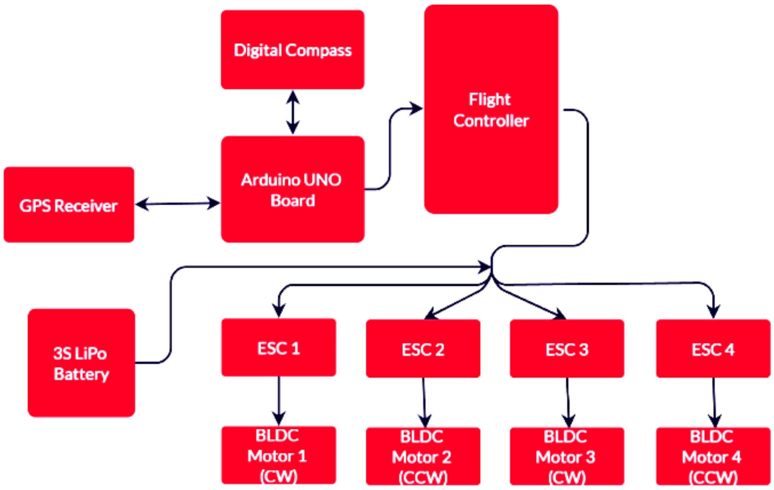

Figure 1. Block diagram of the project work

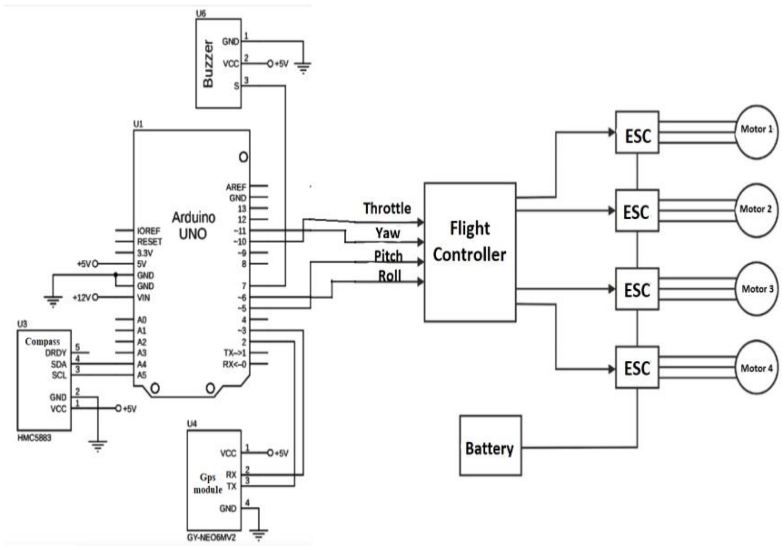

Figure 2 Circuit diagram of the project

e-ISBN: 9788770229647 https://doi.org/10.13052/rp-9788770229647.007

We have utilised an Arduino UNO board as the primary controller to accomplish our goal. We selected Arduino since it is simple to use and has a vast array of libraries. As a result, connecting numerous sensors to an Arduino UNO becomes simpler. The U-blox NEO-6M GPS module is the GPS receiver we selected for the job. It reaches the maximum degree of sensitivity and can track up to 22 satellites on 50 channels. The GY-271 module, which is based on the Honeywell HMC5883L microprocessor, houses the digital compass. Both are inexpensive modules that use Arduino libraries that are easily accessible. The HMC5883L utilises the I2C serial protocol, whereas the U-blox NEO-6M uses the UART serial communication interface.

We utilised an 11.1v, 2,200 mA-hour 3S (LiPo) Lithium-Polymer battery to power the four ESCs (Electronic Speed Controllers), which in turn provide power to the Arduino UNO, GPS module, digital compass, and flight controller. The block diagram and circuit diagram for the suggested system are shown, respectively, in Figures 1 and 2.

3. METHODOLOGY

A flow diagram of the algorithm the quadcopter uses to follow its leader is shown in Figure 3.

