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Use of UAVs for mining applications

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ABSTRACT

Unmanned Aerial Vehicles (UAVs) have been gaining a lot of impetus in the recent times. Drones are constantly being made available for a myriad of day-to-day applications like food delivery, surveillance, farming, etc. One of the most overshadowed regions in the list of applications remains to mine. Mining is a dangerous activity and more often than not, there are certain unknown hazards to it that are too dangerous for humans to be experimenting with all by themselves. Hence it makes sense to use a UAV in the form of a First-Person View (FPV) drone.

For the development of a UAV, there are thousands of different permutations that can be used. After a detailed analysis of various of them ranging from a simple tri-copter to an octocopter, a quadcopter design was unanimously selected as it provides elegant support in the form of control, structure, reliability, cost, size, etc. Most important of them being size and structure. Mines can be constricting places and a wide frame may become very difficult to control inside such enclosures.

This project has been implemented on a much smaller scale than an actual prototype, primarily because of an ambitious development schedule coupled with a very limited budget. These constraints have forced a compromise on the quality of the components used but have not tampered with the real application objectives that the drone has to suffice. The drone at present is being controlled by a remote-control transmitter, receiver couple but we are working on creating our own GUI which will provide a direct control over all the systems from a remote laptop or android device.

Keywords: *Unmanned Aerial Vehicles, Quadcopters, Mining Applications.*

1. INTRODUCTION

The most important aspect of human life is the ability to innovate. It is the introspective thought process which drives us to make ground-breaking discoveries and inventions to help us in our endeavor of a life full of luxury and away from the necessity of survival instincts. One of the most crucial inventions in this regard was “The Wheel”. The invention of the wheel probably made the progress which could have been made speed up by at least tenfold. The invention of the wheel brought with it the concept of rotation and revolution and opened the doors for seamless transportation without the need of water.

Enter road transport, everyone was fascinated by this aspect which made people eligible to travel small distances at astonishingly fast rates. Now water transport was still best suited for long-distance transportation until the Wright Brothers invented the airplane which was a humongous stride in the further progress of humankind. It opened floodgates of trade, travel, and tourism. Air transport took care of covering longer distances at astoundingly rapid rates. But it couldn't be afforded by many, took too large a shape and had very less security for day to day use.

We have been innovating and teetotaling with the airplane design for almost a century now and the latest invention in our trophy cabinet right at the top is a drone. Drones are an extremely agile, highly controllable and a secure mode of transport. In the field of electronics and communication, drones are getting all the glory as they are being put to more and more use day-by-day. Drones have been recently getting a lot of support in the FPV domain, to which this project adds our contribution in the form of an application. This project brings one such device into creation for an unmanned aerial vehicle with the attached camera module and a volatile gas sensor all coupled with a Raspberry Pi, which can be deployed for exploration of mines where there is a probability of explosive and harmful being present. Better blast optimization, improved safety, faster surveying, and construction of the most comprehensive and continuous project datasets are just some of the advantages of this technology.

The paper has been divided into VII sections. Section I has given a brief introduction to the history of transport leading to UAVs the project. Section II will be a monologue on the various parameters to be considered while the drone is in flight mode and some stabilization techniques. In Section III we will take a look at the components used and some information about them. In Section IV we will delve into the applications of UAVs while laying the foundation for the main objective of the project. In Section V use of UAVs in mining will be discussed in detail. Section VI will deal with the future scope and conclusion will be presented in section VII.

2. FLIGHT CONTROL OF A QUADCOPTER

A. Mode Selection: Predominantly when it comes to quadcopters, there are two main modes of operation,

a. '+' Mode
b. 'x' Mode

For this project, we will go with 'x' mode settings. The difference between both comes from the idea that the roll, pitch and yaw angles vary from a motor at 0----o to the other at 180o, in '+' mode. But in 'x' mode, these angles vary from the midpoint between opposing planes of the motors. By analysis of various drones, we conclude that 'x' mode operation has a much higher stability and gives the motors some leniency while making turns and grooves.

