# Design and Development of Unmanned Aerial Vehicle (UAV) Directed Artillery Prototype for Defense Application

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**ABSTRACT-** Unmanned Aerial Vehicles (UAVs) technology is one of the fastest growing technologies nowadays and is deployed in various fields. UAVs are used in many domains such as surveillance, precision agriculture, mapping and surveying, militaries etc. UAVs can move fast, it can enable the user to look past walls and fences, and it provides a large aerial view of the area where the drone flies. UAVs can also be used to harness information from dangerous places to prevent human casualties. These advantages of UAVs allow us to use Unmanned Aerial Vehicles in many fields. This paper proposes a prototype of an automatic artillery system that can get GPS coordinates of a target location based on the intelligence provided by an Unmanned Aerial Vehicle which spots the location of the target easily. The artillery system can be used to eject a projectile and make it fall on the target position. This system has applications like riot control in urban cities. It can also be used by police or military personnel to take control over terrorist infested areas without manually entering into the region of terror. This UAV directed artillery system is a very viable, cost efficient and effective when compared to conventional methods to control riots and counter terrorists. This system enhances peace in cities and ensures safety and security of the people.

**General Terms:** Unmanned Aerial Vehicles.

**Keywords:** Aerodynamics, Aircrafts, Camera, Data acquisition, Drones, Satellite Communication, Weapons, Wireless Communication.

## 1. INTRODUCTION

This paper proposes the design of a UAV directed artillery prototype, the core idea of the system is remote target acquisition and automatic artillery control. The system mainly consists of two parts: the artillery and UAV. The artillery system is made up of Arduino and a ground control station, Arduino is used to drive the motors controlling the artillery barrel and also acts as telemetry for the system with the help of HC-12. And the ground control station does the angle calculations required for the artillery and also controls the trigger. The artillery receives the coordinates of the target from UAV which is made up of another Arduino which also acts as the telemetry for the drone, the UAV also has an FPV camera which sends the video feed to the ground control station where it is viewed by the user.

Aerial Reconnaissance and missile guidance with GPS precision are finding an increased use over the past few decades with applications ranging from the recent sophisticated long range satellite guided missile systems such

as the M982 Excalibur 155mm artillery projectiles which are recently being used by the US military [1], to small drones being deployed by the local police for surveillance and patrol [2]. Our concept is more or less similar to satellite-based missile launching systems, but instead of using satellites here a UAV is deployed to do aerial Reconnaissance.
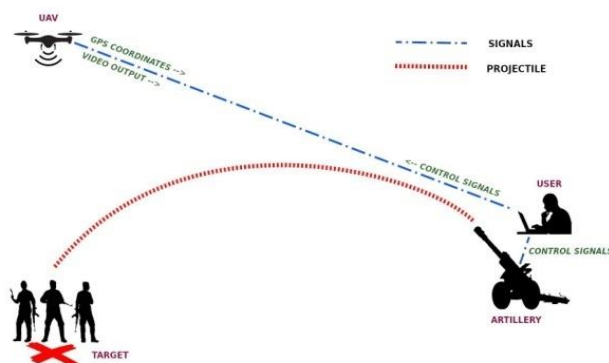


**Figure 1:** Visual Representation of our system

The main advantage of our system over satellite-based systems is obvious the cost involved, satellite imaging is a lot expensive compared to UAV and not all governments have the equipment to do so. Other than that satellite-based systems have a certain propagation delay which can be avoided in UAV based localized systems. And satellite imagery can be greatly affected by weather with clouds obstructing the view. The system also greatly benefits from the use of GPS technology and aerial footage which helps to greatly overcome

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the previous limitations by radar technology used for surveillance and target acquisition [3-13]. There are other GPS based systems where they use an onboard GPS on the projectile or artillery shell to make it a self-guided system with is very useful to strike moving targets and has a high precision, but this system is more advanced and more costly to our proposed system where all the projectile math is done before the launch in the ground control station [4]. Our technology can be used in armies where satellite technology is not viable and can be used by the army to orchestrate mid-range sieges and infiltrate the enemy base. The other main use case of the system apart from the military is for policing. The UAV can be used for surveillance and for patrol as discussed before but our major concern here is for riot control. In riot control the system allows the police personnel to monitor and survey the local population and can control the riot by using the artillery unit to launch non-lethal projectiles such as tear gas, smoke bombs and rubber bullets on strategic locations to dispel the mob far away from the riot scene. Similar efforts have been done before where UAVs have been designed to carry the riot controlling equipment such as smoke grenades, rubber bullets etc. but all this makes the system bulkier which makes it an easier target to hit and the weight limit of the drone is also one major factor.

