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Unmanned Aerial Vehicle Surveillance and Monitoring System Based on IoT

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Abstract: Now a day Internet of Things (IoT) technologies based unmanned aerial vehicles (UAVs) find use in many areas such as Industrial surveillance, transportation , health care, military safety etc. This research paper aims to propose a new system for surveillance and monitoring using drones equipped with artificial intelligence (AI) controls and IoT technology. In addition, there are a number of advantages for UAVs communication when the Internet of Things (IoT) could integrated with cloud computing environments. Many IoT applications deploy IoT devices in rural and distant locations without access to a ground network infrastructure. The proposed systems enabled by UAVs is aerial scene classification for effective image representation of monitoring. As UAVs has the potential to revolutionize, the way surveillance is conducted. The proposed system utilizes high-performance aerial vision, both day and night, with the help of high-definition and infrared sensors, to collect still pictures, motion pictures, or real-time videos of objects like people, cars, or certain places. Additionally, the proposed system utilizes object and human body recognition for monitoring the sites, making it more efficient and effective than traditional surveillance methods. The UAVs can operated using ATMega328p for the main flight controller and is equipped with a camera and a Raspberry Pi as a processing unit for image processing and data uploading. The proposed IoT based UAVs model outperformed the existing state-of-the-art methods and achieved maximum accuracy as discussed in result section. Such type of system is very much useful in Military operations. Although the UAV is a multifunctional tool, we have solely assigned it to military uses. Instead, we have utilized it as a set of networks.

Novelty & Objective: Our paper proposed Surveillance and monitoring are two of the primary uses for IoT-based unmanned aerial vehicles (UAVs) and are crucial to many industrial, military, and public safety applications. With much greater mobility and flexibility than conventional sensing platforms, IoT-based UAVs can function as aerial sensor networks to gather more comprehensive and consistent data. This is made possible by cutting-edge technology and intelligent control techniques. The main objective of work is to provide cheap and easy to use surveillance UAV system

Keywords: Artificial Intelligence; Aerial Vision; Infrared Sensors; Line Monitoring; Site Monitoring; ATMega328p; Raspberry Pi; Internet of Things

1. Introduction

Drones, often known as unmanned aerial vehicles (UAVs)[1,2], are highly advanced technology that cane used for tracking vehicles and individuals. These aircraft do not have human operators and should controlled either remotely or through pre-programmed flight paths. They come in various sizes and can be equipped with a range of powerful tools such as laser radar, thermal scanners, license plate readers, moving target indicators, high-powered cameras, light detection, ranging, and facial recognition software. Due to the development of micro-electro-mechanical systems, flight controllers, sensors, microprocessors, high-energy Lithium Polymer batteries, and more effective and compact actuators, drone technology has significantly advanced in recent years. Drones are now a common sight in daily life and employed in a wide range of tasks, such as aerial mapping, surveillance, aerial combat, checking pipelines and power lines, and pipeline and power line inspection. Drones have also integrated into robotic manipulator platforms for activities like aerial manipulation, grasping, and collaborative transporting.

The field of robotics has extensively researched the challenges presented by the unstable dynamics of robotic arms, particularly in the context of unmanned aerial vehicles (UAVs). As technology in the UAVs, industry continues to address a wide range of needs. The features and capabilities of drones should influenced by both their intended applications and competition in the commercial market.

According to a recent study[3] that examined the most recent UAVs uses in the cryosphere, these aircraft have many benefits over conventional spaceborne or airborne remote sensing platforms. In terms of data acquisition windows, the capacity to revisit locations more frequently, and a greater variety of sensor types and viewing angles, UAVs can offer more versatility. Additionally, UAVs can fly at a variety of altitudes and with different levels of overlap, making them highly versatile tools for a variety of applications. The study also found that UAVs should use in a variety of applications around the world, with both multi-rotor and fixed-wing platforms being utilized.

Drone surveillance involves using unmanned aerial vehicles (UAVs) to monitor and track individuals, groups, objects, or situations to identify and prevent potential threats. An effective drone surveillance system must integrate robust hardware with advanced automation software to achieve this. There are lots of research is going on this topic as depicted in Fig. 1, the data is taken from Web of science year wise. As shown in Figure 1 the use and development of UAVs is increase in last five years and research is going on this topics.

