# Quadcopter Video Surveillance UAV

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# 1 Goal

Since as early as 1920, multicopter vehicles have been designed, built, and used to experiment with aerial vehicle designs [1]. The quadrotor or quadcopter design is one example of the many prototypes produced. This particular design uses four identical rotors mounted symmetrically; the result is a very stable flight platform. The goal of this project is to use the stable aerial quadcopter design for practical uses by attaching a live feed camera to a small-scale, remote controlled, quadrotor, unmanned aerial vehicle (UAV). The video received will be transmitted by digital or analog signals. If the captured video is an analog format it must be converted to digital video after transmission. With a digital signal, the video can be easily processed for analysis and storage.

## 1.1 Summary of goals

- Determine a suitable quadcopter RC UAV design.
- Select a camera system to mount on the quadcopter.
- Determine a method to transmit live video to the controller.
- Design a method to convert video to digital for further processing.

# 2 Project Overview

The ultimate goal of our project is to create a live aerial video feed which can be processed and stored. This technology can be used for search and rescue, firefighting, law enforcement, military, and news reporting by being able to deploy aerial correspondence much faster than conventional helicopters. The end result of producing a digital video signal will allow for future expansions such as UAV sentience, target tracking and video compression.

There are many components to this project and we must decide which areas will developed ourselves and which areas will be implemented with 3rd party products. The three main components of the UAV are the quadcopter/controller system, the video transmission system, and the digital video analysis system.

The quadcopter chassis and controller system consists of everything needed to build and control the flying platform in which the camera will be mounted. This includes a frame, DC motors, power supply, rotors, flight control circuit board, flight control software, and an RC controller.

The video transmission system consists of the components that record, transmit, and display the live video to the controller. Included are the camera, transmitter, receiver, and display.

The digital video analysis system will take the raw video data, convert it to digital if necessary, and load it into a program. This system will need a video capture card, a computer receiver, and video processing software.

# 3 Detailed Project Description

## 3.1 Budget

We will be required to purchase many of the diverse components necessary to construct the quadcopter. We have established a maximum budget of $1000 to build a financially accessible solution.

## 3.2 Quadcopter Chassis and Controller

The quadrotor design was chosen for this project due to its high degree of stability and lifting power. The design consists of a symmetrical array of four motors commonly attached with an 'X' shaped frame. The rotation direction of the motors is alternated, so opposite motors spin in the same direction, to counteract the reaction torques produced by the rotors. This design eliminates the need for a yaw stabilizing rotor commonly used on helicopters. Figure 1 shows the reaction torques and how they cancel each other out to produce zero angular acceleration.

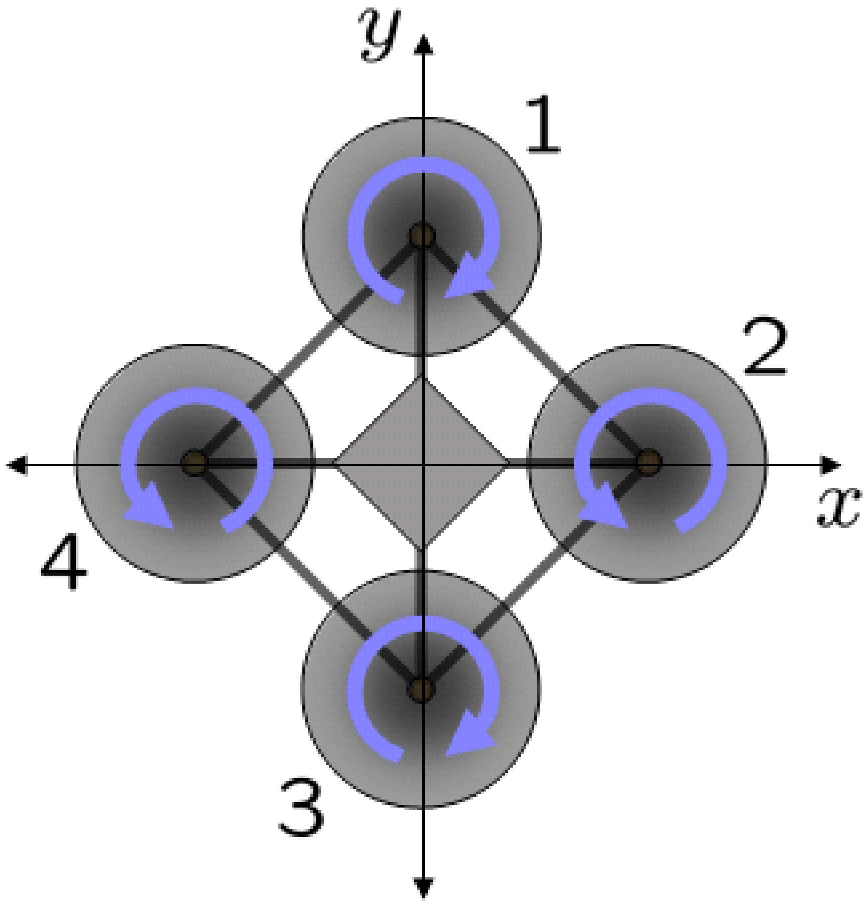


Figure 1: Reaction Torques [2]

