DESIGN AND DEVELOPMENT OF UNMANNED GROUND AND AERIAL VEHICLE WITH THE CONCEPT OF INTEGRATION OF DRONE AND ROVER

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Abstract: Technology has seen much advancement in the recent decades. Fuel Engines to electric engines, Telephones to Smartphones and so many. Advancement in any field does not stop with invention of existing method or product. Similarly we have seen much advancement in unmanned aerial systems, and even in unmanned ground vehicles. Nowadays they are used for various purposes that may be military, or may be in space Research. We have seen concepts of all terrain drones, similarly this project is mainly about developing an unmanned ground and aerial vehicle.

Keywords **– MOSFET (Metal Oxide Semiconductor Field Effect Transistor), Flight Controller, Thrust, ESC (Electronic Speed Controller).**

I. INTRODUCTION

The ability to both fly and drive is useful in areas with a lot of barriers, as you can fly over ground obstacles and drive under overhead obstacles. Standard drones can't maneuver on the ground at all. A drone with wheels is much more mobile and has only a slight decrease in flying time. Unmanned Ground and Aerial vehicle is a concept which brings the functions of UAV's and UGV's together in single unmanned vehicle. We have seen in many places where humans can't operate, drones are sent for the task which is mainly surveillance or other. But sometimes even aerial vehicles are unable to perform some tasks due to many reasons which include battery management, low altitude movement, noise problem etc. creating a problem in executing the task. There may be situations where the operation has to be done silently for longer time without being identified. Camouflage may be big solution. A drone can be used operate at a single place by landing on certain terrain but when required to move it has to be lifted which makes a problem again to be in silence mode. So the integration of UAV and UGV is helpful achieving these kinds of tasks.

II. OBJECTIVE

Normal Drones cannot maneuver on ground, so the developments of drones that can drive will be of great help. Suppose Being Undetected while in task for a drone might be difficult while it is operating closer to ground. For Example when observation has to be made in a smaller area, while being undetectable and has to change its location, this integration might be helpful.

III. DESIGN DETAILS

The design details include about how components are chosen and how calculations are made.The frame chosen is f450 which is shown in figure below.

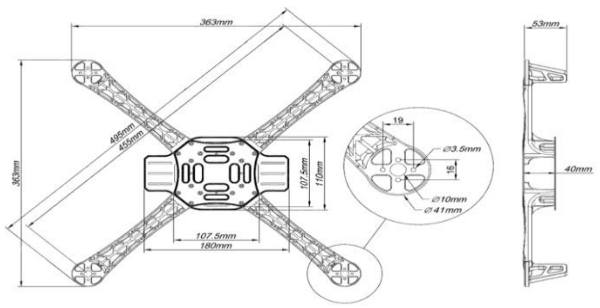


Figure 3.1 Frame

The motors used are brushless DC which comes in various variants depending on their rpm. While the lower rpm provides higher torque when compared to higher ones. We use 2200 kV motors (i.e. capable of 2200 rpm per 1Volt).

Using three pairs of MOSFETs arranged in a bridge structure is by far the most common configuration for sequentially applying current to a three-phase BLDC motor, as shown in Figure 2.2. Each pair regulates the switching of one motor phase. Using pulse-width modulation (PWM), which transforms the input DC voltage into a modulated driving voltage, the high-side MOSFETs are regulated within a typical system. The usage of PWM enables the start-up current to be restricted and provides regulation of speed and torque. The PWM frequency is a trade-off between high-frequency switching losses and low-frequency ripple currents that can damage the motor in extreme cases. Usually, designers use a PWM frequency of at least an order of magnitude higher than the maximum speed of rotation of the motor.

