DESIGN AND DEVELOPMENT OF INTEGRATED UNMANNED AERIAL AND GROUND VEHICLE WITH OMNI DIRECTIONAL WHEELS

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***Abstract*: In this paper we are going to make a robot which will works as unmanned ground as well as aerial vehicle. The term unmanned means the vehicle is driven using the remote control and there will not be any person at the robot section. Using the technology of BLDC motor, Stepper motor and the Transreciever all the function is carried out. The microcontroller used here is arduino for digital signal processing. As an advancement the Omni wheels are used to travel at the ground level in Omni direction. Moreover the TFT display is used to get feedback from the robot section and microphone is used to sends audio signals. The propellers are used to created thrust to fly in air.**

***Index Terms*: Unmanned Ground Vehicle, Unmanned Aerial Vehicle, Omni Wheels, BLDC motor, Arduino, Propellers.**

I. INTRODUCTION

In the past decades use of drones, ground robots, and water based robot has increased to a greater extent. The use of integrated structure for the complex design and combine technology. Due to increase in technology there is need of advancement in the structure of surveillance robots. They must be such a kind of robot, where they can travel through air as well as on ground. With the help of wheels and BLDC motor we can make this happen. There are drones in the world which ranges from microscopic level to macroscopic level. Some are Teleoperated, some are hybrid while some autonomous. The robot which we are building here is a Teleoperated robot. While building this robot we have inserted a GPS module which could be used to track the real time location of the subject. To get more detailed information about the subject a telemetry camera is also inserted which a FPV is known as first person view camera. It is a compact sized high definition camera along with long range antenna. RC (radio controlled) technology is developed in almost every sector such as RC cars, RC planes, RC ships, etc. As a future scope the robot can further modified as a water vehicle to. The technology used in the robots such as transformers can be used to switch between one modes to another. But the main aim of this project is to design and develop a technology which could withstand on ground as well as in air. The chassis is made of plastic fiber to reduce weight constraints. The robot can be used for surveillance and to go in hazardous areas where mam cannot reach, for any kind of announcement in restricted areas with the help of speakers