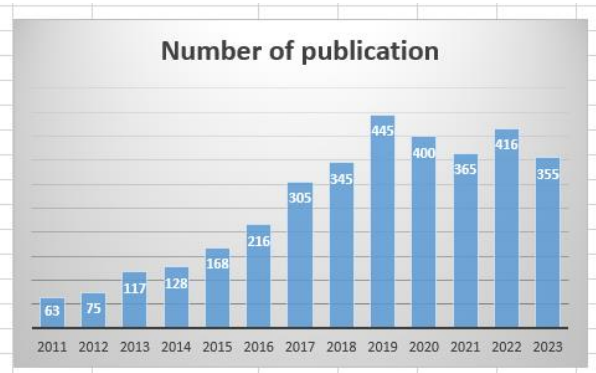

Fig. 1: Number of publications on surveillance UAVs from the Web of Science Core Collection.

The main components of such a system include a flight controller, an infrared camera, and an IoT-based processing platform, such as a Raspberry Pi. The UAVs is equipped with these components to enable it to capture real-time images automatically, with minimal human interaction. The IoT system then transmits the images, along with the GPS location of the detected object or person, to the ground control station (GCS)[4].

To ensure efficient and accurate surveillance, the system combines the use of IoT technology, live image and video feedback, and control of the camera. This allows for real-time monitoring and tracking of the target, providing valuable information to the ground control station. This system should designed to provide real-time images using an infrared camera with fewer human interactions using IoT-based technology[5].

The structure of this research paper is as follows: In Section-I problem statement, existing systems and the concept should discussed. Section II provides an overview of the related work in the field. The methodology of the proposed design should outlined in Section III. In Section IV, the paper concludes the results with a summary of the findings, section V concludes the project with future works mentioned in section VI, and references provided at the end.

1.1 Problem Statement

Despite the increasing demand for unmanned aerial vehicle (UAVs) surveillance systems, there remains a lack of efficient and effective solutions that can used in confined areas, such as military zones, government buildings, and private properties. The proposed system aims to address this gap by utilizing infrared cameras and a processing unit to enhance the capabilities of UAVs surveillance.

Drone use has many benefits, but there are also several important considerations that must be made, particularly when using them in urban areas. These include privacy, security, and flying safety. Since there is always a greater risk of injury to citizens, making the effects of any flight delays considerably more severe.

The goal of this research is to design, implement, and simulate an efficient UAVs surveillance system that utilizes image processing and recognition techniques, specifically using Python and Deep Learning. The system should tested in confined areas to evaluate its effectiveness in detecting and identifying potential threats. The data collected by the UAVs should uploaded to the cloud through a connected network and should accessed by the Ground Station. The proposed system should evaluated in terms of its detection accuracy, image quality, and overall performance.

2. Review of Related Work

2.1 Existing System

Currently, available surveillance drones are costly and not very user-friendly. The flight controllers used in these drones are closed-source, which means that they should not easily modified to meet specific requirements. This also contributes to the high cost of these UAVs systems.

The different types of available drones and their opportunities are mention in table 1. Additionally, some of the UAVs and ground station systems used for surveillance are quite large and bulky, making them difficult to operate for those without specialized training or certifications. This limitation in terms of accessibility may prevent some users from utilizing these systems effectively.

2.2 Basic UAV System Approach

The Ariante, G. et all describes a methodology for an aerial UAVs surveillance system, which would intended to be used in both civil and military areas[6]. The proposed model includes a feature that allows for custom mission planning through GPS waypoint navigation. This could achieved by programming a series of specific waypoints into the system at a ground station, which should then transmitted to the UAVs for flight navigation. The quad copter can fly through these waypoints, allowing for targeted surveillance in specific areas.

A study[7] proposed, implemented, and evaluated a model called Adaptive Computation Offloading for Drone Surveillance Systems (ACODS) to enhance the energy efficiency and response time of military drone surveillance applications. The study were conducted under different scenarios, and the results showed that the ACODS design effectively improves the performance of drones for tactical surveillance operations compared to traditional local computing methods.

In[8] researchers proposed an amateur drone surveillance system that utilizes cognitive Internet of Things (IoT) technology. The study first provided an overview of current research on anti-drone techniques and then proposed a new system called Dragnet. The system would designed specifically for amateur drone surveillance and should built on the cognitive IoT framework[9]. The proposed system aims to tailor the latest emerging cognitive IoT framework for amateur drone surveillance by providing a cognitive IoT-based solution to detect, track, and identify the presence of amateur drones in a given area using a combination of technologies such as computer vision, machine learning, and sensor fusion.