B. Principles of Operation: A quadcopter is basically an aerial vehicle which operates on the use of four motors. Typically, brushless motors are used because of their power efficiency, speed, and ulterior control. In operation, the two opposite motors rotate in the same direction while the remaining orthogonal motors rotate in the opposite direction, as shown in the diagram below:

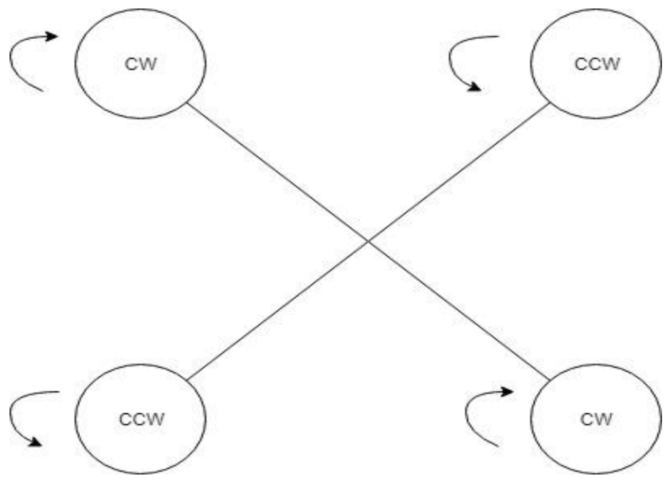

Fig. 2.1 Direction of rotation of brushless motors

This is of utmost importance because if all the four motors rotate in one direction, the quadcopter will hover, but at the same time rotate about its axis continuously. This is the same reason why helicopters have the tail fin – to reverse the direction of rotation caused by the main rotor. Thus, the opposing motion of the motors negates the yaw that is generated in the quadcopter. Similarly, if more yaw is needed, the rotation of either of the opposing motors is slowed down. Thus, if clockwise motors slow their rotation, the drone will yaw left, and if the counterclockwise motors slow down, the drone will yaw right. Thus, yaw is basically the rotation of the motor along its axis of gravity.

The throttle of the quadcopter follows on the aforementioned principles too. If the throttle of all the four motors in increased simultaneously, higher will be the thrust and thus the quadcopter will start lifting up.

C. Principles of Flight: More often than not, quadcopters are moved on the basis of them pitch and roll instead of up and down and yaw. So, we use the concepts of elevation and aileron. Elevation determines the pitch of the quadcopter. If it is a positive value, the drone will move ahead. If it is a negative value, the drone will move backward. Aileron determines the roll of the quadcopter. A positive aileron will roll the drone to the right and a negative aileron will roll it to the left. This operation can be seen from the following figure:

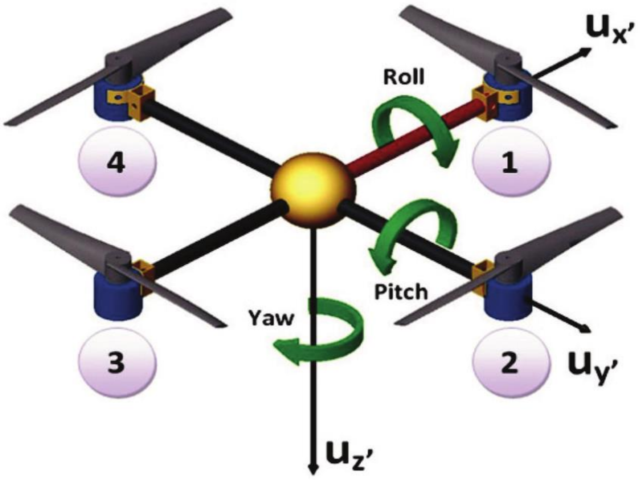

Fig. 2.2, Quad Band Signal Strength Monitoring System Using Quadcopter and Quad Phone - Scientific Figure on ResearchGate.

Available from: https://www.researchgate.net/Yaw-pitch-and-roll-rotations-of-a-Quadcopter_fig1_280573614 [accessed 14 Apr, 2018] [1]

D. The concept of PID: PID stands for 'proportional integral derivative'. It is a common form of closed-loop error control. PID system is deployed on the flight controller, which is KK 2.1.5 in our case. This system takes the input from the accelerometer and the gyroscope and varies the power delivered to the electronic speed control (ESC) circuit, which in turn controls the motor.