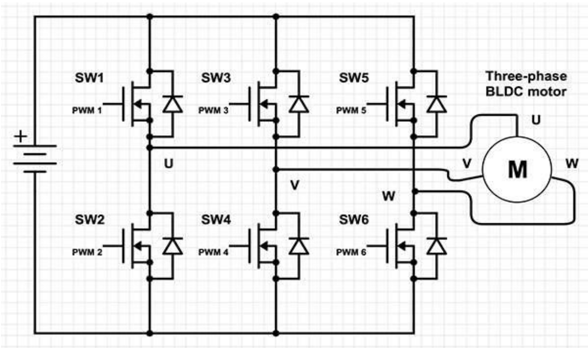


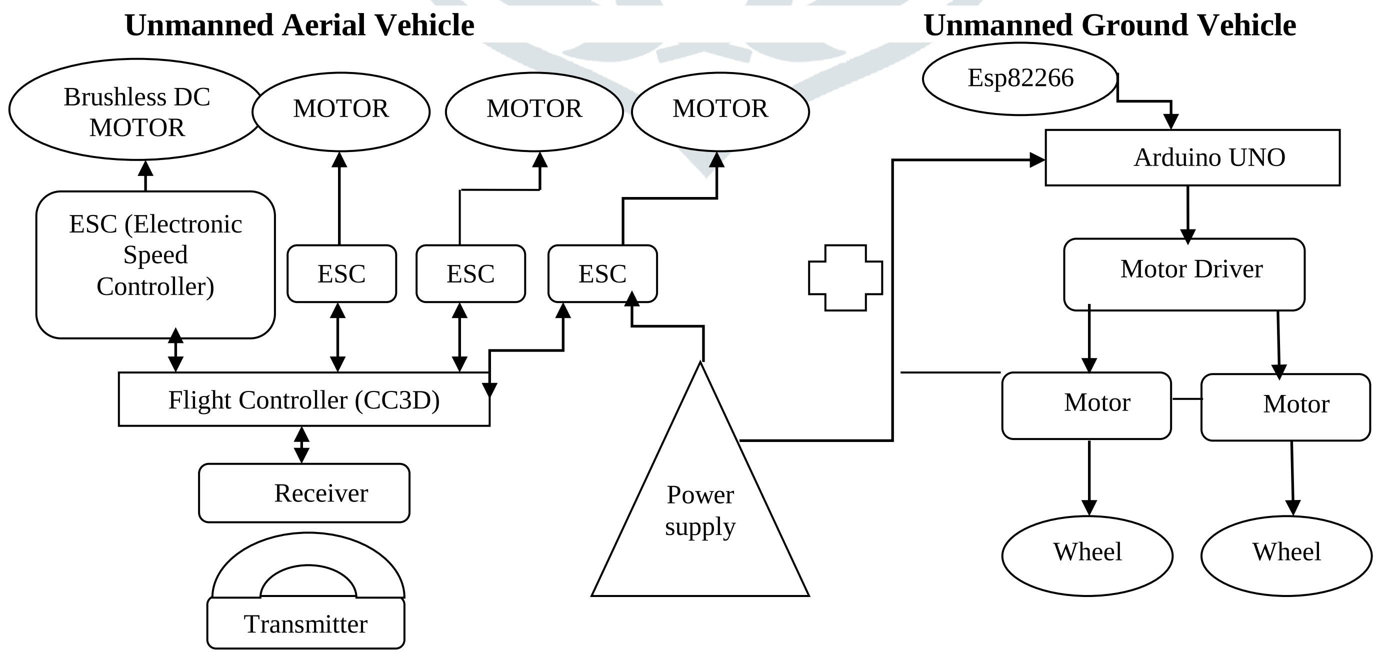
Figure 3.2 : MOSFET Circuit

As mentioned above a MOSFET circuit is required to give PWM output required by the BLDC, this circuit is simplified and known as Electronic Speed Controllers (ESC). Propellers of 10 inch and Pitch of 4.5 are chosen for better lift. These all are connected to Flight controller which receives instructions from Remote controller which is automatic frequency hopping digital frequency system, which supports 6 PPM channels commonly known as FS-i6.

As shown in the fig 2.1 we attach body of ground vehicle which 40mm away from the lower area which is 40 mm from away from the top.