2.3 Flight Controller Based on microcontroller

The authors of[10] present a design and development of a low-cost, affordable flight controller for quadcopters based on the Arduino Uno microcontroller. The flight controller is equipped with GPS and other sensors to ensure stable and controlled flight. This design aims to provide a cost-effective solution for quadcopter enthusiasts, hobbyists, and researchers, who are looking for an affordable flight controller that should easily modified to meet their specific requirements.

The[11] paper focuses on the utilization of Arduino-Uno and MPU-6050 gyro/accelerometer in the creation of custom flight controllers. The authors used the YMFC-AL[12] an open-source flight controller program, to program the Arduino-based flight controller and developed a self-balancing drone. The drone was capable of maintaining its balance along the XYZ axis, providing a stable and controlled flight. This research provides insight into how Arduino-Uno and MPU-6050 can used to create custom flight controllers, and how these controllers can used to develop drones that can maintain their balance.

2.4 Addition of IoT in UAVs

In another study, Saifeddine Benhadhria and his team[13] developed an intelligent and fully automatic drone that should base on Raspberry Pi. The drone is equipped with automatic piloting capabilities, which can controlled by a Raspberry Pi 3B+ with Android embedded in the Ubuntu server[14]. This drone can detect obstacles during its navigation, and provides live streaming while maintaining high performance, memory efficiency, and security[15]. This research demonstrates how the use of Raspberry Pi can utilized to create drones with advanced features such as automatic piloting and obstacle detection while maintaining real-time performance[16]

3. Proposed Methodology and System Architecture

The proposed system should be designed with an ATMega328p microcontroller as the main flight controller, and a 12V Li-Po battery should power it. The flight controller could be designed with the ATMega328p microcontroller and MPU-6050 gyro/accelerometer. Arduino Uno or Arduino Pro Mini with a separate sensor module can be used as an alternative. The programming of the flight controller may done using a modified version of the YMFC-AL program (17) The complete flow of system architecture of proposed model were shown in Fig. 2.

Novelty of the system:

Unique Integration**:** This work proposes a unique integration of ATMega328p as the main flight controller and Raspberry Pi as a processing unit for image processing and data uploading. This combination is novel and not commonly seen in existing drone surveillance systems.

Infrared Sensors for Night Vision**:** The drone's surveillance capabilities would have enhanced by using infrared sensors for night vision, enabling the drone to operate efficiently both day and night.

Object and Human Body Recognition**:** Object and human body recognition would have utilized for site monitoring, which is more efficient and effective than traditional surveillance methods[18].

PID Control Algorithm: The PID control algorithm were implement for maintaining the stability and control of the drone. This is a noteworthy aspect of this research[19].

This proposed design with PID controller allows for an Enhanced Surveillance, Efficient and Effective Monitoring and Cost-effective solution for a quadcopter flight controller that can easily modified to meet specific requirements.

Table. 1 Comparison of the Design, weight, opportunity and uses of available UAVs

Drone type & Purpose	Design requirements & Weight	Opportunities and Uses	Limitations
Featherweight drones Military surveillance	Nanoscale drones Less than 11 grams (0.011 kg)	can only carry payloads ranging from 4 grams to 100 grams (0.004 to 0.1 kg)	Only one task can be performed but very much secure.
Lightweight drones Habitat surveillance	Sensor mounts 200-1000 g (0.2-1 kg)	Can be performed by inexpensive models	Light designs unable to operate in wet/windy conditions
Middleweight drones Insecticide deployment	Payload capacity 1-600 kg (2.20-1323 lb)	Low payload requirement Faster and more even distribution than ground release	Compaction and chilling for drone release reduces survival
Heavy-lift drones Insect release	Release device More than 160 kg	Technology readily adaptable from agriculture High precision application Can deploy insecticide to inaccessible terrain	Complex in design and heavy power requirment