II. CIRCUIT DIAGRAM:

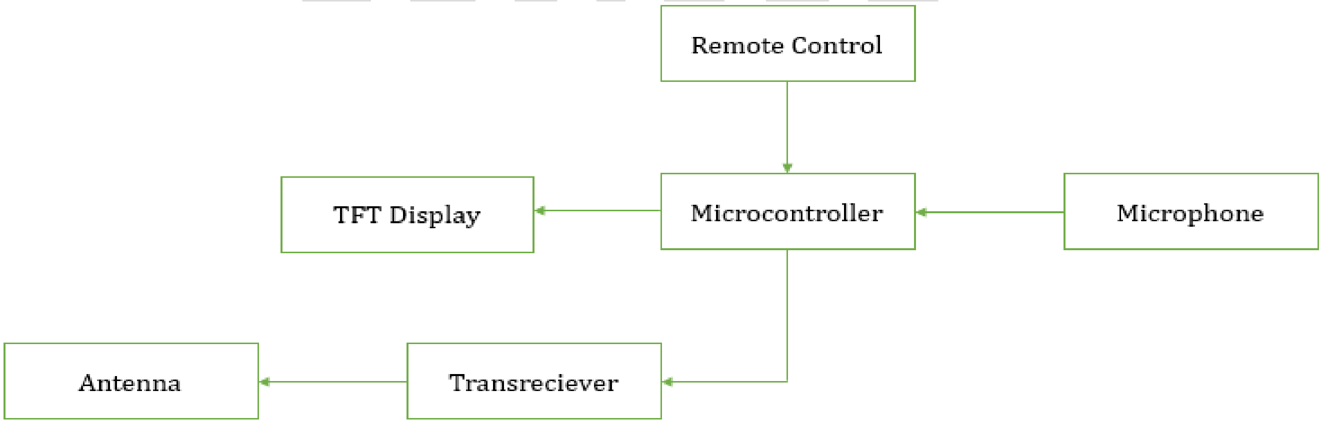

FIGURE 1: REMOTE CONTROL

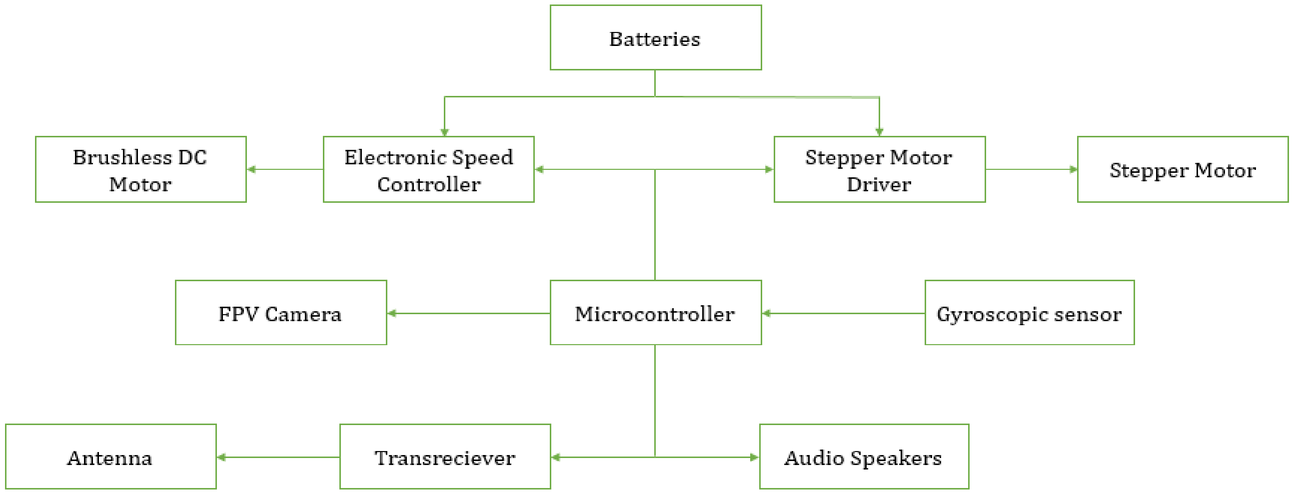

FIGURE 2: ELECTRONICS FLOWCHART ROBOT SIDE

An arduino is used as microcontroller unit in both the sections i.e. in remote section as well as in robot side. In the remote section there is a specially designed remote control attached to sends any commands to microcontroller. This microcontroller then decodes this command into binary code and transfers it using the Transreciever which is attached with the antenna. The antenna at the robot section receives the signals using the Transreciever and transfers it to the microcontroller this binary code is then decoded and then performs the necessary function as given by the user.

If the user commands to fly then the microcontroller at the robot side sends the commands to the electronic speed controller which is then bypasses the current from the batteries towards the BLDC motor. This bypassing of the current depends upon the signals sends by the microcontroller. In mechanical terms the ESC acts as flow control valve and the knob is in the microcontroller's section. The ESC is nothing but the motor driver with only difference is it is having three terminals at the output section and controlled using single control pin, as soon as the current and voltage received by the BLDC motor then it starts rotating and creates the thrust force.

If the user commands to drive the Omni wheels then the microcontroller at the robot side sends the commands to the stepper motor driver which is then bypasses the current from the batteries towards the stepper motor. The stepper motor driver is a special purpose driver which is used to sends current to each winding of the stepper motor separately. The stepper motor driver is controlled using the two direction control wire and two speed control wire. The rotational direction of the motor is controlled using the controlled using the direction wires and the speed is controlled using two speed wires. This number of wires depends upon the cores of the stepper motor. The more the cores the more the number of wires. So when the signals is reached towards the stepper motor then it starts rotating which then rotates the wheels as per need.

The robot section in return sends the video signals with the help of the first person view camera and the altitude signals with the help of gyroscopic sensor sends the signals using the Transreciever. This signals from the robot section is then receive by the remote section. This received video and the altitude is displayed on the TFT (thin film transistor) display. Then user gets the feedback from the camera as well as gyroscopic sensor. As an advancement the remote section is equipped with the microphone to send the voice signals. These signals is then executed using the audio speakers at the robot section. In this way the electronics section of the remote and the robot side works..