## 2. PROPOSED SYSTEM
### 2.1 Components
The proposed system "UAV directed artillery prototype" comprises three parts. UAV, Ground Control Station (GCS) and an Artillery prototype. The following block diagram (Fig .2.) elaborates all three parts of the system. The first main component of the system is the UAV can also be referred to as a drone.
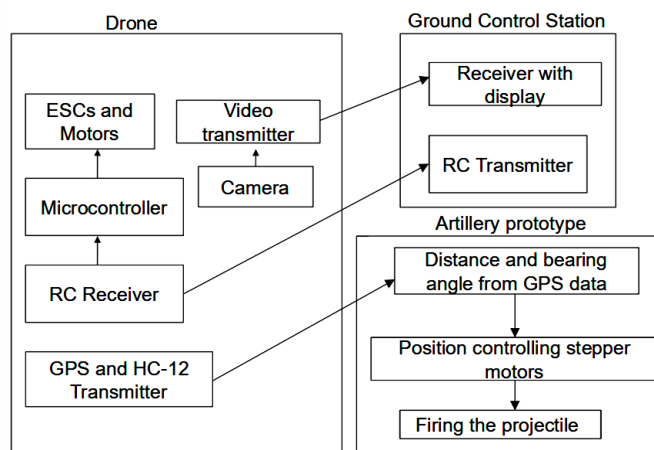


**Figure 2:** Block diagram of the Proposed System

The UAV consists of necessary components such as a video camera to get the aerial footage and telemetry along with an onboard GPS to transfer the necessary information to the ground control station. Then the ground control station [15] is where the data is received from the UAV and the aerial footage will be monitored over here at the station. The station is also responsible for sending the control signals to the UAV and also does all the necessary calculations for the artillery. The final main component of the system is the artillery.

Artillery is an automatic system which gets some of the latitude and longitude coordinates of the target from the ground control station and it calculates the horizontal and vertical angles from that data to launch the projectile at the desired location.
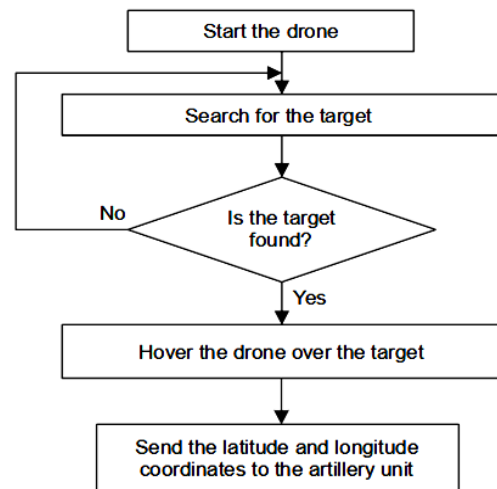


**Figure 3:** Flowchart I

The working of the proposed system will be explained using *fig. 3 and 4*. The first step is to fly the drone and search for targets over a large area. Then the UAV is hovered over the target location to obtain the latitude and longitude coordinates of the target, then the obtained coordinates are sent via telemetry to the ground control station where the user is located.
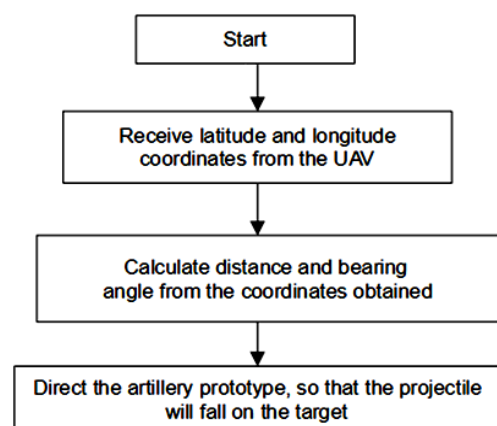


**Figure 4:** Flowchart II

Then at the ground control station the required calculations for artillery are made and the bearing angle and projectile angle are found with respect to the obtained coordinates. The output angles are then sent to the artillery and the artillery changes the direction of its barrel and finally the projectile is fired by the user.