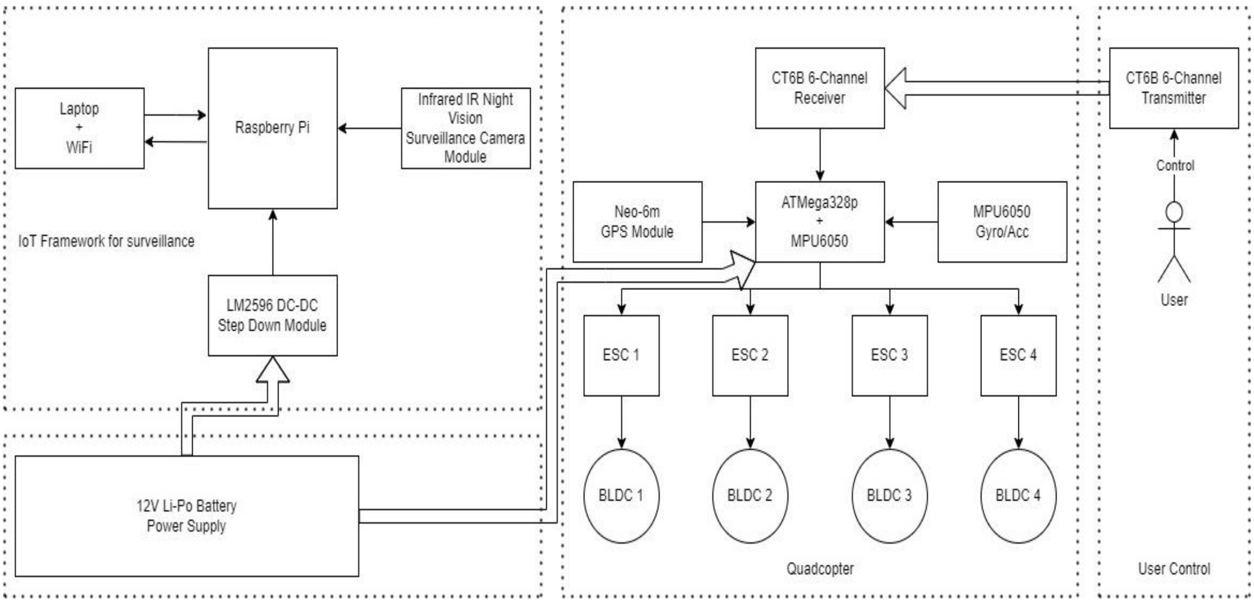

Fig. 2: System architecture of Proposed Methods and Design

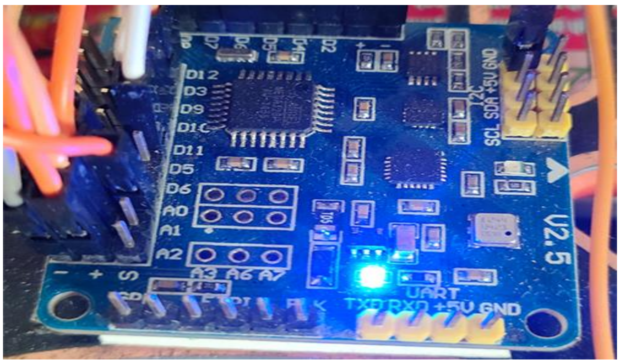

Fig. 3: CRIUS Multiwii 2.5 SE Board

Fig. 4: Raspberry Pi with IR Surveillance Camera Module

Designing a flight controller using the Arduino UNO board and the MPU6050 module poses certain challenges:

- The size and structure of both modules make them susceptible to noise caused by vibrations from the motors.
- Jumper wires can often used to connect the sensor to the Arduino board, which can lead to interference and measurement errors, resulting in low accuracy.
- It is difficult to accurately predict and calculate the response time for maintaining drone stability.

To address these challenges, we have employed the use of a CRIUS Multiwii 2.5 SE flight controller module, which includes both the ATMega328p and MPU6050 mounted on-board and supports an open-source platform as shown in Fig. 3. This board is easily available and Low coast as compare to traditional method.

Additionally, the module also has a built-in step-down module that provides a 12V to 5V/3V power supply for both the microcontroller and sensor, ensuring a stable power supply as shown in architecture diagram. This will help overcome previously encountered challenges and provide a more robust and accurate flight controller.

The IoT framework of the proposed system includes the use of a Raspberry Pi and an IR camera that was connect to the module as shown in Figure 4 for capturing high quality picture and sending for the surveillance and monitoring. To ensure a stable power supply for the Raspberry Pi, a step-down module can used to convert the 12V main power supply into a stable 5.2V output. This design allows for the integration of IoT technology with the flight controller and sensor module, providing an intelligent and efficient solution for drone surveillance.