III. MODEL

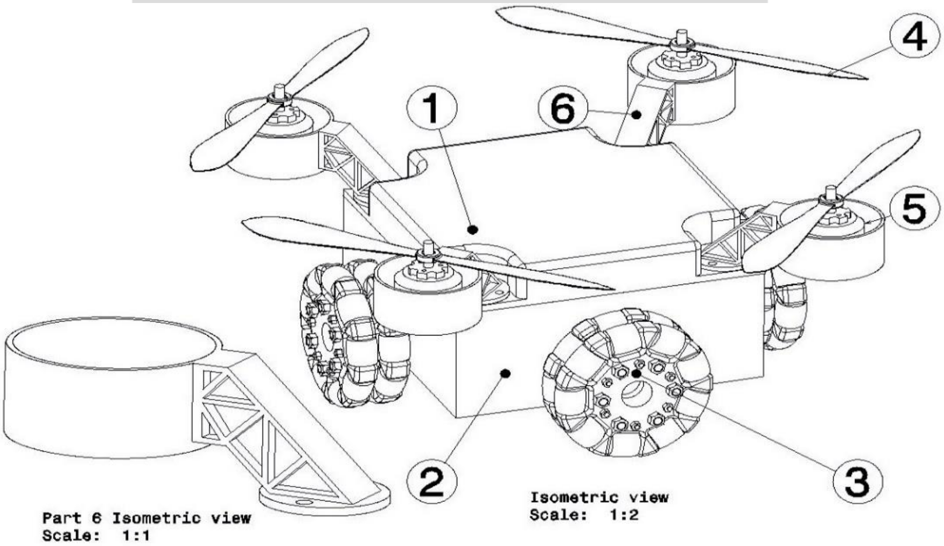

Figure 3: Isometric View

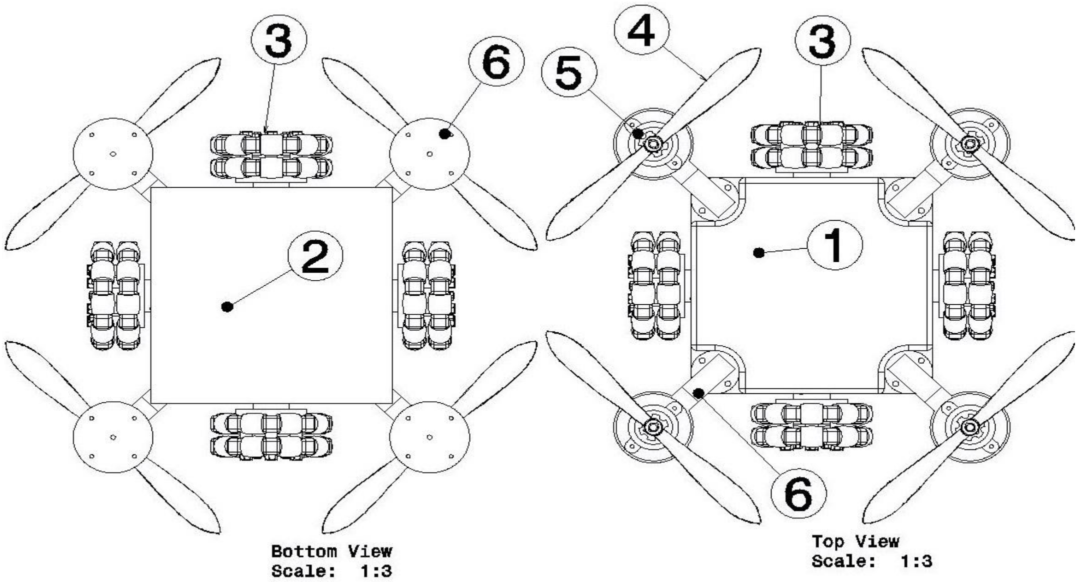

Figure 4: Top & Bottom View

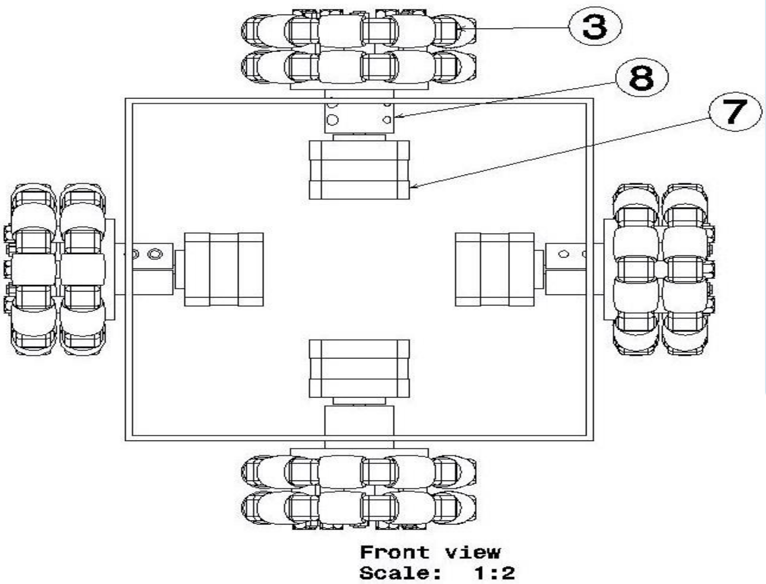

Figure 5: Sectional View

IV. PARTS DESCRIPTION:

Part 1: Top Lid Of Chassis

This part helps to support the support wings and the base chassis. It is mounted on the top of the base chassis and at the bottom of the support wings. There are four drilled holes at each corner to mount the support wings and is made up of plastic using molding process.

Part 2: Base Chassis

Base chassis is used to hold the battery packs, stepper motor and top chassis lid. The base chassis is drilled with four holes at each side walls of the chassis to fix the motor. There are there are another drilled holes at the base of the chassis to couple the top lid and the base chassis itself.

Part 3: Omni Directional Wheel

This wheels are specially designed to move in Omni direction. There are rollers at the periphery of the wheel, it is also tangent of the diameter of the wheel. This wheels are placed parallel to each face (side walls) of the base chassis. Fixed exactly at the center of each face. The wheels are coupled with the stepper motor using the anti-slip coupling.

Part 4: Propellers

The propeller is most important part of the design where it is used to fly by creating the thrust force against the gravity. The propellers are coupled with the BLDC motor using transition fit.

Part 5: BLDC Motor
BLDC motor is also known as the brush less DC motor. This motor is specially designed light weight and high speed motor. This motor is driven by ESC (electronic speed controller) using three polarity wires. The motor is coupled between the support wings and propellers at each corners of the model.

Part 6: Support Wings
Support wings are designed to keep away the base chassis and the propellers, to avoid collision between the propellers with each other. The support wings are coupled with the top chassis lid using the nut and bolt joint at each corner of the chassis along the direction of diagonal of chassis.