Proverbially speaking, the 'P' gain value in the flight controller depends on the present error, the 'I' gain value depends on the accumulation of the past errors and the 'D' is a corrective measure to prevent future errors [2]. The following diagram shows the PID loop for a quadcopter. X_pos', Y_pos' and Z_pos' are the previous errors in X, Y, Z axes respectively, while X_pos, Y_pos and Z_pos' are the corrections sent to make the self-level of the quadcopter stable. The loop tries to rectify the quadcopter's roll and pitch by varying the amount of current each motor receives. PID correction in KK 2.1.5 is carried out by the heart of the flight controller that is the microcontroller Atmega644.

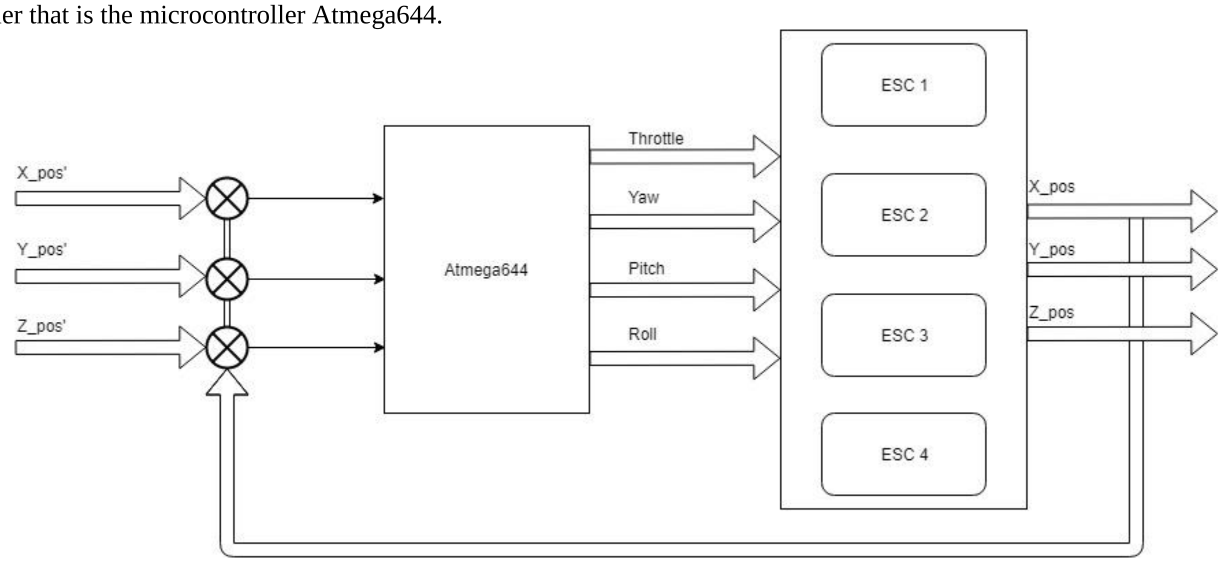

Fig 2.3 PID control loop for roll and pitch error rectification

3. COMPONENTS USED

Table 1. Component List Used For the Project

Component Name	Quantity
Q250 – Quadcopter H - frame	1
Brushless Motors – 1000kV	4
ESCs – Simonk Firmware – 30A	4
Tri-Blade Bullnose 6045 propellers	4
Li-Po Battery – 2200mAh	1
Flight Controller – KK 2.1.5	1
Remote Controller – FS CT6B (TX, RX)	1
Volatile Gas Sensor – MQ2	1
Raspberry Pi 3 Model B	1
Power Distribution Board	1
FPV Camera – 5MP	1

A. **Frame:** Quadcopter frames have a significant impact on the flight performance. Aerodynamics, weight distribution, rigidity, etc, all play a part in flight characteristics. A mini quad frame can be made from any material we can possibly think of Wood, 3D printed plastic, injection moulded plastic, fiberglass, aluminum, or even PVC pipes. However, carbon fiber remains the most popular material because of its strength and the ability to dampen unwanted noisy oscillations. A lighter frame will require lower thrust to hover and therefore gives you longer flight time.

B. **Motors:** Thrust is probably the most important factor of the motor. Motor efficiency is typically calculated by dividing thrust by power at 100% throttle, measured in grams per watt (g/w). The higher this number is, the more efficient the motor. Generally, the more thrust generated, the larger the current drawn to produce that thrust, so motors with high thrust and low current are preferred. Hence, as our drone was on the heavier side, very low kV motors have been used, which draw very less current and provide much higher thrust at the 11.1V power supply.

