DESIGN, DEVELOPMENT AND IMPLEMENTATION OF QUADCOPTER AN EMBEDDED SYSTEM FOR DIGITAL SIGNAL PROCESSING AND WIRELESS COMMUNICATION APPLICATIONS

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ABSTRACT

In our proposed technique, a quad rotor-based auto-camera system is built and installed. A standard video camera has been added to the quad copter to allow for target location monitoring and video recording as the quad copter follows the reporter's position and orientation relative to the camera, the microphone, and the quad copter to ensure that the camera on the quad copter has a proper view of the reporter. This quad rotor has had its autonomous flight capabilities thoroughly upgraded, including sonar and optical flow sensors, and it is still capable of maintaining both flight tracking and obstacle avoidance. While a laptop CPU-expandable board is used to collect and process sensor data, it is processed locally on a Nano-sized Arduino board. This new proposal has the potential to significantly reduce the number of on-location reporters needed for breaking news broadcasts, which is an appealing feature.

Keywords: Auto Cameraman, Quad copter, Computer Vision are all terms that can be found in the index.

I. INTRODUCTION

The primary goal of this proposed method is to design and operate a quadcopter capable of acting as an independent news reporter. A microphone with special markers will be used by the news reporter. A quadcopter will be used to transport the camera. Using data from its camera and sensors, the drone can keep a fixed distance from the human individual, i.e. the reporter, and gradually optimise the direction of its camera to confirm a reporter is frequently within its area. The newscaster will be able to monitor the quadcopter's viewpoint without touching it by moving or changing the direction of the microphone. Figure 1 depicts the quadcopter used in this project. The proposed quad copter design has the potential to improve the comfort and cost-effectiveness of live media coverage. The digital image unit, control systems, obstacle detection system, and communication module are the four major components of this project. The remainder of the paper is structured as follows.
II. RELATED WORK

In recent years, the number of companies engaged in quadcopter research and development has increased dramatically.

Fig. 1. An illustration of the quadcopter-based auto cameraman

Quadcopters’ effectiveness and reliability it has drastically improved over time, whereas the their production costs have dropped significantly. As a result, the number of civilian applications for quadcopters is growing. Quadcopters will also be used by organizations of any size to enhance competitiveness and examine market opportunities. Amazon launched using quadcopters to deliver products to customers in 2015. They claim that this move will save them money on delivery while also giving their customers new shopping experiences [1]. Quadcopters are used in monitoring and weather forecasting applications, according to Patel et al. in [2. Quadcopters can be used in an almost infinite number of ways. Quadcopters will become more accessible to the general public as their cost and size decrease. Quadcopters in flight are currently uncommon, but the public market will be flooded with quadcopters in a few years. Based on current drone production and sales rates, this forecast is accurate. Quadcopters are, first and foremost, a popular Christmas and birthday gift for teenagers. Photographers and sports fans both value them. In addition, the number of companies offering drone services is growing.

Many new applications are becoming possible as drone autonomy improves. Quadcopters were once simply remote-controlled planes, but they now have intelligent autonomous modes that eliminate the need for human interaction and control. Professional drones now come standard with software flight stabilisation and the ability to pre-program flights. Drones that use GPS to navigate, avoid collisions, and adapt to changing weather will become more common in the future. Drones that can communicate with one another exhibit swarm behaviour. For a variety of applications, swarms can increase range, flight duration, and payload capacity. [4] For instance, if one drone's battery dies, the mission can be transferred to another. This could increase the drone's flight range above and beyond the previous one. [8] Because multiple drones can carry larger payloads, the payload capacity of a single drone can be exceeded. As part of a communication infrastructure, low-latency, energy-efficient transmission technology is used. They can also be used for remote access and emergency/disaster communication. Drones can serve as flying base stations or gateways, assisting terrestrial communication networks (cellular radio networks) in expanding coverage and/or capacity. Miniaturisation, autonomy, and swarms are all areas where quadcopter technology is constantly evolving. Miniaturisation is the most gradual of these three developments. (Each new drone generation is smaller, lighter, and less expensive than the previous one.) New materials, as well as more efficient and lighter batteries, enable better trade-offs between a drone's flying range, maximum altitude, and payload capacity, for example. (9th) The smallest drone available right now is the size of a credit card. However, in a few years, we can expect to see drones the size of insects.