Part 7: Stepper Motor
This stepper motor is used to drive the wheels with each degree of control and with specific speed. The stepper motor is coupled with the Anti-slip coupling and with the face of the base chassis using nut and bolt joint.

Part 8: Anti slip Coupling
Anti-slip coupling is used to couple the wheel and the stepper motor, without any slip between the shaft of the stepper motor and inner diameter of anti-slip coupling. It is one type of flange coupling with specific design at the hub.

V. DESIGN PARAMETERS:

The design of the model should follows the following criteria:

1. The design should be lightweight.
2. Compactness
3. High thrust capacity with less power consumption.
4. Should be able to move in Omni direction during on road condition.
5. Design for surveillance.
6. Each degree of rotation of the wheel should be controlled and measured.
7. Selection of battery should be light weight, high power and high discharge rate.
8. Resistance of air during fly should be less as possible.

VI. SELECTION OF MOTORS:

The motor is selected on the basis of rpm, maximum thrust produced, voltage and ampere required to operate. As per requirement the following motor is used:

Brand	EMAX
Model	RS2306
Motor KV	2750
Maximum Thrust	1762 gram
Length	30.1 mm
Width	28.3 mm
Weight	34 gram
Shaft Diameter	5 mm
Type	BLDC

THRUST CALCULATION:

$m = mass\ of\ Robot\ in\ (Kg)$
$v = Battery\ Supplied\ Voltage = 14.8\ \ (Volts)$
$g = Gravitational\ Accleration\ in\ \left(\frac{m}{s^2}\right) = 9.81\ \left(\frac{m}{s^2}\right)$
$P = \ \ Power$
$D = Propeller\ Diameter\ in\ (m) = 0.125\ (m)$
$n = Propeller\ Speed\ in\ (RPS) = \frac{2750}{60}\ (RPS)$
$Q = Propeller\ Torque\ in\ (Nm)$
$T = Thrust\ Force\ Generated\ \ in\ (N)$
$\eta_{prop} = Eficiency\ of\ propellers$
$\mu_0 = Flight\ Velocity\ in\ \left(\frac{m}{s}\right) = 8\ \left(\frac{m}{s}\right)$
$J = Advanced\ Ratio$
$\rho = Density\ of\ Air\ in\ \left(\frac{Kg}{m^3}\right) = 1.225\ \left(\frac{Kg}{m^3}\right).$

