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Autonomous Quadcopter with GPS Hold RTH_ and Altitude Hold Features Using STM32

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ABSTRACT—

This research paper discusses the development of a quadcopter with a barometer altitude hold system, GPS, and telemetry using an STM32 microprocessor. A quadcopter is a small unmanned aerial vehicle (UAV) that can be used for a variety of tasks, including mapping, surveillance, and aerial photography. Four rotors on the quadcopter offer vertical lift and control. The quadcopter's flying, including its height, speed, and direction, is managed by the STM32 microprocessor. The telemetry system is implemented to send real-time data from the quadcopter to the ground station, while the GPS module is used for location tracking and navigation. The quadcopter's height is kept constant under a variety of climatic circumstances by the barometer altitude hold mechanism.

Keywords— GPS, UAV, Quadcopter, Telemetry.

I. Introduction

Due to their numerous applications, unmanned aerial vehicles (UAVs) have been increasing popularity recently. One form of UAV that has four rotors for control and vertical lift is a quadcopter. Microcontrollers, sensors, and other electrical components are being inserted into quadcopters to make them more complex and cutting edge. One such component that may be utilised to manage the flying of the quadcopter is the STM32 microcontroller.

The 32-bit STM32 microcontroller was developed for real-time applications. It is the perfect device for operating a quadcopter because of its rapid processing speed, low consumption of power, and variety of peripherals. The design and development of a quadcopter utilising an STM32 microcontroller will be covered in this research paper..

A quadcopter's GPS and telemetry systems are crucial parts. The GPS unit is utilised for navigation and position tracking. It gives precise position data, which is necessary for piloting the quadcopter. The quadcopter transmits real-time data to the ground station using the telemetry system. It offers details regarding the flight of the quadcopter, such as altitude, speed, and direction, and battery life.

A quadcopter's barometer altitude hold mechanism is crucial since it aids in maintaining the quadcopter's height in a variety of environmental circumstances. The quadcopter's height is determined by measuring air pressure, and the motor speed is adjusted correspondingly to maintain a consistent altitude.

II. LITERATURE REVIEW

This part is divided into three sub-parts as follow:

A. ANCIENT DEVELOPMENT

Louis Breguet created and piloted the first quadrotor helicopter in 1907, making him the inventor of the quadcopter. The drones were then primarily used for combat activities by the US army. The quadcopter was really created in this century when advances in electronics enabled the creation of cheap, lightweight flight controls that could operate an unmanned aerial vehicle (UAV). The flight controller also received a number of sensors to increase the quadcopter's stability. The gyroscope, and accelerometer were the in question sensors. Quadcopters for small UAVs became common as a result. Due to their smaller dimensions and flexibility, the quadcopters were used inside as well as outside. These quadcopters, however, lacked basic controllability and stability in their early phases. As a consequence, more dependable sensors have been included to the quadcopters' enhanced architecture. These sensors enhanced stability and allowed it to remain at a predetermined altitude. Due to errors in the output of the controller and the intricate design of the used microcontrollers, flight control was difficult at this time.

B. SUBSEQUENTIAL DEVELOPMENTS

The addition of sophisticated and reliable sensors contributed to the drone's increased hovering stability. The PID controller design, which makes use of a microprocessor, was used to regulate hovering. This increased the need for drones in agriculture to monitor crops in a particular region [3]. However, the drones were still not advanced enough to carry out certain duties. Future advances might have been possible. Thus, to increase the drones' productivity in their missions, scientists included a few more sensors such as tilt sensors, infrared sensors, etc. The infrared sensor distinguishes the item of interest from other objects based on differences in body radiation while the tilt sensor tracks the drone's pitch [4]. The drones were still less effective at this point since it was difficult to remotely control them and they lacked sensors to track their whereabouts as they flew. Later, scientists installed a GPS (Global Positioning System) module that determined the location of the region in which it was flying and transmitted that information to the remote controller. At this point, the remote controller and quadcopter were linked by Wi-Fi is used in place of conventional radio waves. As a result, the controller's range was multiplied and it could now be controlled remotely from a distance. At this point, the quadcopter might fly a predetermined course stored in the controller's memory [4-5]. Low wind speeds made it comfortable to fly the drones inside. But because of the strong wind flow outside, it was subject to aerodynamic drag forces. The sensors utilised lost stability since they couldn't withstand the wind forces outside. The drone eventually drifted away in the direction of the wind flow as a result of this [5]. The sensors were improved in order to stabilise the flying. However, the employed outdated microcontrollers were incompatible with the sophisticated sensors. As a result, since the last ten years, new microcontrollers have been developed that supply the necessary output to the sensors and stabilise flight. The Arduino microcontroller is the one that has been used the most up to this point since it is so simple to use and programme [6-7].