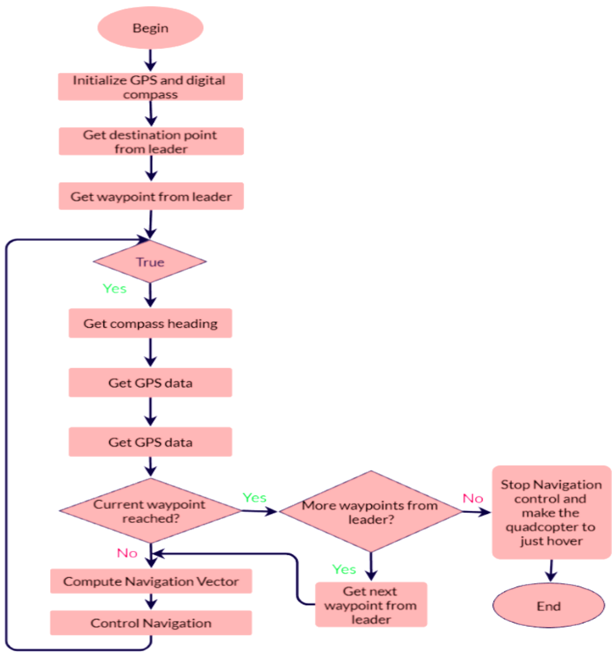

Figure 3: Flow diagram describing the algorithm

e-ISBN: 9788770229647 https://doi.org/10.13052/rp-9788770229647.007

As already noted, we utilised the Forward Azimuth Formula to determine the leader's orientation with regard to magnetic North and the Haversine Formula to get the distance to the leader's position. The algorithm will proceed to pitch the quadcopter forward by regulating inputs of the flight controller if the distance between the leader and the follower exceeds a specified distance tolerance error (1m). Additionally, the algorithm will yaw the quadcopter until its face is pointing in the direction of the objective if the heading angle of the quadcopter with respect to the leader is outside of a specified heading tolerance error (plus or minus 5 degrees). If another waypoint is located, the algorithm will continue to fly the quadcopter until it reaches the leader's location; otherwise, it will hover at a certain height. Because more distance and direction errors are introduced into the system with each movement, the Arduino must repeatedly calculate the navigation vector and regulate its motion.

3.1. NAVIGATION VECTOR CALCULATION

The definition of the Navigation vector (distance and direction) is illustrated visually in Figure 4. The leader's coordinates, the quadcopter's coordinates, and the quadcopter's direction in relation to magnetic North are used to calculate these two components. The mistakes that we will next attempt to minimise with our control method are heading and distance. The quadcopter's distance error can be decreased by applying a linear velocity via a PWM signal from the Arduino UNO board to the PITCH input pin in the flight controller, and the angle error can be reduced by applying a pertinent angular velocity via a PWM signal from the Arduino UNO board to the YAW input pin in the flight controller. We may get the distance error "d" using the Haversine Formula, and we can determine the azimuth (waypoint angle) using the Forward Azimuth Formula to determine the heading error.

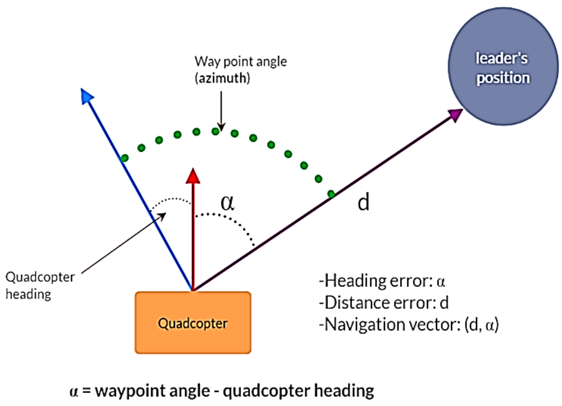

Figure 4: Computation of navigational vectors

e-ISBN: 9788770229647 https://doi.org/10.13052/rp-9788770229647.007

To determine the separation between two places on the surface of the Earth, one can use the Haversine formula, which is a general formula in spherical trigonometry. We need the coordinates (Latitudes and Longitudes) of two places on the surface of the Earth in order to compute their separation. Equations 1 and 2 provide, respectively, the generic Haversine formula and the trigonometric identity of the Haversine function. Equations 3, 4, and 5 make up the algorithm's logic and are a breakdown of the general equations.

$$hav\ (d/r) = hav\ (\varphi 2 - \varphi 1) + \cos(\varphi 1) * \cos(\varphi 2) * hav\ (\lambda 2 - \lambda 1) \rightarrow 1$$

$$hav\ (\theta) = \sin^2 (\theta/2) = (1-\cos(\theta))/2 \rightarrow 2$$

$$a = \sin^2 (\blacktriangle\ \varphi/2) + \cos(\varphi 1) * \cos(\varphi 2) * \sin^2(\blacktriangle\lambda/2) \rightarrow 3$$

$$c = 2 * \arctan 2(\sqrt{}a, \sqrt{}1\text{-}a) \rightarrow 4$$

$$d = r * c \rightarrow 5$$

where, $\varphi 1$ = follower's latitude, $\varphi 2$ = leader's latitude, $\lambda 1$ = follower's longitude,

$\lambda 2$ = leader's longitude, d = arc (distance), r = Earth's Radius,

$\blacktriangle\ \varphi = \varphi 2 - \varphi 1$,

$\blacktriangle\lambda = \lambda 2 - \lambda 1$.