In order to find out the motor torque constant we first know the Motor voltage constant in equation 1 we get the motor voltage constant by putting the voltage equals to 14.8 volt as a standards battery voltage of 4 cell lithium polyamide battery. Moreover, the speed of motor is constant and is given in motor datasheet. The

$$Motor\ Voltage\ Constant\ (K_e) = \frac{Voltage\ (V)}{Speed\ (rpm)} \quad (1)$$

$$K_e = \frac{14.8}{2750\ X\ 14.8} = \frac{1}{2750}$$

$$\boldsymbol{K_e = 0.0003636}$$

As soon as we get the voltage constant we put that value in the empirical relation of Motor torque constant which given by equation 2.

$$Motor\ Torque\ Constant\ (K_q) = \frac{K_e}{0.000955} \quad (2)$$

$$K_q = \frac{0.0003636}{0.000955}$$

$$\boldsymbol{K_q = 0.3805}$$

The torque produced by the motor is directly supplied to the propellers. The power produced in propellers is given by equation 3. During this density of air and the propeller diameter is used is already defined. Speed of the motor is give in revolution per minute so to convert this into revolution per seconds divide this speed value by 60.

$$Propeller\ Torque\ (Q) = (K_q)\ \rho\, n^2 D^5 \quad (3)$$

$$Q = 0.3805\ X\ 1.225\ X\ \left(\frac{2750}{60}\right)^2\ X\ (0.125)^5$$

$$Q = 0.05316\ X\ 1.225\ X\ 2100.69\ X\ 0.0000305175$$

$$\boldsymbol{Q = 0.02988158\ (Nm)}$$

The propeller power constant is an important factor to find out the actual power delivered the equation 4 gives the actual power delivered to the propeller

$$Propeller\ Power\ Input\ (P_i) = 2\,\pi\, n\, Q \quad (4)$$

$$P_i = 2\ X\ 3.14\ X\ \left(\frac{2750}{60}\right)\ X\ 0.02988158$$

$$\boldsymbol{P_i = 8.6009}$$

As per the equation 5 we get the power coefficient of propeller. In this equation with the help of torque constant the value is obtained.

$$Power\ Coefficient\ (P_c) = 2\,\pi\, K_q \quad (5)$$

$$P_c = 2\,\pi\ 0.3805$$

$$\boldsymbol{P_c = 2.38954}$$

This Propeller constant is find using the propeller pitch. There is an empirical relation between propeller constant and propeller pitch which is given in equation 6.

$$Propeller\ Constant\ (K_p) = \left(\frac{Propeller\ Pitch}{1853.2}\right) \quad (6)$$

$$Propeller\ Constant\ (K_p) = \left(\frac{114.3}{1853.2}\right)$$

$$\boldsymbol{K_p = 0.06167}$$

The thrust coefficient is find out using the equation 7 which is formed using air density, speed of propeller, diameter of the propeller and thrust itself.

$$Thrust\ Coefficient\ (K_t) = \frac{T}{\rho\, n^2\, D^5} \quad (7)$$

To find out the thrust coefficient we first need to find out the thrust using the diameter of the propeller, air density, velocity of air near propeller and velocity of air accelerated by the motor. The thrust can be calculated by equation 8. The equation is based on the momentum theory.

$$T = \frac{\pi}{4}\, D^2\, \rho\, v\, \Delta v \quad (8)$$

It is considered that velocity of air near propeller and velocity of air accelerated by the motor is in 1:2 ratio. The equation is equation is given below as 9.

$$\left\{ v = \frac{1}{2}\,\Delta v \right\} \quad (9)$$

Substituting the value of velocity of air accelerated by the motor in terms of velocity of air near propeller we get the equation 10.

$$T = \frac{\pi}{8}\, D^2\, \rho\ (\Delta\, v)^2 \quad (10)$$

P is the power and is given by the equation below which is again simplified to eliminate the velocity of air accelerated by the motor. Substituting this value of velocity of air accelerated by the motor in equation 10 we get the following optimized equation as 12.

$$P = \frac{T\,\Delta v}{2} \ \rightarrow\ \Delta\, v = \frac{2P}{T} \quad (11)$$