The proposed system utilizes Raspberry Pi OS (32-bit) as its operating system, which captures and transmits live video and images to a laptop or ground station through Ngrok and uploads processed images to cloud. This allows for live monitoring of the drone's feed without the need for a physical connection, reducing the risk of security breaches. The live feed can accessed through a terminal command run via Ngrok, which can providing a secure and efficient way to remotely access the drone's data.

Further capturing of live video using AI tools and processing through following steps:

1. Video Acquisition: The drone captures videos using a raspberry infrared camera module during daylight and nighttime[21]. This allows the drone to operate effectively in various lighting conditions, ensuring comprehensive surveillance coverage.

2. Video Processing: Videos captured by the drone are analysed to identify objects of interest. This can achieved using a deep learning model, specifically YOLO, which has trained to recognize various objects, including people and cars[22]. The human body may identified in real-time in a video stream.

3. Body Detection: When a human body can detected in the frame[23], the frame (image) should captured and saved[24] . This real-time detection capability can be crucial in applications such as search-and-rescue operations.

Fig. 5. RF-Remote with Transmitter module

Fig. 6: RF Receiver module

4. Remote Access: The live video feed should accessed remotely on laptop using Ngrok under LAN[25]. This remote access capability enables the correction of the drone's position or the identification of a potential threat.

5. Uploading: The captured frame (image) is uploaded to the cloud as evidence of detection[26]. This ensures that the evidence is securely stored and can accessed for further analysis.

The proposed system allows for the control of the drone's path and location from a ground station[27]. The communication system used for this purpose in this paper were specifically a radio frequency (RF) module of 2.4GHz frequency, employed for transmitting signals from the ground station and receiving signals by the UAV system. Both transmitter and receiver module are depicted in Fig. 5 and the receiver module is in Fig. 6 and working with the raspberry pi module mounted in UAVs. This communication system enables the ground station to control the drone's movement and location, providing an efficient and reliable way to control the drone's flight path with both transmitting and receiving module. This module should very inexpensive and easily available in market.

The Quad-copter is equipped with a GPS module that enables it to determine its location relative to a network of orbiting satellites. By using GPS navigation, the drone can detect its location and send the coordinates to the ground station, allowing for precise positioning and control of the drone's flight path. NEO-6M GPS module is used for the purpose[28)].

The NEO-6M GPS module is a cutting-edge GPS receiver that features a compact ceramic antenna with dimensions of 25mm x 25mm x 4mm, and easily available in market with very considerable prices. In this paper, it should give impact for detection of exact location of the targets and providing all geographical details[29)].

This compact size does not compromise its performance; in fact, the antenna offers exceptional satellite detection capabilities. This ensures that the module maintains a constant connection to GPS signals, providing reliable and accurate location data.

The module is equipped with power and signal indicators, which allow users to monitor its performance in real time. This real-time monitoring capability can be crucial in applications where timely and accurate data is paramount[30)].

One of the standout features of the NEO-6M GPS module is its data backup battery. This feature safeguards against data loss in the event of a power failure, ensuring that important location data is not lost and can retrieved once power may restored.

These features make the NEO-6M GPS module an ideal choice for a variety of applications. Its reliable performance and advanced features are particularly useful in drone navigation and robot guidance systems, where accurate and real-time location data is crucial.

In the context of drone navigation, the latitude and longitude values obtained from the Neo-6m GPS module would transmitted to the ground station[31)]. This data allows us to monitor the live location of the drone. With this information, operators can make necessary adjustments to the drone’s position or identify potential threats in its path. This capability enhances the safety and efficiency of drone operations, making the NEO-6M GPS module an invaluable component in modern drone technology.

4. Flight Controller and IoT flow Diagram

The complete architecture of flight controller with all microprocessor , GPS and sensor module of UAVs is shown in Figure 7, the suggested flying controller and its user interface are been examined and explained.