## 3. MATHEMATICAL MODELING
### 3.1 Calculation of Bearing Angle (β)
Bearing angle is the horizontal angle between the artillery and the target with respect to true north, otherwise it's simply the

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angle that the artillery has to turn horizontally to fire the projectile. The bearing angle is calculated with the help of below formula

$$\beta = atan2(X,Y) \tag{1}$$

In equation (1), X and Y are two variables which can be calculated using the *equations (2) and (3)* respectively.

$$X = \cos(lat2) * \sin(\Delta londifference) \tag{2}$$

$$Y = \cos(lat1)*\sin(lat2)-\sin(lat1)*\cos(lat2)$$
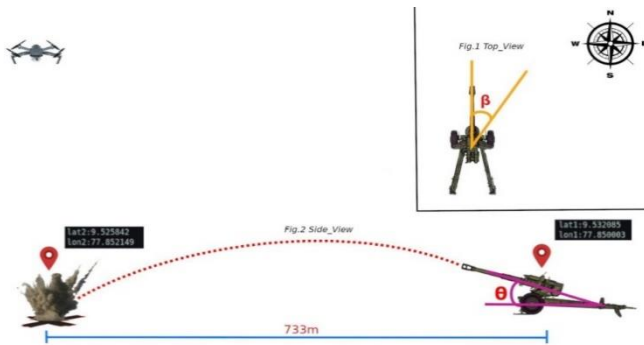
$$= *\cos(\Delta londifference) \tag{3}$$



**Figure 5:** Diagram for Mathematical Modeling

## 3.2 Calculation for Projectile Angle (θ)
Projectile angle is the vertical angle that the artillery has to move to fire the projectile, it is represented by θ in *fig.5*.

First the distance between the target and the artillery should be calculated, this can be done with the help of Haversian formula [7].

$$Y = 1.1a = \sin^2(\Delta latdifference/2) + \cos(lat1).\cos(lat2).$$

$$= *\sin^2(\Delta lonDifference/2) \tag{4}$$

$$c = 2.atan2(\sqrt{a}, \sqrt{(1-a)}) \tag{5}$$

$$D = R*c \tag{6}$$

Here a and c are variables, and D is the distance that we need, R is the radius of the earth in meters which is 6371km[14].The angle can be calculated by the following equations

$$\theta = \frac{\sin^{-1}\left(\frac{D*g}{V_0^2}\right)}{2} \tag{7}$$

In *equation (7)*, D is the distance between the target and the artillery, g is the acceleration due to gravity (g=9.8 m/s^2) and $V_o$ is the initial velocity which is actually the muzzle velocity of the projectile or artillery shell. It is a constant and its set by the user depends on what ammunition he uses.

## 3.3 Mathematical Proof
In this section, we will take an example of latitude and longitudinal coordinates of two locations and calculate the necessary values needed to be fed to the artillery to make it position itself pointing towards the target location. Let us

consider, Lat1 = 9.8923861, Lon1 = 78.117055, Lat2 = 9.8912825, and Lon2 = 78.1171296

Where, Lat1 and Lon1 are latitude and longitude coordinates of the artillery unit, and Lat2 and Lon2 are latitude and longitude coordinates of target location and substitute it in the Haversian formula described in *equation (4)*

Where,
*ΔlatDifference* = Lat1 - Lat2,
*ΔlonDifference* = Lon1 - Lon2

Therefore,
*ΔlatDifference* = 9.8923861 - 9.8912825
*ΔlatDifference* = 0.0011036
*ΔlonDifference* = 78.117055 - 78.1171296
*ΔlonDifference* = -0.0000746

$a = sin^2 (0.0011036/2) + cos(lat1). cos(lat2). sin^2 (-.0000746/2)$

$a = sin^2 (0.0005518) + cos (9.8923861). cos (9.8912825). sin^2 (-0.0000373)$

From the above calculations,
$a = (9.630726812* 10^{-6})^2 + (0.98513216)*(0.985135473) * (6.51007811 * 10^{-7})^2$

$a = (9.27509001 * 10^{-11}) + (4.113039243 * 10^{-13})$

$a = 9.31542928 * 10^{-11}$

From *equation (5)*, Where *a* is the value found using the previous equation.

c = 2 * atan2(9.31542928 * 10^-11,0.9999999)
c = 2 * 9.6516471564158 * 10^-6
c = 1.9303294312 * 10^-5

Distance D = R * c
Where R = radius of earth (R = 6371000m)

D = 6371000 * 1.9303294312 * 10^-5
D = 122.9812881

Using projectile equation (7),
Angle along vertical axis, θ = 24.4367989 Degrees.