To calculate the thrust at this position we have diameter of propeller, density of air but we don't have power so in order to calculate the power we need rpm of motor, power factor (2.39) from equation 5 and propeller constant from equation 6.

$$T = \left(\frac{\pi}{2}\, D^2\, \rho\, P^2\right)^{\frac{1}{3}} \quad (12)$$

Substituting the value of the above parameters in equation 13 we get the power which we again substitute in the equation 12.

$$Power = Propeller\ Constant\ X\ \left(\frac{RPM}{1000}\right)^{Power\ factor} \quad (13)$$

$$Power = 0.06167\ X\ \left(\frac{2750\ X\ 14.8}{1000}\right)^{2.39}$$

$$\boldsymbol{Power = 428.04}$$

$$T = \left(\frac{3.14}{2}\ (0.125)^2\ X\ 1.225\ \ X\ \ (428.04)^2\right)^{\frac{1}{3}}$$

$$\boldsymbol{T = 17.658 \quad (Nm)}$$

From this we get the thrust force generated by the single motor now to calculate the thrust coefficient we need to get the value of thrust, density, speed of motor and diameter of propeller. By substituting the above values in equation 14 we get the thrust coefficient.

$$T = K_t\, \rho\, n^2\, D^4 \tag{14}$$

$$K_t = \frac{T}{\rho\, n^2\, D^4}$$

$$K_t = \frac{17.658}{1.225\ X \left(\frac{2750}{60}\right)^2 (0.125)^4}$$

$$\boldsymbol{K_t = 28.106}$$

To find efficiency of propeller we need to find power input to power out from propeller. Theses we can get from the equation 15 and 16.

$$Power\ Supplied\ to\ Propeller\ (P_i) = 2\,\pi\, n\, Q \tag{15}$$

$$Useful\ Power\ output\ to\ Propeller\ (P_{out}) = T\,\mu_0 \tag{16}$$

Efficiency of propeller is the ratio of power output to power input and after substituting the value we get the simplified equation of efficiency as 17.

$$\eta_{prop} = \frac{1}{2\,\pi}\frac{K_t}{K_q} J \tag{17}$$

J is also called as the active ratio and can be calculated as below.

$$J = \frac{\mu_0}{D\, n} \tag{18}$$

$$J = \frac{8}{0.125\ X \left(\frac{2750}{60}\right)}$$

$$\boldsymbol{J = 1.396}$$

Substituting the values we the efficiency of propeller as below.

$$\eta_{prop} = \frac{1}{2\,\pi}\frac{28.106}{0.0785}(1.396)$$

$$\eta_{prop} = 79.61\ \%$$

Thrust is nothing but the force exerted by the motor on the ground. So by newton law of motion we know that the force is a product of mass and acceleration. By using this function we could get the total amount of mass that an single motor can lift.

$$F = M\, g \tag{19}$$

$$m = \frac{\left(\frac{\pi}{2} D^2\, \rho\, P^2\right)^{\frac{1}{3}}}{g} \tag{20}$$

$$\boldsymbol{m = 1.8\ Kg}$$

The mass which could be carried by a single motor is 1.8 Kg. Which is a theoretical Value, in practical there will be some environmental condition which will affects the state of motor and also affects its efficiency. Therefore the mass which will lift by the single motor is less than that of the theoretical value as follows.

$$M_{actual} = \eta_{Propeller}\, m \tag{21}$$

$$M_{actual} = 0.7961\ X\ 1.8$$

$$\boldsymbol{M_{actual} = 1.4329 \quad (Kg)}$$

As there will be four propellers and four motors there will be the mass which the four motors could carries is equal to four times the actual mass value. The required weight of total robot is equal to:

$$M_{Total} = 4\ X\ 1.4329$$

$$\boldsymbol{M_{Total} = 5.7316\ \ (Kg)}$$

VII. DISCUSSION:

1. The robot is capable enough to carry an all together a weight of 5.18 Kg
2. Robot is equipped with a light weight high discharge capacity LIPO battery to increase the power to weight ratio.
3. An Omni directional wheels are mounted to drive the robot on ground in Omni direction I. E. In 45, 90, 135, 180, 225, 270, 315, 360 degrees
4. The load carried by a single motor is approximately 1.43 Kg.
5. Features includes: Audio Speakers, Video Transmission, Location Tracker and Altitude Sensing.

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