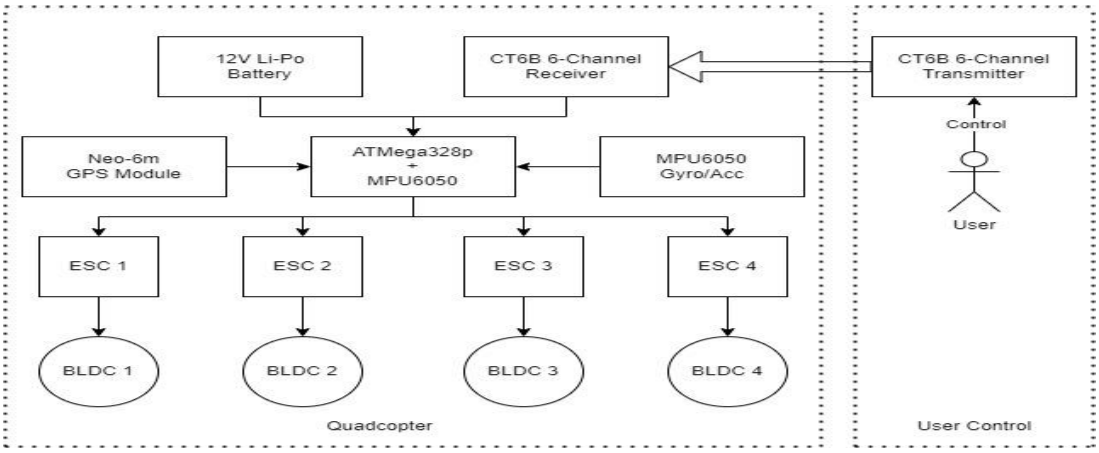

Fig. 7: Quadcopter Flight Controller and User control for UAVs

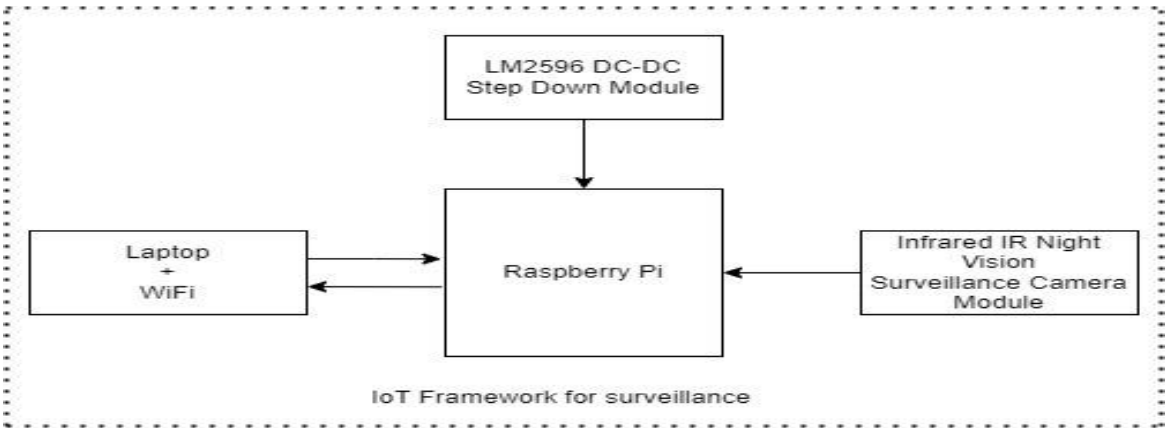

Fig. 8: IoT framework flow diagram for surveillance and monitoring with camera and sensors

It have been shows included receiver-transmitter module, GPS tracker module, microcontroller and camera module with drivers of all motor and wings of drone. Iot Framework have designed with another microcontroller raspberry-pi and Wi-Fi module for tracking and sending data to server or control room as shown in Fig. 8. It also equipped with Infrared IR Night vision surveillance camera for capturing any images in absent of light and in non-visible situations. The Iot Framework have powered with buck converter as discussed in flow diagram.

5. Proposed PID Control Algorithm

PID, short for Proportional, Integral, and Derivative is an algorithm that would integrated into the flight controller software. It reads data from sensors and processes commands from the radio stick to calculate the necessary speed for the motors to rotate to achieve the desired rotational speed of the aircraft. The PID controller have utilized to control the quadcopter along the XYZ axis and it is a closed-loop controller. The control chart of the PID controller explain in detailed using flow of gain in Fig. 9. The main parameters are the gain values for Roll, Pitch, and Yaw. Figure 10 illustrates the PID values and algorithm implementation that can used in the proposed model to achieve stability and control of the quadcopter. The PID control algorithm uses the following equation:

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{de(t)}{dt}$$

Where:

$u(t)$: PID control variable

K_p : Proportional gain

K_i : Integral gain

K_d : Derivative gain

$e(t)$: Error value

t : Instantaneous time

τ : is the variable of integration.