A direction line, which is defined by two locations on the surface of the Earth, and a North base line or meridian are the two points from which the azimuth is measured. We may determine the actual azimuth by using true North as a point of reference. The matching "magnetic azimuth" is obtained by taking the magnetic North. Therefore, we can determine the angle between the line connecting the quadcopter's location to the North and the line connecting the quadcopter to the leader's position using the azimuth formula. Equation 6 illustrates the azimuth formula, which calls for the coordinate values for the leader and follower.

$$\theta = a\ \tan^2 (\sin \blacktriangle\lambda * \cos \varphi 2, \cos \varphi 1 * \sin \varphi 2 - \sin \varphi 1 * \sin \varphi 2 * \quad \cos \blacktriangle\lambda) \rightarrow 6$$

where, $\varphi 1$ = follower's latitude, $\varphi 2$ = leader's latitude, θ = waypoint or azimuth

$\blacktriangle\lambda = \lambda 1 - \lambda 2$

The heading error (), which is just the difference between the azimuth and the follower's heading with regard to North as determined by the digital compass, may be calculated once the azimuth or waypoint angle has been determined.

Heading error (α) = waypoint angle (θ) – quadcopter's heading

3.2. NAVIGATION CONTROL

e-ISBN: 9788770229647 https://doi.org/10.13052/rp-9788770229647.007

The quadcopter navigation control algorithm is made straightforward. Initially, the quadcopter's heading error is minimised by giving the flight controller in the quadcopter a YAW command to the right if the angle error is positive or to the left if the error is negative. We have established a tolerance range of plus or minus 5 degrees because it is challenging to decrease the inaccuracy precisely to zero. The distance inaccuracy is decreased by instructing the forward PITCH operation to the quadcopter's flight controller using an Arduino UNO once the follower has been positioned at the proper angle. However, this process tends to make the angle error bigger, whether it's positive or negative. This happens as a result of tolerance problems that affect both the sensor modules and outside disturbances. Therefore, until the follower reaches the leader's position, we must continuously repeat over the computation of a new navigation vector and the minimising of both errors.

4. CONCLUSION

The paper mainly focuses on the effective way to make a quadcopter follow its leader autonomously using a pre programmed microcontroller (Arduino UNO) which processes the data from sensor modules (GPS module and digital compass) and makes an effective decision to reach the leaders location. Here the leader's location can be provided to the Arduino board either by pre defining it in the algorithm or can be transmitted wirelessly with the help of Bluetooth or Wi-Fi module. By implementing this approach in several number of drones where one drone acts as a leader and others as follower then a more complex formations of drones can be achieved which can contribute in completion of tasks without much human interference in wide variety of applications. Figure 5 and 6 shows the pictures of the follower drone that we have made using kk flight controller.

Figure 5: Flying quadcopter using kk flight controller

Figure 6: Top view of our quadcopter

e-ISBN: 9788770229647 https://doi.org/10.13052/rp-9788770229647.007

REFERENCES

[1] Xuan-Mung N, Hong SK. Robust adaptive formation control of quadcopters based on a leader–follower approach. International Journal of Advanced Robotic Systems. 2019;16 (4).

[2] Pebrianti, Dwi et al. "Leader Follower of Quadrotor Micro Aerial Vehicle." Journal of Telecommunication, Electronic and Computer Engineering 10 (2018): 67-73.

[3] Falin Wu, Jiemin Chen and Yuan Liang (2016) "Leader-Follower Formation control for Quadrotors", IOP Conference Series: Materials Science and Engineering, Volume 187, 2016 Second International Conference on Mechanical and Aeronautical Engineering (ICMAE 2016) 28–30 December 2016, Hong Kong

[4] Lee, K.U.; Choi, Y.H.; Park, J.B. Backstepping Based Formation Control of Quadrotors with the State Transformation Technique. Appl. Sci. 2017, 7, 1170.

[5] Rifqi Rafifandi, Dea Lana Asri, Estiyanti Ekawati and Eko Mursito Budi (2019) "Leader- Follower formation control of two quadrotor UAVs", SN Applied Sciences, 2019, vol 1:539.

[6] Zain Anwar Ali, Amber Israr, Eman H. Alkhammash, and Myriam Hadjouni (2021) "Leader-Follower Formation Control of Multi-UAVs via an Adaptive Hybrid Controller", Complexity publications, 2021.

[7] Michael James Compobasso (2017) "Leader-Follower Trajectory Generation and Tracking for Quadrotor Swarms", A thesis submitted to the Department of Physical Sciences and the committee on graduate studies, 2017.

[8] K. Nonami, F. Kendoul, S. Suzuki, W. Wang, D. Nakazawa (2010) "Autonomous flying robots-Unmanned aerial vehicles and micro aerial vehicles", Springer

e-ISBN: 9788770229647 https://doi.org/10.13052/rp-9788770229647.007