Advantages of Quadcopter:

1. With their high-quality sensors capable of events at night or in low light conditions.
2. Cost saving technology
3. Flexibility for quick inspection by connecting it to wireless communication.
4. Minimizing obvious danger in hazardous areas and health risks.
5. Tightening the security.
6. Quadcopter technology allows operators to quickly deploy and operate quadcopter even with a relatively minimal technical background.
7. These are used for aerial photography in entertainment industry. [8]
8. It is ideal in situations like COVID-19 to monitor people gathering and making announcements.
9. It is used in disaster management and for geographical mapping. [12]
III. SYSTEM OVERVIEW

The block diagram of the proposed system is shown in Figure 2. The proposed system consists of an Arduino Microcontroller board, and a flight controller, Intel compute stick and a camera. Using the camera & the high-performance computing stick takes a snapshot, processes it, and sends control signals to the Arduino board. The Arduino Uno board will issue control commands to the flight controller after embedding the data from the IR distance sensors.

In the proposed system, a microphone case with colour indicators provides referencing relevant information for the quad-copter to evaluate the journalist's direction in relation to the quad-copter. The corresponding mic case will be shown in Figure 3. Three colour indicators in different angle are installed in the top and bottom of the case.

About Zen Map

NMap is another name for it. Network Mapper (abbreviated as NM) is a free, open-source vulnerability scanning and network discovery tool. Nmap is a network administrator's tool for discovering what devices are running on their systems, discovering available hosts and the services they provide, discovering open ports, and detecting security risks.

3.1.1 Port Scanning

Nmap sends out packets that return IP addresses and a wealth of other information, allowing you to identify a variety of network attributes, create a network profile or map, and create a hardware and software inventory. Different protocols employ various packet structures. TCP (Transmission Control Protocol), UDP (User Datagram Protocol), and SCTP (Stream Control Transmission Protocol) are among the transport layer protocols used by Nmap, as are supporting protocols such as ICMP (Internet Control Message Protocol), which is used to send error messages.

3.1.2. Network mapping

Nmap can discover the devices on a network, such as servers, routers, and switches, as well as how they're physically connected (also known as host discovery). Nmap is capable of detecting the operating systems that are installed on network devices. Network managers can determine their vulnerability to specific flaws by determining what versions of operating systems and applications are running on network hosts.

3.1.3 Service discovery

Nmap can not only identify hosts on a network, but also whether they're serving as mail, web, or name servers, as well as the specific applications and versions of the software they're using.
3.1.4 VNC viewer

On the local computer, a VNC viewer (or client) is installed, which connects to the server component, which must be installed on the remote computer. The server sends the viewer a copy of the remote computer's display screen.

It also interprets the viewer's commands and executes them on the remote computer.

VNC is platform agnostic, meaning it works with any operating system. TCP/IP must be used to connect computers, and open ports must be available to allow traffic from IP addresses of devices that may need to connect.

IV. CONTROL LOGIC

Each frame captured by the camera will be examined by a colour detection programme to determine the location and direction of the mic case on the screen. The information is then used to compute the specific instance and journalist's relative positions and viewpoints to the quadcopter. The drone's position is then adapted by the motion controller so that the journalist shall remain in the middle of the screen. The quadcopter will start moving in a two-dimensional plane perpendicular to its camera, gesturing in the chosen position, if the front coloured indicators are identified but not in the centre. If the quadcopter sensors detect side colour indicators, it will rotate until the front colour indicators are identified, at which point it will make further adjustments.

Tracking Techniques

A. Colour Detection

Using OpenCV, the suggested technique illustrated how to locate objects depending on their color combinations. This software, on either hand, can only identify one colour scheme, which is inadequate for the task. As a result, depending on Hounslo's model, a separation technique capable of identifying different colors is established. The system is designed by converting a camera frame to HSV format.