C. LATEST DEVELOPMENTS

Over the past ten years, quadcopters have undergone significant developments in terms of both design and flying controllability. This is as a result of the usage of improved microcontrollers and sensors that are attached. The drone was able to maintain control of its height thanks to the addition of the BME 280 (temperature, pressure, and altitude) sensor and gyroscope. At this point, the remote station's GUI has been enhanced to provide the user with a pleasant flight experience. In military missions involving remote package delivery, drones were effective. Due to its versatility in programming, Arduino over time gained popularity as a microcontroller for use in drone construction. In addition, drones can be equipped with extra sensors like cameras and ultrasonic sensors. This made it possible for drones to calculate their distance from the ground, something they were previously unable to do. This ground-breaking addition significantly boosted its appeal. Now, way point navigation systems might employ drones. The microcontroller receives the waypoint coordinates for a predefined flight. The initial waypoint's distance from the current GPS position and the current position's heading angle in relation to north are calculated using an algorithm. Following waypoints are created during this process, and the quadrotor's height is controlled by a pulse-width modulated (PWM) signal produced by the controller that may also be utilised for terrain mapping and fire suppression [8–9]. Additionally, identical devices are produced utilising the FY90 microcontroller and utilised by the Coast Guard in search and rescue operations [10]. During rescue operations, the drones' infrared sensors may look for living targets [11]. These drones are also in demand in the agricultural sector, where they are utilised for precision farming, spraying fertiliser, and crop surveillance. The drones' infrared sensors may distinguish between healthy and diseased crops. These drones lessened the need for human labour and improved crop quality monitoring [12–15]. By combining microphone-enabled heat sensors with a camera for reconnaissance, it can be beneficial to alert people to the situation and advise them about the necessary safety steps during a natural disaster. Here, we need a number of components for this extra security, including a microphone, a handgun with immobilising darts, a heat-resistant frame, small medical equipment, a mini-quadcopter, and identification tools [16]. These drones have undergone a lot of development. Before, the drones could go along a predetermined route. The drone was also susceptible to crashes. Recently, quadcopters with obstacle sensing and collision avoidance technologies have been developed. The quadcopters employ a variety of ultrasonic sensors in concert to find nearby objects and steer clear of them using straightforward algorithms. Using an Arduino microcontroller, the sensor signals are managed. Here, the sensor signals are combined to create a collision avoidance display on the remote controller, allowing for accurate control of the quadcopter. However, the quadcopter was unable to give the destination to which it was travelling. In the future, this was avoided when a GPS module was added to the system, allowing the quadcopter to fly between two points without colliding. This innovation finds use in systems for delivering packages and preventing road collisions [17–18]. Recent advancements have allowed for voice commands or basic hand gestures to be used to operate quadcopters. Although they are still in the early stages, these advancements will soon come to pass [19–20]. The developed system is built around the Arduino Uno R3 microcontroller, which is used to programme the quadcopter. The microcontroller is also equipped with a number of sensors, including magnetometer and gyro cum accelerometer sensors for pinpointing a quadcopter's precise location as well as sensors for measuring air conditions and altitude. The sensors are linked to a microcontroller IC with Wi-Fi capabilities so that it can automatically send sensor data as needed. Therefore, remote monitoring is a simple process. The created system is built with the idea that as circuitry gets simpler, costs will stay low. A one-touch return button will also be included, allowing users to go back to their starting point with just one click. As a result, the quadcopter is unlosable. Without placing sensors at every place, this kind of system may be used to remotely monitor the atmospheric conditions at a number of locations for irrigation and agricultural production [21]. Additionally, if a camera is placed, it can be utilised for security purposes.

III. Block diagram

Figure 1 depicts the intended system's block diagram. The system's necessary building blocks are outlined below.

C. STM32F103C8T6 MICROCONTROLLER

The STM32F103C8T6, sometimes referred to as the STM32 Blue Pill, is a very well-liked microcontroller from STMicroelectronics' STM32F1 family. It has a 32-bit ARM Cortex-M3 processor that operates at up to 72 MHz and offers sufficient computing power for a variety of applications. It provides enough capacity for storing programme code and data with up to 64 KB of Flash memory and 20 KB of SRAM.