This section will aid for the attachment for wheel control system which is important part of the vehicle. The ground clearance is made around 120mm-150mm. The wheels attached are of 50mm in diameter and 25mm in width. The wheels are placed below the corners of the frame, which are driven by a shaft connected to one of the motor which is present in the front portion of the vehicle along with the differential gear that allows perfect steering of vehicle. The rear wheels are driven by second motor with the help of shafts. The speed and direction of the wheels is remotely controlled by a Arduino Uno Board which is microcontroller with the help of ESP8266Wifi.h module via smart phone and also through standard remote control.

IV. HARDWARE BLOCK DIAGRAM



V. METHODOLOGY

Step 1: Making the Frame - No matter what your drone is going to be, it must have a frame. So, the first task is to make a frame. For this purpose, you can use different materials, such as metal, plastic, or wood. We are using a frame of 390 grams of weight and 4-axis drone with dimensions of 21.4cm*11.5cm*9.2cm.

Fig 5.1 Frame.

Step 2: Propellers, Electronic Speed Controllers, and Motors - The ESCs (Electronic Speed Controllers), the motors, and the propellers are among the most important elements of a functional drone. They must be in accordance with the size of your drone. The ESCs used in our project is about 30A. Propellers used in our project is of 8-inch. A motor used is of 2200kv Brushless dc motors.

Fig 5.2: Motor and ESC mount.

Step 3: Assemble the Motors – Install the motor in the appropriate place and fix it to the frame using the screws and a screwdriver. Tighten the screw, so that a vibration doesn't affect the motor mount.

Step 4: Mount the Electronic Speed Controllers - In order to fix the ESC very well to the frame, we need to use zip ties or a cello tape. This way, our ESCs are tied down and well secured while flying. All the ESC's should be soldered to the power distribution board.

Step 6: Flight Controller - This electronic system allows a drone to be stable in the air while flying and processes all the shifts and changes in direction and the wind. This electronic controller should be mounted on anti-vibration stick pad on top of the frame. The wiring should be done from flight controller to all the ESC's and to the receiver. The flight controller used by us is CC3D controller board.

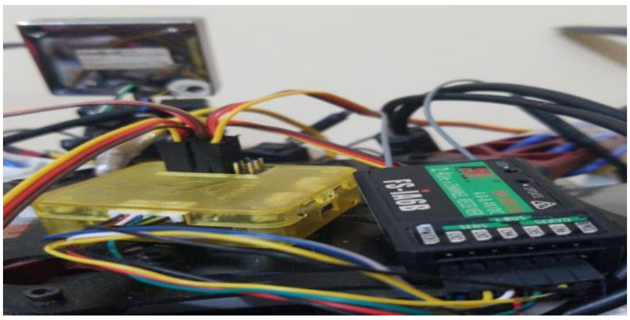


Fig 5.3: Flight controller (CC3D) and receiver wiring.

Step 7: Choosing a Right R C Tx-Rx (Wireless Remote Control System) - This is the remote control system that is needed to control a drone. In addition to this system, you'll also need a few channels for yaw, pitch, throttle, and roll, as well as the additional channels if you want to mount a camera control to our drone for some aerial photography. The R C controller used in our drone is Fly sky FS-i6X 6CH 2.4GHz AFHDS RC Transmitter w/ FS-iA6B Receiver.

Step 8: Fixing of ground vehicle chassis – The ground vehicle chassis which is rover chassis is being fixed at the bottom of the frame by using screws and nuts.

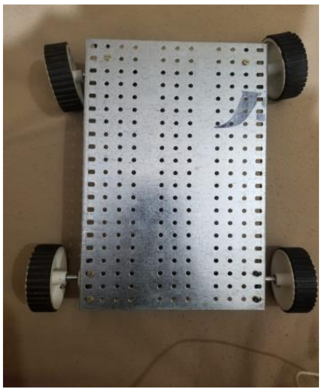


Fig 5.4: Ground Vehicle Chassis.