The procedures below are used to extract the colour markers from the HSV file.
Step 1: The HSV frame is first filtered using the HSV values for high reflection conditions to obtain the first filtered result.
Step 2: The original HSV frame is filtered using the HSV values for normal lighting conditions to produce the second filtered result.
Step 3: Combine the results of the two filters.
Step 4: Finally, determine the total number of filtered objects. The size and \((x,y)\) coordinates of each object are also saved.

To recognize objects with a target colour, an HSV frame is only filtered with one set of HSV values in object tracking. In normal lighting conditions, however, reflections on the pigment of the colour indicators may prohibit the HSV value from effectively screening and identifying them. To address this problem, the filtering process is divided into two parts. Two pairs of HSV values are being used to filter the HSV frame. In normal lighting conditions, the very first set of HSV value systems can filter out objects. On the other hand, the second set of values is used to eradicate objects with a high level of reflection. The same technique can be used to increase system robustness and overcome lighting difficulties.
B. Avoiding False Tracking

In terms of the number of foreground objects and with their on-screen positions, the statistics obtained from two pairs of HSV values can be incongruent. The outcomes of the chromatic detection phase have to go through the mentioned verification methods to avoid false tracking. First, if the total number of identified objects exceeds a physical limit \( l_1 \) (in this case, \( l_1 = 10 \)), the identified result will be rejected. In the second step, any object with a surface area greater than a predefined value \( l_2 \) (in this case, \( l_2 = 5000 \) pixels) is rejected. The majority of noise and background colour effects can be removed with the first two steps. From all of the obtained objects, the two objects with the largest areas will be chosen, and the on-screen distance between their centroids will be measured. The detection result will be accepted if the distance \( d \) is within a predefined range, i.e. \( l_3 \leq d \leq l_4 \). The two largest objects are usually the two colour markers on the top and bottom of the microphone case, which have better camera alignments. (In this work, \( L_3 \) is equal to 15 pixels and \( L_4 \) is equal to 200 pixels.) The distance between their centroids can be used to confirm that they are the markers pair (one at the top and one at the bottom) in the microphone case because the sizes and spacings between the markers on the microphone case are known and fixed.

C. Obstacle Avoidance

Obstacle avoidance is a critical safety feature of the proposed system because the auto cameraman may encounter obstacles during its operation. The obstacle avoidance function will override all other control commands issued by the target tracking system. It's important to note that the drones' propellers will generate a lot of pop wash, which could interfere with the ultrasound readings from the range sensors. Figure 8 depicts the pop wash effect. As a result, we've decided to implement infrared (IR) depth sensors.

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![Fig. 5. An illustration on the camera’s FoV.](image1)

![Fig. 6. An illustration on the process of dividing a frame into strips.](image2)
Fig. 7. The remote controller used in manual mode [3].

Fig. 8. An illustration of the Pop Wash effect [4].
VI. IMPLEMENTATION

A. Communication Protocol

To communicate between the onboard Compute Stick, Arduino board, and flight controller, the proposed system employs two communication protocols. The flight controller in the proposed system supports a variety of protocols, including SBUS, PPM, and PWM. Because it requires more wiring than the other supported protocols, PWM may present additional implementation challenges. When implemented, SBUS and PPM, on the other hand, can result in smaller footprints. Because SBUS is a serial protocol, it will make use of one of the Arduino's serial ports. SBUS is a less appealing option because the Arduino only has one hardware serial port. PPM was chosen for this project because of its ease of use.

UART is used to communicate between the Compute Stick and the Arduino board. It operates at a baud rate of 57600 when sending and receiving data. A CH340G USB-to-UART module connects the two modules. Figure 7 depicts a manual-control radio controller capable of sending PPM signals on seven parallel channels.

B. Sensors

To help it avoid obstacles, the drone has four depth sensors mounted on its four sides. The sensors will suffer from the Pop Wash effect as a result of the air flow introduced by the four propellers, which will seriously affect the accuracy of ultrasound or other acoustic based depth sensors [4]. Instead, infrared-based depth sensors will be used. The infrared depth sensors used in this project have an effective range of 80 cm, which is more than enough for the desired safety distance of 60 cm for the proposed system.