A variety of peripherals and interfaces are offered by the microcontroller, including GPIO pins for general-purpose

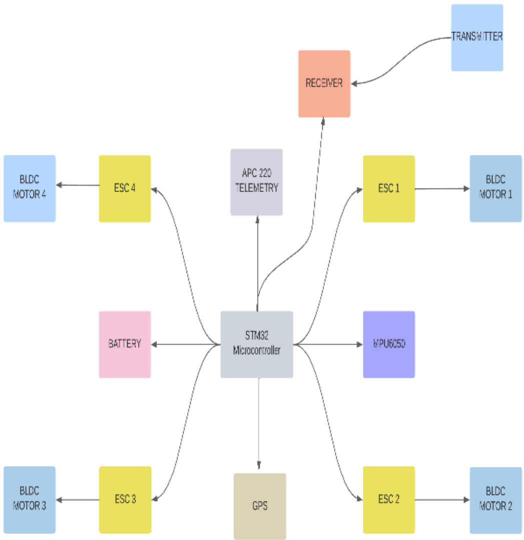

Fig. 1. Block diagram of the designed system

Input/output, USART interfaces for serial communication, SPI and I2C interfaces for interacting with other devices, timers for accurate timing and control, an ADC for analog-to-digital conversion, and PWM outputs for creating analog-like signals.

It is adaptable and power-efficient with a supply voltage range of 2.0V to 3.6V and power-saving modes. An extensive development environment, including the STM32Cube software development platform and associated IDEs, supports the STM32F103C8T6, making it simple to create applications.Overall, the STM32F103C8T6 microcontroller is a feature-rich, cost-efficient option appropriate for a variety of embedded system projects, from DIY endeavours to commercial applications.

D. MPU 6050 (3 AXIS ACCELEROMETER & GYROSCOPE)

The 3-axis gyroscope & accelerometer in MPU 6050 enable for independent measurements of both parameters around the same axes. As a result, the problem with cross-axis inaccuracies while employing individual sensors is resolved. In this work, the quadcopter's flight is balanced and its flight dynamics are maintained with the aid of the MPU 6050 IC.

E. apc220 telemetry

Popular wireless communication equipment, such as the APC220 telemetry module, is utilised in many different applications, notably in the fields of robotics and hobbyist electronics. It offers a quick and dependable means to create a wireless connection between two devices so that data may be sent.

The APC220 module transmits and receives data using Frequency-Shift Keying (FSK) modulation while operating in the 2.4GHz spectrum of frequencies. This modulation method guarantees steady transmission with little disruption. The module is suitable with a wide range of devices since it supports serial communication protocols. devices that communicate via UART (Universal Asynchronous Receiver/Transmitter), including microcontrollers, Arduino boards, and other hardware.

The excellent range capabilities of the APC220 module is one of its primary characteristics. Long-distance communication between devices is possible thanks to its ability to reach communication ranges of up to 1000 metres in open areas. However, environmental elements like obstructions, interference, and line of sight between the transmitter and receiver might affect the range. The module has a programmable baud rate that enables customers to modify the data transmission speed according to the needs of their applications. Typically, 19,200 bps is the highest permitted baud rate, allowing for a reasonably quick data transfer time between devices. The APC220 module provides several channels to reduce interference from other devices using the same radio band. It usually provides 16 channels, allowing customers to choose the best one for their particular application. By reducing the influence of outside signals, this channel selection function guarantees steady and reliable connection.An onboard interface allows for simple configuration of the APC220 module. Both a specific module setup tool and a USB-to-serial converter may be used to access this interface. Users may modify a number of settings, including as baud rate, transmission power, and channel choice, to optimise performance for their unique requirements. The APC220 module uses 3.3V as its operating voltage, which is common among microcontrollers and development boards. It's crucial to keep in mind, though, that the module normally needs a separate power source or regulated voltage source to function properly. Applications for the APC220 telemetry module may be found in many different industries. It is often utilised in remote control systems, robotics, wireless sensor networks, unmanned vehicles, and home automation applications. It is a popular option for delivering data between devices without the requirement for physical connections because of its capacity to offer a wireless link with a respectable range.In conclusion, the APC220 telemetry module provides an efficient and dependable wireless communication option for do-it-yourself robotics and electronics applications. It is a flexible option for wireless data transmission needs because to its features including long-range capabilities, variable baud rate, numerous channels, and simplicity of deployment.

F. BLDC MOTOR

A brushless direct current (BLDC) motor is an electric motor that uses electronic commutation rather than the brushes and commutator found in standard brushed direct current (DC) motors. A synchronous DC motor is another name for an electronically commutated motor (ECM).