Step 9: Installing the drive motors and wheels for the chassis – The drive motor is being fitted to the chassis by using clamp and the two wheels are connected to the motor mount. The two dummy wheels are fixed at front part of the chassis. The wheels using are fit for all terrain.

Fig 5.5: All Terrain Wheel.

Step 10: Mounting the motor driving driver and connecting with Arduino UNO – The motor should be connected to Arduino UNO using a motor driver L298N 2A.

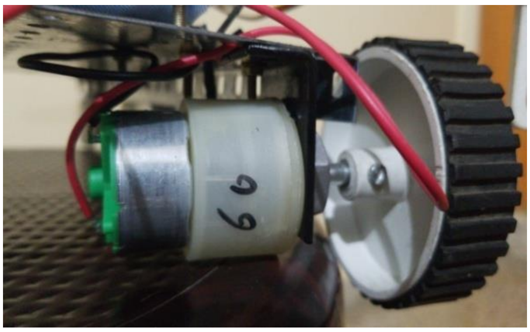


Fig 5.6: Motor used for driving the wheel

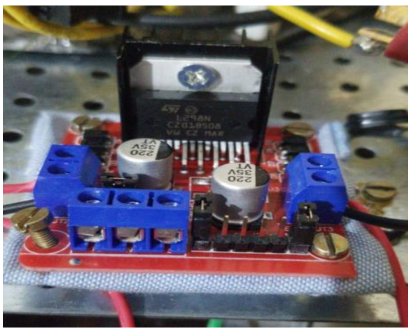


Fig 5.7: Motor drive

Step 11: Write code to Arduino UNO using Arduino software – The code for the movement of left, right, forward, and backward should be written using Arduino software should be written.

Step 12: Placement of Battery and soldering battery to power distribution – The battery of 5200mAH Lithium ion is placed and soldered to the power distribution board where all the ESC’s are connected.

Step 12: Connect the Open Pilot – We have used open pilot software to configure the CC3D flight controller it balances all the Electronic speed controller and links the R C Transmitter and Receiver.

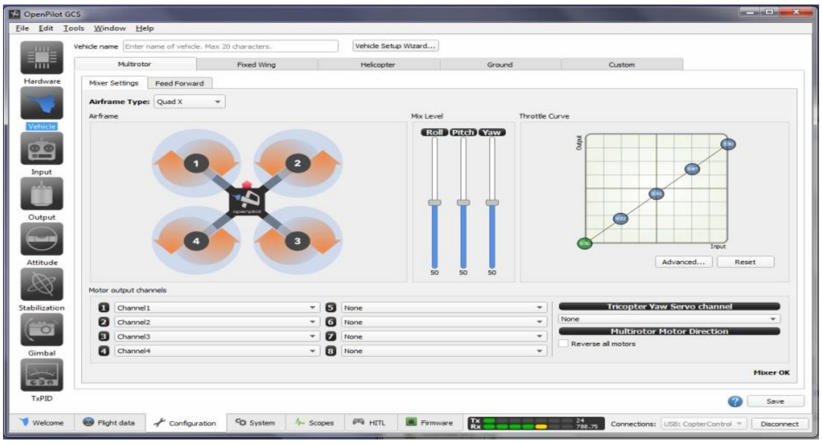


Fig 5.8: Open Pilot Software.

Step 13: Camera mounting: The camera is mounted on the vehicle.

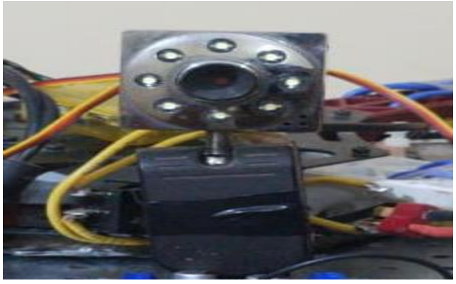


Fig 5.9: Camera mount on the vehicle.

Step 14: Interfacing of arduino uno with esp8266 and motor driver. This interface leads us to control the rover vehicle.