For bearing angle calculation, we must use *equation (1)*,
β = atan2(X, Y)

Where, X and Y are,
    X = cos Lat2 * sin(ΔlonDifference),
    Y = Y = cos Lat1*sin Lat2 – sin Lat1*cos Lat2 * cos(ΔlonDifference)

Therefore, X = cos (9.8923861) * sin (-0.0000746)
X = -1.282661776 * 10^-6
Y =cos (9.8923861) *sin (9.8912825)– sin (9.8923861) * cos (9.8912825) *cos (-0.0000746)
Y = -1.926145348 * 10^-5
β =atan2( -1.282661776 * 10^-6, -1.926145348 * 10^-5)
β = -176.193008996 Degrees

## 4. RESULTS & DISCUSSIONS

In this section, the hardware implementation of UAV & artillery and output obtained from it will be highlighted.

### 4.1 UAV Modelling

In our proposed system, we have used an Arduino Uno microcontroller as a flight controller for the UAV, as it is more affordable and more flexible. Arduino based UAVs have already been implemented for several applications and are quite effective for our system [6]. The circuit diagram is described in *fig.6*.
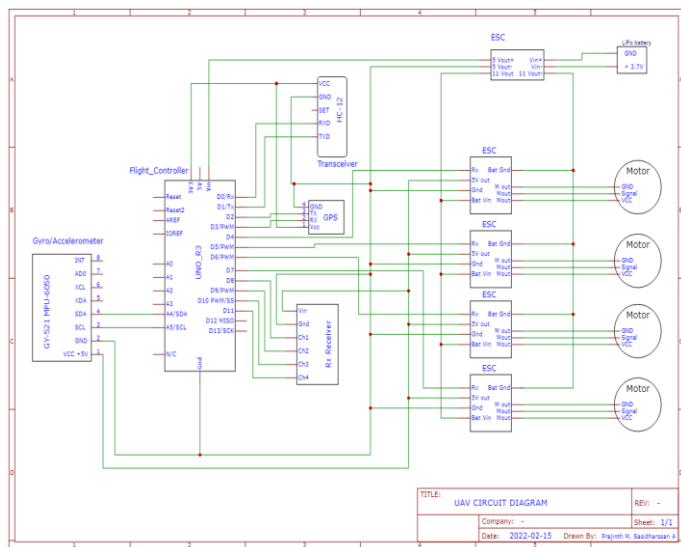


**Figure 6:** Circuit Diagram

First, the drone frame parts are screwed together. Different types of drones are used for different purposes. Each frame has a designated size class, based upon the longest distance from motor to motor measured in millimeters, typically taken by measuring diagonally across the frame. A frame measuring
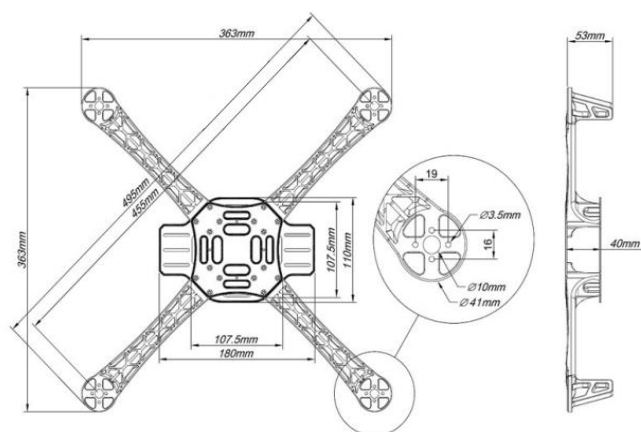


**Figure 7**: Drone structure

less than 150mm motor-to-motor is categorized as a micro. A frame larger than 150mm motor-to-motor is considered a mini. In this project we have used a DJI F450 frame to hold the drone.

A DJI F450 is a medium sized drone frame has a diagonal motor to motor distance of 450mm. Its structure can be seen in *fig. 7*.Then the drone BLDC motors are screwed with the ends of frame arms. The ESCs and battery connectors are soldered to the Power distribution board on the drone frame. ESCs are connected to the power supply, the flight controller and BLDC motors. They receive input signals to control the motor from the Arduino Uno microcontroller. Arduino Uno gets input from a radio frequency receiver. We have used the *Flysky i6* transmitter and receiver here.