The PID controller uses the error signal to compute expected output. The control input signal Kp, Ki, and Kd are the gain parameters that should use to adjust the controller's behavior as depicted in Fig. 9. The Proportional gain (Kp) is used to control the speed of the system's response to an error. Integral gain (Ki) helps to eliminate the steady-state error. Derivative gain (Kd) helps to reduce the overshoot and stabilize the system . The control algorithm chart is given in Fig. 10.

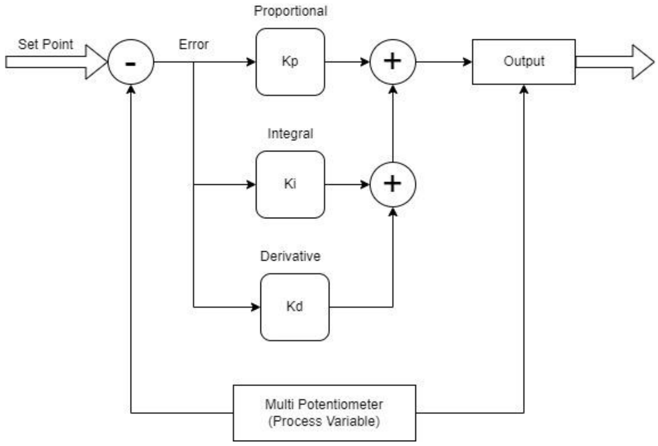

Fig. 9: PID Control Algorithm Chart

The YMFC-AL flight control program includes a PID algorithm, and the gain values can adjusted through variables as shown below in Fig. 10. Finding the optimal values for the gains requires a lot of trial and error, which includes testing the quadcopter with different values in a controlled manner. This process of hit and trial is necessary to find the perfect values that will provide the best performance and stability for the quadcopter.

Unmanned aerial vehicles have benefited in improved unstainable development in a number of ways. Drones with cameras are a very helpful tool while flying over vast tracts of land. With a limited emission of pollutants, they may swiftly capture photos of cultivated regions, forests, areas with fire threats, etc., and reach the location of interest faster before the situation gets too serious.their are many application of UAVs in field of military, monitoring any area and searching things etc.

```
//////////////////////////////////////////////////////////////////////////////////
//PID gain and limit settings
//////////////////////////////////////////////////////////////////////////////////
// PID for ROLL
const float pid_p_gain_roll = 3.00;               //Gain setting for the roll P-controller
const float pid_i_gain_roll = 0.00;               //Gain setting for the roll I controller
const float pid_d_gain_roll = 17.60;              //Gain setting for the roll D controller
const int pid_max_roll = 400;                     //Maximum output of the PID-controller (+/-)

// PID for PITCH (same as ROLL)
const float pid_p_gain_pitch = pid_p_gain_roll;   //Gain setting for the pitch P-controller.
const float pid_i_gain_pitch = pid_i_gain_roll;   //Gain setting for the pitch I-controller.
const float pid_d_gain_pitch = pid_d_gain_roll;   //Gain setting for the pitch D-controller.
const int pid_max_pitch = pid_max_roll;           //Maximum output of the PID controller (+/-)

// PID for YAW
const float pid_p_gain_yaw = 4.00;                //Gain setting for the pitch P-controller.
const float pid_i_gain_yaw = 0.02;                //Gain setting for the pitch I controller.
const float pid_d_gain_yaw = 0.00;                //Gain setting for the pitch D-controller.
const int pid_max_yaw = 400;                      //Maximum output of the PID-controller (+/-)
```

Fig. 10: PID Control Algorithm Chart

6. Results and discussion

The primary outcome of this research is a prototype of a quadcopter capable of flying to any desired location and providing live surveillance through real-time video. The quadcopter, as shown in Fig. 11, demonstrates the successful integration of the ATMega328p microcontroller and Raspberry Pi for surveillance purposes. This represents a significant advancement in leveraging technology for surveillance, providing a platform for efficient data capture and monitoring.

The live video stream, depicted in Fig. 12, is a testament to the system's real-time surveillance capabilities. The IoT system of the quadcopter should connected using Ngrok, a tunneling software that ensures secure and stable communication. This setup allows for efficient and accurate surveillance capabilities, with the Raspberry Pi serving as an IoT platform and the IR camera capturing real-time video and images.