C. **ESC:** ESC is a device that interprets signals from flight controller and controls the speed of brushless motors. Brushed motors don't require ESC because they can be driven simply by power transistors which are normally built into the flight controllers that are designed for brushed motors. Each motor requires an ESC to work due to the three-phase architecture.

D. **Propellers:** Every quadcopter has two motors spinning CW (clockwise) and two others spinning CCW (counter-clockwise). Therefore, matching CCW and CW propellers are required to generate thrust, as well as having opposing yaw motion that cancels each other out in flight. Tri-blades are preferred because it has more grip in the air.

E. **Radio Receiver and Transmitter (6 Channel):** A Quadcopter is usually controlled wirelessly by a radio transmitter, and the Radio Receiver (or RX) is what receives commands from the transmitter and tells the flight controller. The number of channels determines how many individual aux functions and control one can configure in the TX. For example, throttle, yaw (rotating right and left), pitch (lean forward and backward), and roll (roll left and right), each takes up 1 channel. Four channels are the bare minimum to control a quadcopter (pitch, roll, throttle, yaw).

F. **Battery:** LiPo batteries are the power sources of the quadcopters. The capacity of a LiPo battery is measured in mAh (milli-amp hours). "mAh" is basically an indication of how much current you can draw from the battery for an hour until it's empty.

G. **Power Distribution:** Power distribution can exist in the form of a board (PCB) or harness.
The PDB contains the connectors which plug directly into the LiPo battery and it's responsible for distributing power the ESCs and motors, as well as providing power to other electronics with the correct voltage.

H. **FPV Camera:** An FPV camera allows the pilot to wear video goggles and see what the quadcopter is seeing during flight. FPV cameras might not have the best video quality, but they are designed for wide dynamic range and low latency which is extremely important to FPV. An i-Ball 5Mp camera was used for the same because of its light weight and high frame rate.

I. **Mq2 Sensor:** This sensor can be used to Measure or detect LPG, Alcohol, Propane, Hydrogen, CO, and methane. It uses an electrochemical sensor. They are sensitive to a range of gasses and the analog values can be read by using PWM on a GPIO input. Due to its fast response and high sensitivity, measurements can be taken as soon as possible and sensitivity can be adjusted using a potentiometer.

J. **Raspberry Pi 3:**

- Chipset: Broadcom BCM283
- CPU: 1.2GHz quad-core 64-bit ARM Cortex A53
- Ethernet: 10/100 (Max throughput 100Mbps)
- USB: Four USB 2.0 with 480Mbps data transfer
- Storage: MicroSD card or via USB-attached storage
- Wireless: 802.11n Wireless LAN (Peak transmit/receive throughput of 150Mbps), Bluetooth 4.1
- Graphics: 400MHz VideoCore IV multimedia
- Memory: 1GB LPDDR2-900 SDRAM
- Expandability: 40 general purpose input-output pins
- Video: Full HDMI port
- Audio: Combined 3.5mm audio out jack and composite video
- Camera interface (CSI)
- Display interface (DSI)

K. **Flight Controller:** The KK2.1.5 was engineered from the ground up to bring multi-rotor flight to everyone, not just the experts. The LCD screen and built-in software make install and setup easier than ever. A host of multi-rotor craft types are pre-installed, we select X type, check motor layout/propeller direction and calibrate our ESCs and radio. All of which is done with easy to follow on-screen prompts. The original KK gyro system has been updated to an incredibly sensitive 6050 MPU system making this the most stable KK board ever and allowing for the addition of an auto-level function. At the heart of the KK2.1.5 is an Atmel Mega644PA 8-bit AVR RISC-based microcontroller with 64k of memory. An additional polarity protected header has been added for voltage detection, so no need for onboard soldering. A handy piezo buzzer is also included for audio warning when activating and deactivating the board [3].