The use of multiple rotors allows the vehicle to have a large lift capacity. For our design we will aim to build a quadcopter with a lifting force that is double its own weight. For example, if the rotors used have a lifting force of 2.5kg each the total mass of the UAV will be 5kg. This relation will allow the operator to preform aerial maneuvers and accelerations with adequate response.

Schematics, build kits, and parts for quadcopters are readily available online. Since designing and building a quadcopter from scratch would be a full project in itself, we will opt to purchase a kit which includes the frame, motors, rotors, and controller board. Following is a list of web stores which provide such kits.

http://www.aeroquadstore.com/AeroQuad_Kits_s/40.htm

http://store.diydrones.com/category_s/28.htm

http://store.scoutuav.com/products/product-category/scout-kits/

The basic kits range in price from $250 - $900. The lower priced kits provide a smaller chassis for the quadcopter and are likely to not have enough lift force for the added camera system. Consequently the higher priced kits are too expensive to balance our budget and include extra features such as GPS tracking. The mid-range kits provide a large chassis and the essentials for a working UAV. To complete the setup a battery and an RC transmitter would also need to be purchased, adding another $20 - $30 for the battery and $40 - $100 for the transmitter. An 11.1V 3000mAh LiPo battery will last for approximately 15 minutes of flight time. Since we will be transmitting from the controller and also transmitting video from the camera, the transmission frequencies need to be different so that they do not interfere with each other. Common transmission frequencies are 35MHz, 2.4GHz and 5.8GHz [3].

## 3.3 Video Recording and Transmission

The choice of video system is one of the most crucial decisions for the project. The camera needs to be light enough so that the UAV can fly unabated and compact enough so that it does not interfere with the landing gear and rotors. The video system must also be able to transmit a suitable distance over open space without interference or losing signal. For our prototype design we will consider 100m to be a suitable range, though many of the products we researched can transmit up to 1000m.

### 3.3.1 Video Camera

There are many different options for the camera. One of the first solutions was to mount an IP camera to the fuselage of the quadcopter which would be able to produce a high resolution image with its own transmitter. The downside to using such a camera is the necessity to be connected to a network; the system would not be able to function without an internet connection and would not be useful in wilderness areas.

CCTV cameras were also considered but were quickly discarded as they are generally too large and heavy for our application.

Digital cameras and helmet cameras with Wi-Fi connectivity like the Samsung SMART and Go Pro series were investigated. The cameras were designed to have a separate device, such as a smartphone, act as a viewfinder for the camera. Potentially, our viewfinder could display the live video to the operator while the camera records. One detriment to this method is not being able to easily transmit the video to a computer for post analysis. Another detriment is the transmission distance of the Wi-Fi signal, though it is not documented on the products website, the transmission distance is likely not adequate for our purposes.

CCD cameras were researched and found to be a viable candidate. The cameras operate by having an image projected onto a capacitor array. The intensity of light the capacitors are exposed to determines the electric charge accumulated on the capacitor [4]. This technology is a key factor in digital imaging and allows for very small camera units. Cameras available online range from 420 TV lines to 600 TV lines of resolution for extremely low cost, from $15 - $50.

**Figure 2: CCD Board Camera**

### 3.3.2 Transmitter and Receiver

There are two methods to transmit video wirelessly: using analog transmission or digital transmission. Analog wireless is an older technology than digital and has its benefits in being cost effective with transmitters and receivers costing as low as $15 each. Analog transmitters are able to accommodate multiple receivers while digital transmitters can only be paired to a single receiver. Having multiple receivers could be useful to separate the quadcopter controller screen from the video analysis performed by our computer. The disadvantage of analog transmission is that it is more susceptive to interference from common household technologies such as wireless routers, cordless land lines, and microwave ovens which cause static on the video feed [5]. Digital wireless is a much more robust system that does not suffer from interference induced static. Higher quality video can be transmitted using a digital signal and can transmit over farther distances than analog, but such systems are much more expensive; as low as $100 per piece. The digital systems are also larger and heavier than their analog counterparts, making them less ideal for mounting on a quadcopter.