C. Fail-safe Designs

As a fail-safe design, a wireless safety switch has been installed on-board, bypassing the Arduino board and allowing the remote control to communicate directly with the flight controller. There are also some new features on the safety switch. The switch's default mode is A, as shown in Fig. 9. The Arduino board will send a PPM signal to the flight controller, which will be controlled by the Compute Stick in mode A. In an emergency, the user can switch to manual control mode B. The flight controller can receive PPM signals directly from the radio receiver, bypassing the Arduino board. Fig. 10 shows a circuit board with two relays that can control four switches at the same time. The PPM signal is bypassed with the other. The other two switches turn off the hardware serial connection, which may cause issues when programming the Arduino board in debugging mode. The last one is used to turn on a Bluetooth module, which enables wireless programming.

Fig. 9. The remote safety switch module used in this project.
D. Over-the-Air Programming (OTA) is a type of broadcast programming that is delivered over the airwaves.

When programming the Arduino board, asynchronous serial communication is used for downloading. Making the process more user-friendly, a Bluetooth module – HC-05 – can be used to make it wireless. The code in APPENDIX I makes it easy to configure the module. Once the Arduino board has been initialised, programmes can be wirelessly downloaded using Arduino IDE 1.5.6. After each download, the Arduino, on the other hand, requires a hardware reset. To make the process completely wireless, a reset circuit based on Newell's design on Makezine is used, as shown in Fig. 11. The reset threshold voltage and RC time constant have been fine-tuned to meet the requirements of our application. When the HC-05 is connected to a master, the setting "AT+POLAR=1,0" pulls pin32 (PIO9) LOW.

E. PCB Design

Using a custom PCB, this project connects switching components, an Arduino Nano board, and a Bluetooth module. The circuit board (PCB) was designed with a small form factor in mind, as well as the ability to connect to other third-party flight controllers. Four additional ports on the IR-based ranging sensors are connected to the Arduino board via a PCB. Despite the fact that the hardware only has one serial port,

![fig11.png](attachment:fig11.png)

**Fig. 11.** The schematic of the reset circuit used in this project.

<table>
<thead>
<tr>
<th>Real distance (cm)</th>
<th>Pixel distance (pixels)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>114</td>
</tr>
<tr>
<td>60</td>
<td>90</td>
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<td>70</td>
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<td>170</td>
<td>33</td>
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<tr>
<td>180</td>
<td>31</td>
</tr>
</tbody>
</table>

**TABLE I**

RELATIONSHIP BETWEEN REAL DISTANCE AND ON-SCREEN DISTANCE
On an Arduino Nano board, the communication port can be multiplexed for use with the wireless switching mechanisms mentioned earlier.

F. Angle and Range Estimation

This system's camera has a horizontal resolution of 610 pixels and a field of view of about 170 degrees. As a result, the approximated angle of the microphone case to the camera's centre is $170 \times 85 = 170 \times 85 = 170 \times 85 = 170 \times 85$ (3) 601. The information is organized in a table. I'm used to figuring out how physical and virtual distances interact with one another.

G. PID (Proportional Integral Derivative) control (G)

After applying the colour detection, angle estimation, and distance estimation functions to a captured frame, a control signal for the drone's movement will be generated. Three PID functions are used in this project to convert detection results into control signals. A single PID function controls the drone's horizontal shifting movements. The second one controls its forward and backward movement. The rotation of the drone is controlled by the last PID function. The ranges and midpoints of the values generated by these PID functions are shown in Table II. The output of the PID functions will be converted into control signals that the flight controller can use.