4. APPLICATIONS

Drones are revolutionizing a multitude of industries. The best thing that drones can be used for is remote monitoring and image processing. Labor-based tasks are being replaced by skill-based tasks and drones will be instrumental in that change too. As this paper focuses on the applications pertaining to the mining industry, some similar technologies can be applied to domains like spotting hazardous leakages in industries, industrial safety inspection, military surveillance, forest fire control, a proper sprinkling of pesticides on farms, etc.

The application we will delve further into in this paper is the use of UAVs in mining.

5. MINING WITH UAV DRONES

This section will deal with the actual application-based approach and the need and analysis of mining industry with respect to the hazards involved and how this project aims to mitigate them. Methane is a highly explosive gas trapped within coal layers. Mechanical errors from improperly used or malfunctioning mining equipment like torches or mobile phones or use of improper explosives can trigger a methane outburst and initiate a chain reaction of explosions which are extremely dangerous not only for the mining industry staff but also to people and animals living around the site of the explosion.

Foot traffic has long been forbidden or ill-advised in many places in a mine, such as near the crests and toes of high walls, under operating machinery, on stockpiles and muck piles, or near blasts. Under such circumstances, obtaining measurements, mapping the entire mine or use of mining equipment is problematic. UAV aerial photography and remote sensing allow us to capture all the information without putting humans in harm's way [4].

6. UAV DEVELOPMENT

Aerial photography has been around for a long time now. We have exploited all type of aeronautic vehicles for such purposes, but all of them have been very expensive and quite impractical for niche applications. Quadcopters have proven to be a natural fit for mining and the advent of lithium polymer battery has transformed the development of airborne photogrammetry.

Brushless motors tend to store up charge which previously gave very short thrust capabilities. With newer technologies involved in the making of the motors, drones are now capable of carrying medium level payloads like a camera and a few sensors and actuators that can be used to carry out certain tasks. This technology allows capture of data in near real-time from areas that would've otherwise been inaccessible or unsafe for staff. Whether it is for heavy-duty tasks like analysis of a particular demographic area for blast fragmentation, analyzing the volume of stockpiles, predetermination of unknown hazardous or explosive substances that may be present in the mine, data can be captured, analyzed and worked upon quickly and safely.

ANALYSIS USING HARDWARE AND SOFTWARE TOOLS

The MQ-2 sensor coupled with a raspberry pi (Rpi), connected to a remote laptop is the pearl of an oyster to the project. The data output of the sensor is fed to a general-purpose input-output (GPIO) pin of the raspberry pi. This data is read and processed by a python script running on the Rpi and displayed on the terminal. Moreover, the live feed of the maneuver gets stored on the SD card mounted on the device. This video feed can be later used for processing and analyzing the mine for desired purposes.

In terms of the essence of a gas explosion, it is a fierce oxidation reaction produced by a certain concentration of methane and oxygen in the air under a certain temperature. The ignition source ignites in the gas-air mixture which has reached explosion limits, and gas starts combustion reactions by the basic combustion rate of 0.5m/s in the air. The precursory shock waves of gas explosion compress unburned gas in propagation process. The explosion overpressure can reach 0.7-0.8 MPa, and temperature of the unburned gas rises by compression. This volatility of the gaseous mixture is detected by the gas sensor and various values are transmitted to the Rpi via the analog output.

7. FUTURE SCOPE

This project still uses 2.4 GHz spectrum for transmission and reception of data, which has its own set of limitations when it comes to transmitting the signals through enclosed spaces. Hence a technique can be devised to overcome that hurdle. Moreover, techniques like image processing and artificial intelligence will help quadcopter become autonomous and complete a given task all by itself without human interference and thus the error. Use of GPS modules and ultrasonic sensors will make the autonomy more achievable.

8. CONCLUSION

To conclude, UAVs are a brilliant invention which can be put to use so very efficiently across a plethora of domains. Mining and industries having problems dealing with hazardous gases which must not make contact with humans can be alleviated of such issues by the use of simple and easy to learn the technology that is UAVs. With the cost of electronic components required dropping gradually, drones may make a way into our lives soon. But this carries along with it a risk of privacy. Many cities across the globe have put restrictions on UAVs being used for surveillance as they can be easily used to invade people's privacy which is a terrible offense. Hence it is up to the engineers and lawmakers that we collaborate and control the use of drones in a way that is tremendously useful to society as a whole whilst making sure that malignancy is strictly taken action against.

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