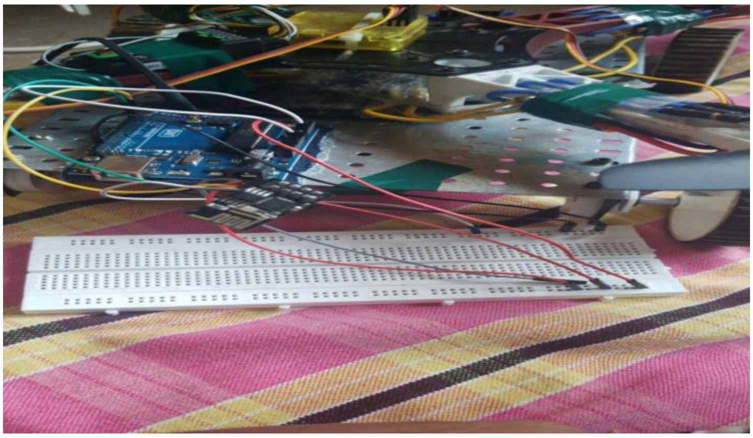


Fig 5.10: Interfacing of Arduino Uno with ESP8266

Step 15: Controlling Rover vehicle through blynk

VI. MATHEMATICAL CALCULATION.

The estimated weight of the vehicle is around 1.8 KG. The calculations to be made in selecting components are shown below. The weight in the form of thrust is taken into consideration. Static Thrust and Dynamic thrust are the two types of thrust which plays a vital role in calculating and choosing the right components. The formula is shown in below figure 3.1. To get a better maneuver we should always consider at least that static thrust i.e. the capacity to lift should be 3 times greater than the actual weight. As mentioned the weight of the vehicle is around 2000g and hence the capacity of thrust should be always greater than 6000g for better control and to achieve heights.

Dynamic Thrust Equation

F = thrust (N), d = prop diam. (in.), RPM = prop rotations/min., pitch = prop pitch (in.), V_0 = propeller forward airspeed (m/s)

Expanded Form:

$$F = 1.225\frac{\pi(0.0254\cdot d)^2}{4}\left[\left(RPM_{prop}\cdot 0.0254\cdot pitch\cdot\frac{1min}{60sec}\right)^2 - \left(RPM_{prop}\cdot 0.0254\cdot pitch\cdot\frac{1min}{60sec}\right)V_0\right]\left(\frac{d}{3.29546\cdot pitch}\right)^{1.5}$$

Simplified Form:

$$F = 4.392399x10^{-8}\cdot RPM\frac{d^{3.5}}{\sqrt{pitch}}(4.23333x10^{-4}\cdot RPM\cdot pitch - V_0)$$

Figure 3.1: Dynamic Thrust Equation

The thrust required is and its calculation is shown below.

Let's take into few considerations such as

The motors can spin at 2200rpm per volt Since we are using 11.3v lipo battery but lets say 10V, and current can be drawn be around 20A.

So the motors are capable of 22000rpm.

The length of the propeller is 10 inch and pitch 4.5 inch. Now lets calculate the thrust by considering air temperature to be around 25° Celsius.