### 3.4 Video Analysis

In order to analyze the captured video the system will need to have the images in digital format. Since the most viable camera solutions record in analog format, we will need an AD converter to transform the video after it is received.  There are many USB 2.0 converters that take a composite video feed and convert it into MPEG1, MPEG2 or MPEG4 encoded video using proprietary software.  For our purposes, we wish to receive the raw video data so that we may preform motion tracking and our own data compression.  Unfortunately, most of the commercial converters do not have adequate documentation to know what kind of data is being transmitted to its software.  The Booktree Bt878/879 is an exception as its family of video capture chipsets are well documented and widely used. The Bt879 takes a 4:2:2 YCrCb data stream from its decoder and formats the data into 32-bit wide DWORDs. The color format can then be read in RGB32 and 12 other supported formats [6]. The Booktree cards can be configured within the Linux operating system for post analysis [7].

# 4 Workload Distribution

Initially our group had three members and research was planned to be divided evenly between everyone, however our third member sought a different group opportunity early in the research process.  The remainder of the research was conducted by both of our current members, though primarily by Anton Nakazawa. Discussion about the various methods to implement our camera, transmission, and flight systems allowed us to weigh the pros and cons of each solution and determine the best for our purposes.  The final report was written by Anton Nakazawa and the website was built by Bai Xiang Jin.

# 5 Project Discussion

Because of the widely available hardware for quadcopter UAVs, we will opt to purchase a full kit as opposed to building the vehicle from scratch. While building from scratch would provide valuable learning experience it would constitute a full project by itself.  Since the overall goal of the project is to build an aerial camera, we will focus development on transmitting and displaying the images to the controller and providing post video analysis. We have decided that the AeroQuad Cyclone ARF kit is a suitable choice for our prototype as it is a mid-priced unit with the largest rotors and frame, allowing for a larger payload capacity to accommodate our camera system. Additionally we will purchase a 35MHz controller and receiver which will be used to operate the UAV. A 35MHz signal provides a larger range than 2.4GHz and allows us to use a 2.4GHz signal for our video transmission [3].

The camera and transmitter system needs to be small, lightweight, have good resolution and be able to transmit over long distances. We have chosen Sony 1/3” CCD camera as the CCD board cameras are the smallest and lightest cameras with high resolution. To transmit the video feed a 2.4GHz analog transmitter will be used as it is easily connected to CCD cameras and has a range of around 1000m.

We will take advantage of the multi-receiver abilities of analog signals and have two receivers: one for the UAV operator’s monitor and a second to our processing computer. A 2.4GHz receiver will be connected to a Linux machine using a Bt879 video capture card allowing us to program software to analyze and compress the video data. A major feature we would like to implement is a motion tracking system which will be able to distinguish the movement of people and vehicles from the video while compensating for the quadcopter’s movement.

Table 1 shows an estimate of the cost to build a prototype quadcopter UAV. The prices are based off of online price listings in US dollars and do not include any applicable taxes or shipping fees.

Table 1: Estimated Prototype Cost

| Component | Price (USD) |
|---|---|
| AeroQuad Cyclone ARF kit | 535 |
| Battery | 25 |
| Controller + receiver | 100 |
| Camera | 30 |
| Video transmitter + receiver | 40 |
| Bt879 capture card | 30 |
| | Total: |
| | 760 |

# 6 Summary and Future Works

Our ultimate goal for this project was to design a quadcopter UAV with live video surveillance. Very early in the project we discovered that quadcopter designs and parts were readily available and open source. With that information we decided not to develop the quadcopter hardware and control software in favour of concentrating on designing and building the wireless camera system and the video analysis. We chose the AeroQuad Cyclone to be an appropriate design and decided to use a 35MHz frequency for the controller. For our video camera we decided to use a CCD camera due to their small profiles and light weight. The camera will then be connected to a lightweight 2.4GHz transmitter to send the video to the controller monitor and our computer. Once the signal has been received, it will be fed into a Bt879 capture card to translate the video into readable data. With a digital data stream, the possibilities for data analysis, compression and storage become accessible. At this stage we would be able to develop our own video compressor and experiment with computer vision motion tracking.

For future development, our motion tracking software will have the goal of being able to track multiple targets consisting of humans and vehicles. The tracking algorithm would need to compensate for any movements to the image produced by the UAV's own movement.

We also consider developing an automated control system for the UAV, allowing the vehicle to fly without human intervention. The system would consist of GPS tracking for location tracking, ultrasonic range finders for collision detection, and an autopilot controller to tie all the systems together. The autopilot software would be the greatest challenge but also the most useful feature. With a completely automated system the UAV could be given patrol routes for constant surveillance in secure areas. The device could also be programmed to perform a systematic sweep over a large area for search and rescue purposes. Overall a computer controlled system will eliminate human errors and allow for safe, consistent flying.

# 7 References

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Report grade (75%): _______________

**Total Grade** (100%): _______________

Supervisor's Comments:

Supervisor's name (Print) Signature Date

Notes for the supervisor:

1. Please return the marked hard copy to Prof. Tao Lu by Monday, December 10.
2. Attached additional pages for comments if necessary.