The details of the PID controller are shown in the equations below:

$$\text{Error} = \text{Set point} - \text{Real distance} \quad (6)$$

$$\text{Integral} = \text{Previous Integral} + \text{Error} \times \text{dt} \quad (7)$$

$$\text{Derivative} = (\text{Error} - \text{Previous error}) \div \text{dt} \quad (8)$$

<table>
<thead>
<tr>
<th>PID Function</th>
<th>Minimum value</th>
<th>Middle point</th>
<th>Maximum value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward &amp; Backward</td>
<td>1407(Forward)</td>
<td>2176(Stationary)</td>
<td>2868(Backward)</td>
</tr>
<tr>
<td>Left &amp; Right</td>
<td>1389(Left)</td>
<td>2152(Stationary)</td>
<td>2871(Right)</td>
</tr>
<tr>
<td>Rotation</td>
<td>1312(Anti-Clockwise)</td>
<td>2176(Stationary)</td>
<td>2953(Clockwise)</td>
</tr>
</tbody>
</table>

With techniques of curve fitting, their relationship can be expressed by the following equation:

$$y = 5574.4x^{-1} \quad (4)$$

An illustration on the fitted curve using exponential regression is shown in Fig. 12. Therefore, the real distance can be estimated as

$$\text{Real distance} = \frac{5574.4}{\text{pixel distance}} \quad (5)$$
VI. EXPERIMENTS

A. Keeping Obstacles at Bay

The Arduino program's effective IR range is 0 to 80 cm. Distances beyond the maximum range are measured in centimetres and counted as 80 cm. In other words, for objects within 80 cm of the drone, the Arduino will override the remote controller's commands. The previously mentioned PID input variables are left, right, front, and back. Output l, Output r, Output f, and Output b are the output values that correspond to them. In each PID function, the variable Set point 2d defines a set point. Elevation and roll values are translated using Output f and Output b, as well as Output l and Output r. The middle points of the elevation and roll values are 2176 and 2152, respectively.

1. F - Denotes a positive output (Large error between reference distance and measured distance)
2. The value of output b is zero (Zero error between reference distance and measured distance).
3. **In the range of 0 to 660
4. Result greater than 2176 = channel value[2] = 2176 - 0 + positive number
5. The auto cameraman must fly backward because the current evaluator value is greater than 2176. (See Figure 7).
6. If the back measures 20cm and the front measures 2m (Reference distance to 80cm)
7. The f output is null (Zero error between reference distance and measured distance)
8. There is a significant difference between the reference and measured distances.) The value of output b is positive.
9. You have a 20cm front distance and a 2m back distance if your front distance is 20cm and your back distance is 2m (Reference distance to 80cm)
B. Object tracking and movement control

Using the distance estimation technique and the PID function, which controls forward and backward movement, the distance between the drone and the microphone case holder can be kept at around 1.2 m. When the case gets close enough to the drone, it generates a control value greater than 2176, causing the drone to back up. However, as the case moves away from the drone, a value less than 2176 is generated. However, for safety reasons, the value of channel 1 is limited between 1970 and 2370 to prevent the drone from moving too quickly.

The PID function, which controls the drone's left and right shifting movement, enables it to lock its position in front of the microphone case. When an object is detected on the left side, the PID function generates a controlling value less than 2152 to control the drone shifting left. The PID function generates a value greater than 2152 to control the drone shifting right.

Finally, if the detection result indicates that the drone must turn left or right, the system will instruct the drone to move to the left or right at a constant speed. While shifting, the system calculates a suitable rotation control signal using angle estimation and the corresponding PID function. For example, if the drone needs to turn left, the PID function will generate a value between 2176 and 2953, causing it to rotate clockwise. The drone will keep moving until the front of the microphone case holder reaches the centre of the camera.

![Auto cameraman system](image-url)

**Fig. 13. Auto cameraman system**
VII. CONCLUSIONS

In the paper, an auto cameraman application based on a quadcopter is proposed, implemented, and evaluated. To provide orientation information to the reporter, a microphone case with colour markers is used. Arduino is a component that connects infrared distance sensors to computer stick signals. In Arduino, the PID algorithm is used to implement obstacle avoidance. Instead of creating a new flight controller, the Pixhawk mini receives the PPM signal generated by Arduino. Color detection is used by the software that controls the drone to track colour markers in the microphone case as it follows the reporter. Angle and distance estimations are also developed to collect data about the reporter's orientation in relation to the drone. Finally, three PID functions are used to control the drone based on the data collected from detections and estimations. The front of the microphone case can be tracked and followed by the auto cameraman system. The proposed system's stability can be improved further by using optical flow sensors or an external localization system.