This radio frequency receiver receives data from a remote-controlled transmitter. It also has an MPU-6050 chip. MPU-6050 is a gyroscope and an accelerometer. It measures the change in angle and acceleration of the UAV and is used for auto-leveling. The MPU-6050, ESCs, Arduino Uno and RF receiver are harnessed to the drone.

To convert an Arduino to an UAV flight controller, we have to upload a software code that consists of three parts [8]. First is a setup code, second is an ESC calibration code and third is the actual flight controller code. The first code gets the default values and other values from the remote-controlled transmitter and MPU-6050 and saves those values in EEPROM present in the Arduino microcontroller. These values will be used by the microcontroller to calculate the input and for auto-leveling. The second code is used for controlling the ESC input signals and manipulating it. Then the actual flight controller program is uploaded.

We used a GPS module to measure the latitude and longitude coordinates to locate the target. This GPS module is harnessed to UAV. This GPS signal is transmitted to the artillery unit through a HC-12 long range transceiver module.



**Figure 8:** Our UAV implementation

### 4.2 Artillery Modeling:

The artillery control system is also made up of an Arduino Uno which drives two stepper motors, one for the horizontal displacement and another for the vertical angle displacement.

**Figure 9:** GPS output seen in Arduino serial monitor

The Arduino at the artillery also acts as the other end of telemetry with its interface with the HC-12 module for the UAV and receives the data from the UAV and sends it to the ground control station. In the ground control station, the necessary calculations are made to find both the bearing angle and projectile angle with the help of a python code we made. The code applies the Haversian formula and other projectile equations to get both bearing and projectile angle. The results of this code are again sent to the artillery where the barrel is adjusted and then fired when the user in the control station gives the right signals. *Fig.9* shows the GPS output received by the Arduino microcontroller on the artillery side. This output shows the location of the UAV. The GPS output is sent to the artillery unit wirelessly through a HC-12 transceiver module.
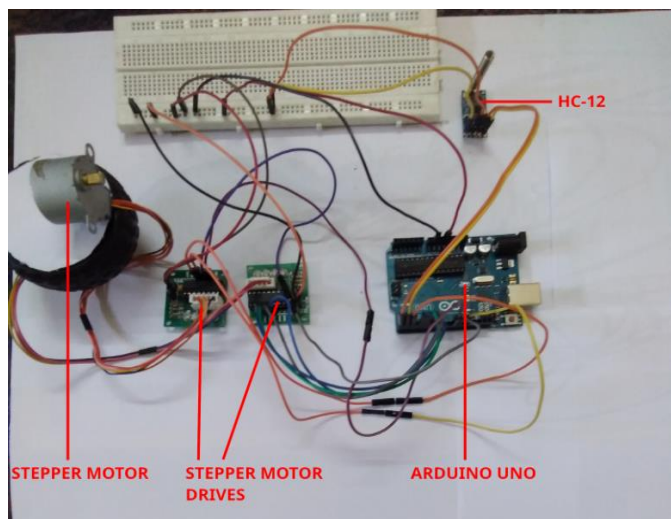


**Figure 10:** Artillery Prototype Unit

*Fig.10* shows our artillery prototype implementation. In this picture, there are two stepper motors that control the barrel direction, a receiver to receive location of the target and an Arduino microcontroller to control the motors. Since the computational power of the Arduino microcontroller is very less, we have used our computer for calculation. Our computer and Arduino microcontroller communicate through a python program using the pyserial module.

**Table 1. Weight of components used**

| Components | Weight (grams) |
|---|---|
| Arduino UNO | 50 |
| Neo6M GPS module | 25 |
| MPU-6050 | 10 |
| IA6 Receiver | 10 |
| BLDC motors (4) | 312 |
| Li-Po battery | 160 |
| 1045 Propellers (4) | 44 |
| Electronic Speed Controllers (ESCs) (4) | 92 |
| Total Weight | 703 |

# 5. CONCLUSION

A low cost hardware prototype of an unmanned aerial vehicle (UAV) directed automatic artillery system activated by GPS co-ordinates is developed. It is capable of ejecting a projectile and make it fall on the target position whose location obtained through UAV. The projecting angle is calculated by using Haversian formula to accurately target the desired location. Arduino Uno is used as a controller to implement the above calculation. Stepper motors were used to control the barrel direction in line with the command received by the receiver about the location of the target.

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