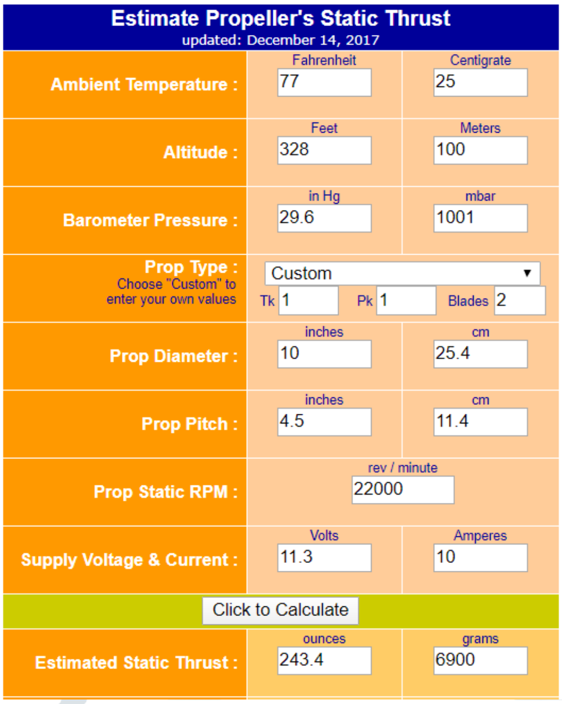


Figure 3.2 : Propeller's Static Thrust

The static thrust is around 6900 g which is sufficient

Now let's calculate estimated flight time of UGAV.

The main factors that influence the flight time are Battery Capacity, Battery voltage, The total weight to be lifted, let's call it as all up weight (AUW), Average amp draw and C rating of a battery.

We know that,

AUW = 2000g

Battery Capacity = 4500 mAh

Battery Voltage= 11.1 V (Say 10V)

C Rating = 25C

Power to lift 1kg in Watts = ?

Average AMP draw(AAD) = ? (since our ESC are rated for 30A , to be on safe side the AAD should be less than 25A)

Watts to lift 1kg of mass

Now let's calculate flight time,

Flight Time= Capacity/ AAD ---------(eqn A)

AAD = Total weight x (Power/ Battery Voltage) --(eqn B)

Power in watts:

Say on Earth let's calculate the Force on ground due to 0.1kg of mass with gravity taken $10 m\text{-}s^{-2}$. It is calculated by Eqn (F=ma)

F=0.1 x 10 = 1 N of Force

Literally 1 N is 1 Kg of weight

Now to lift 1kg of weight to a height of 1m in 1sec let's calculate the energy required. To reach a velocity of 1m/s instantaneously say in 0.1s, let's calculate the acceleration needed,

acceleration = (final velocity – initial velocity)/time

net upward acceleration=(1 m/s – 0m/s)/0.1 s = $10 m\text{-}s^{-2}$

W.K.T Earth gravity pulls any object towards earth at $10 m\text{-}s^{-2}$. To get a net upward acceleration of above calculated we should calculate the upward acceleration to be applied,

Net acc. = upward acc. – downward acc.

10 = x – 10

Upward acc. = $20ms^{-2}$ Which is double the gravity of Earth, Similarly while we calculated static thrust in the fig3.2 , we took three times which for extra capability but the minimum required is two times so the net becomes twice of downward force.

So from the above observations, on earth it takes about 10 Newton-meters (N-m) of energy to raise a 1 kilogram mass to a height of 1 meter. Since 1 N-m equals 1 Joule, that's 10 Joules. If it takes 1 second to lift the weight 1 meter, than you have converted 10 Joules of energy to potential energy in one second. That's 10 Watts of power. If you want to lift same amount of weight to the height of 1m but instantaneously say in 0.1 sec (i.e lets say low speed vehicles can operate at 36 km/hr which is 10 m/s , so we can say 1 meter in 0.1 sec), then 100 watts of power is required to lift 1kg.

Now we know power, we can calculate Average Amp Draw(AAD)

Substituting Power in eqn B

AAD = 2 x (100/10) = 20A

Since ESC used are rated at 30A , we took 25A to be on safer side, but we achieved 20 A, we can power and can achieve 25 A.

Substituting the value of AAD in eqn A,

Flight Time = 4500 mAh /20A

Flight time = 4500 x 10^{-3} A x 60 min / 20A = 13.5 min

But to be fail safe mode we shall take 80% of the total capacity, now the new value will be,

Flight Time = 0.8 x 4500 x 10^{-2} A x 60 min /20A = 10.8 min.

VII. SOFTWARE

1. Open Pilot

The Open Pilot Ground Control Station (GCS) can be used for both configuring the controller board and controlling and tracking the UGAV during flight. Most commonly, we would use a conventional radio control transmitter to control the vehicle, but the GCS is capable of doing so as well. This can used to configure the UAV (unmanned aerial vehicle) system.