Here are some important facts concerning BLDC motors:

BLDC motors are made up of a permanent magnet rotor and a stator with windings. When energised, the rotor magnets provide a steady magnetic field, while the stator windings produce a spinning magnetic field. The interplay of these fields produces torque, which causes the motor to rotate.

BLDC motors employ electronic commutation, as opposed to brushed DC motors, which use physical brushes and a commutator to change the current direction in the windings. This is accomplished by employing sensors or advanced algorithms to identify rotor position and manage current switching timing in the windings.

BLDC motors have significant benefits over brushed DC motors in terms of efficiency and performance. They are more efficient, have a greater power-to-weight ratio, and offer superior speed and torque control. They can run faster, have a longer lifespan due to the lack of brushes, and emit less electromagnetic interference.

Applications: BLDC motors are used in a variety of industries and gadgets. They are frequently used for propulsion in electric vehicles (EVs), cooling fans in computers, appliances, robotics, industrial automation, aerospace, and a variety of other applications that demand precise control of motor speed and torque.

Motor Control: To govern the commutation process, BLDC motors require electronic control circuits or motor controllers. These controllers employ sensor or algorithm data to establish the best time and sequence of current switching in the windings. This regulation ensures that the motor runs smoothly and efficiently.

Regenerative braking: When decelerating or braking, BLDC motors can also operate as generators. The revolving motor turns mechanical energy into electrical energy by reversing the power supply, which may then be fed back into the power source or stored in batteries, allowing for regenerative braking.

In summary, BLDC motors provide excellent efficiency, increased performance, and accurate speed and torque control. Because of their benefits over typical brushed DC motors, they have achieved substantial appeal in a variety of sectors.

V. WORKING PRINCIPLE

A quadcopter's operation is based on the integration of several components, including the STM32 microcontroller, GPS, barometer, telemetry system, and MPU6050 gyroscope and accelerometer for PID control. Here's an outline of how these parts interact:

STM32 Microcontroller: The STM32 microcontroller acts as the quadcopter's core control unit. It collects input signals from numerous sensors, analyses them, and provides output signals to drive motors and other components.

GPS (Global Positioning System): The GPS module detects the geographical position of the quadcopter using signals received from GPS satellites. It offers latitude, longitude, and altitude data that may be utilised for navigation, waypoint tracking, and position holding.

The barometer measures air pressure to estimate the quadcopter's height. The barometer assists the system in maintaining a certain altitude during flight by measuring pressure fluctuations.

Altitude Hold: The altitude hold feature uses barometer data to maintain a consistent height above the earth. The STM32 microcontroller constantly checks barometer data and changes motor speeds to adapt for altitude variations. This allows the quadcopter to keep a stable height without the need for continual manual control input.

Telemetry: The telemetry system allows the quadcopter to communicate bidirectionally with a ground station or remote control. It enables the transfer of real-time data such as battery voltage, flight characteristics, GPS locations, and other telemetry information. The STM32 microcontroller processes this data and delivers it to the ground station, where the operator may view and monitor it.

The MPU6050 gyroscope and accelerometer sensor module combines a gyroscope and an accelerometer. It displays information about the quadcopter's orientation, angular velocity, and acceleration. This data is critical for stabilisation and control.

PID (Proportional-Integral-Derivative) control is a feedback control system used to stabilise and regulate the motion of the quadcopter. The STM32 microcontroller calculates the appropriate motor modifications based on input from the MPU6050 gyroscope and accelerometer to maintain stability and desired flying behaviour. The PID controller changes the motor speeds on a continuous basis depending on the difference between the desired and actual orientation, angular velocity, and acceleration.

The quadcopter can achieve altitude hold functionality using the barometer data, navigate using GPS coordinates, establish communication with a ground station using telemetry, and stabilise and control the flight using the MPU6050 sensor data and PID control algorithms by integrating the STM32 microcontroller, GPS, barometer, telemetry system, and MPU6050 gyroscope and accelerometer. These parts work together to provide autonomous flying, waypoint navigation, altitude control, and precision quad-copter stabilisation.

VI. RESULTS AND DISCUSSION

The quadcopter was put through its paces outside. For use in flight control and navigation, the GPS module gave precise position data. Real-time data transfer from the quadcopter to the ground station was made possible by the telemetry system. The quadcopter was able to maintain its speed and altitude while flying smoothly.

Fig. 2. Image of the designed system

VII. CONCLUSION

In this study, we described the development of a quadcopter with a GPS and telemetry system using the STM32 microcontroller. The quadcopter was able to fly effortlessly and keep its equilibrium on its own..

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