The surveillance focus of this research and project should further emphasized by the use of a Raspberry Pi device in conjunction with an IR camera. This combination enables the system to capture real-time video and images, thereby providing an efficient and reliable solution for surveillance needs. The Motors used in this UAV is A2212 1000 KV BLDC Brushless DC Motor. The speed of each motor is based on RPM, which is define as RPM of each motor: (KV x Voltage) i.e. MAX = 12000 RPM, MIN = 1000 RPM.

The basic Mechanism on which this UAV fly (PITCH/YAW/Roll)in this research is as follow. We use different mechanism for different purpose, like first PITCH axis for nose up and down in fly of UAVs. Secondly YAW axis for turning in left or right direction and lastly ROLL axis for rotating half of the body (Front to Back) in left or right direction.

The results of this research-based hardware UAV demonstrate the potential of the proposed system in revolutionizing surveillance and Monitoring methods. By utilizing high-performance aerial vision, both day and night, with the help of high-definition and infrared sensors, the system can collect still pictures, motion pictures, or real-time videos of objects like people, cars, or certain places. This makes the system especially useful in areas where human surveillance is impossible or impractical.

Moreover, the proposed system utilizes object and human body recognition for monitoring sites, making it more efficient and effective than traditional surveillance methods. The UAV have been operated using ATMega328p for the main flight controller and is equipped with a camera and a Raspberry Pi as a processing unit for image processing and data uploading.

Fig. 11: Flying UAV drone.

The live video stream should viewed in Fig. 11 and Fig. 12. Figure 11 show the complete hardware with all modules in built inside the UAV and Figure 12 show the image capturing by developed system at the far range. The IoT system of the quadcopter should connected using Ngrok, a tunneling software that allows for secure and stable communication. Surveillance is the central focus of this paper and model, and to achieve this, a Raspberry Pi device should employed along with an IR camera. This combination allows for efficient and accurate surveillance capabilities. The use of Raspberry Pi as an IoT platform and the IR camera enables the system to capture real-time video and images, providing an efficient and reliable solution for surveillance needs.

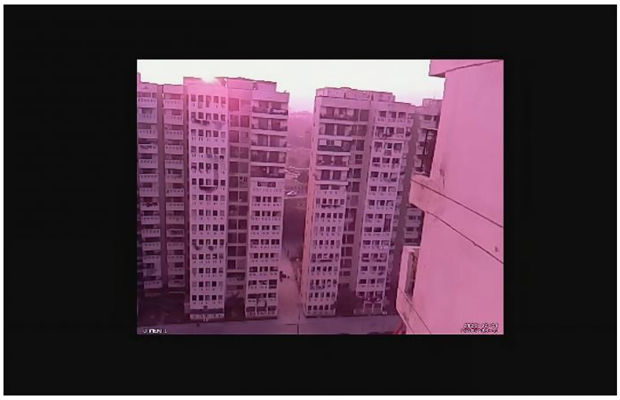

Fig. 12: Live surveillance from the UAV.

Conclusion and Future aspects

This research endeavors to present an affordable and cost-effective method for the development of an ATMega328p and Raspberry Pi-based surveillance Quad-copter. The proposed system is designed to provide precise payloads to hover above designated areas, stream live video feeds as well as transmit images for surveillance purposes. The Quadcopter can be employed for both civil and military surveillance needs.

This system is not only inexpensive but also compact, efficient, and environmentally friendly. It can be utilized for monitoring a wide range of areas such as campuses, offices, and industrial sites by various institutions, for monitoring borders and peacekeeping activities by the government, and for monitoring private properties by individuals. In conclusion, this system offers a low-cost alternative for a plethora of applications.

Many different avenues can be pursued in future work because of the limitations of time during this project. These include further experimentation, testing, and adaptation to improve the performance of the system. These experiments are often time-consuming, often requiring several days to complete a single run. Future work could involve a more detailed examination of specific mechanisms, proposing new methods to be tried, or simply satisfying curiosity about the system.

Several possible future works can be done to this project to further its research purpose, some of them are:

Improving the control algorithm of the drone using advanced control techniques such as fuzzy logic or Model Predictive Control (MPC) to enhance the stability and performance of the drone.

Integrating additional sensors such as LIDAR or ultrasonic sensors to enhance the navigation and obstacle avoidance capabilities of the drone.

Developing a more advanced image-processing algorithm to improve the accuracy of the surveillance system. Implementing a machine-learning algorithm to improve the decision-making capabilities of the drone.

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