2. Arduino IDE

The Arduino Integrated Development Environment (IDE) is a cross-platform framework that is written in C and C++ languages. It is used to write and upload programs to boards which are compatible with Arduino, but also other vendor development boards with the help of 3rd party cores. This is used for UGV (Unmanned Ground Vehicle) programming.

VIII. RESULTS AND DISCUISSION

After integration of the unmanned ground and aerial vehicle, the vehicle was verified and took it for the testing. At the being of our test it was not able lift the massive amount of weight.

Soon we reduced some weight by using the light weighted chassis. Still we were facing with some weight management issues. We tried to balance the weight several times and made to fly.

The flight controller was reconfigured with Open pilot software. We used an anti vibration stick pad to mount the flight controller. So that the flight controller sensors such as Accelerometer and Gyroscopes should be disturbed, if the flight controller gets disturbed this results to loss the stability of the vehicle. Finally the flight was being tested, which lifted the vehicle upwards and made a movement on the surface too. After a lot of trails the unmanned ground and aerial vehicle was constructed.

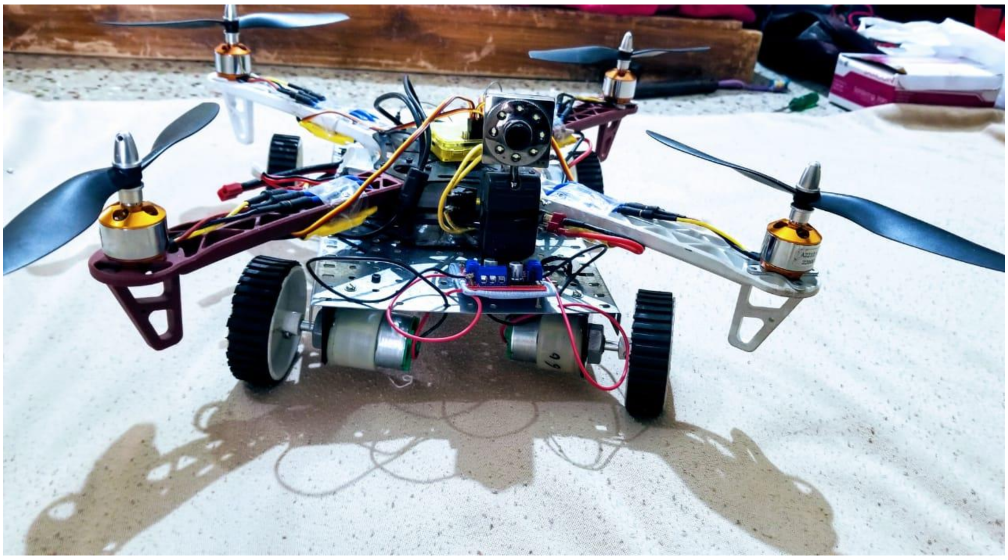


Fig 5.1: Final Unmanned ground and aerial vehicle.

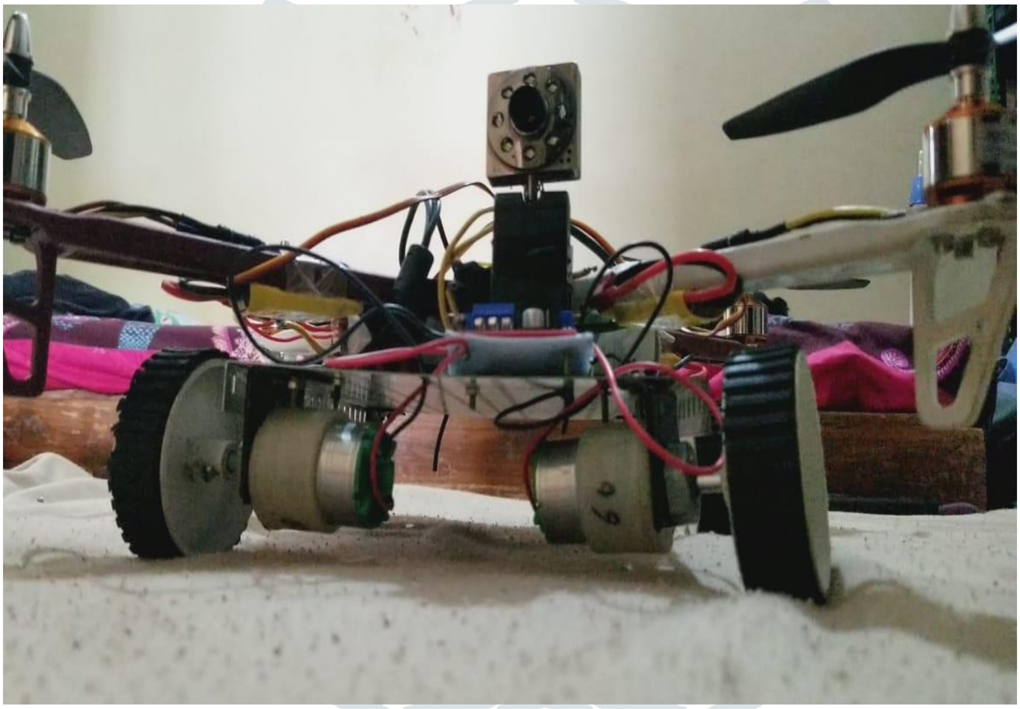


Fig 5.2: Ground view of the vehicle.

IX. ADVANTAGES AND APPLICATION

There is a variety of UGVs in operation today. These vehicles are predominantly used to replace people in hazardous situations, such as handling explosives and disabling vehicles where additional strength or smaller size is required, or where humans cannot easily go. Military technologies include surveillance, tracking, identification and target-acquisition. They are also used in agriculture, mining, and construction industries. UGAVs are highly efficient in naval operations, they play a major role in the fighting of the Marine Corps combat in naval operations, they have great importance in the help of Marine Corps combat; they can also make use of logistics operations on land.
UGVs are also being built for peacekeeping activities, field security, gatekeeper/checkpoint activities, urban street visibility and to reinforce police and military interventions in urban environments. UGAVs can "bring out the first fire" from insurgents reducing military and police casualties. In fact, UGAV are actually being used for search and retrieval operations.

UGAVs are used in a number of emergency situations, including urban search and rescue, fire fighting and nuclear response.

• Flexibility: Aerial and Ground tasks can be executed easily.

• Budget friendly: This type of drone can be done at reasonable price.

The main application involves:

• Executing operations or tasks where only aerial mode becomes difficult.

Closer Observations made on wildlife cannot include humans, animals may get scared due to noise and movements. Example: Wildlife Photography.

X. CONCULSION

Building drone is expensive hobby but lets us to come across lot of concepts in various fields of engineering like mechanics and electronics like design of frame, overall body structure and knowing about gyroscope and barometer and we got to know how to stabilize when it's up in air. We concluded amp rating shall be the prime reason for the efficient functioning of ESCs (electronic speed controller).We burnt two ESCs while testing without voltage regulation this lead to higher amp rating. The biggest challenge in project was to mount the rover equipments to the drone where we came to know 10 inch propeller should be replaced with our 8inch propeller and using powerful BLDC motor of 2200kv /6A instead of 1200kv BLDC. The vehicle design can help users beyond a drone and rover since it is both integrated it can used to fly when required and can run over terrains as well, this lets the system save energy this lets system use energy effectively over a long time and the proper observation and proper task can be carried out using this vehicle.

XI. FUTURE SCOPE

The future scope for this project is to implement by adding few extra equipment to the vehicle and can be used as bomb defusing vehicle. The vehicle can save time to reach the location and then defuse the bomb in a short duration. This vehicle can be camouflage and then used to shoot wild life animals without disturbing them by any means. This vehicle can be implemented to carry out many tasks which can be done in short duration of time. The enhancing and improvement to this vehicle will give rise to much more flight time and increases the operation time too. This must be improved to more rugged structure.

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