BANSILAL RAMNATH AGARWAL CHARITABLE TRUST'S
VISHWAKARMA INSTITUTE OF TECHNOLOGY, PUNE
(An Autonomous Institute affiliated to Savitribai Phule Pune University)
Pune – 411037

Department of Mechanical Engineering

Academic Year 2020-2021

Project Synopsis and Proposal for the Award

Military Robot using Rocker Bogie Mechanism

BACHELOR OF TECHNOLOGY
IN
MECHANICAL ENGINEERING

OF

VISHWAKARMA INSTITUTE OF TECHNOLOGY

Savitribai Phule Pune University

BY

Rutwik Rajesh Bonde

Aishwarya Gulabrao Zambare

Darshana Dnyaneshwar Patil

Omkar Kundlik Dinde

Atharva Vijay Bahurupe

UNDER THE GUIDANCE OF
Prof. G.D.Korwar

PROJECT PROPOSAL

ABSTRACT

Rocker Bogie Mechanism is a suspension arrangement used by NASA for their rovers sent to Mars. This mechanism is very flexible, simple, and reliable. The idea is to modify the planetary rovers made by rocker bogie mechanism in such a way, so that they can be used for military purposes as currently they are only used for the exploration of other planets. The terrain vehicle will be having a Rocker Bogie Suspension system with 6 wheels for greater stability which is capable of operating in multi terrain surfaces while keeping all the wheels in contact with the ground surface. The modification approach will be to make the rover into a highly optimized rough terrain vehicle with high capacity and low power requirement. This project focuses on the use of rocker bogie mechanism for military purpose. In this project, we have designed, simulated, analyzed, manufactured a prototype and coded the robot (prototype) for military purpose. We have also given a theoretical algorithm to design the rocker bogie based on the size of the obstacle. We have also provided an algorithm to calculate the torque of the wheels of the robot. Moreover, we explain how to analyze the rocker bogie mechanism with various forces acting upon it. We describe function of various sensors on the robot which is important for surveillance purpose; and a gun for defense purpose. Furthermore, we propose an algorithm (pseudo code) for the locomotion of the robot based on the feedback from the ultrasonic sensors. We also explain the block diagrams for the robot locomotion and robot sensor working. This project gives the complete package of the robot which includes designing, modeling, analyzing, manufacturing, coding, robot locomotion, and robot sensor working.

OBJECTIVE

The objective is to design and fabricate a robot which can replace or assist the soldiers at places such as country border lines and other places where soldiers are needed to be deployed for defense purposes. Also, the objective is to develop a robot that can be used for both surveillance as well as defense purposes. The robot will basically be a rocker bogie mechanism equipped with various sensors, for surveillance; and will have a small gun actuated by a motor, for defense.

SUB OBJECTIVES

- Design and Calculations: Aim is to design a rocker bogie, for real life military applications which includes surveillance as well as defense.
- Modeling and Simulation: Aim is to model and simulate both the above designs in *Solidworks software*.
- Structural Analysis and Material Selection: Aim is to analyze the parts of the models in *Ansys* software and decide the material.
- Manufacturing: Aim is to manufacture a small prototype.
- Simulation and Implementation of Electronics Circuit with Sensors; and Arduino Coding: Aim is to simulate the electronics circuit and sensors in *TinkerCad software*; and implement them on the prototype, using *Arduino UNO*.

INTRODUCTION

The objective is to design and fabricate a robot which can replace or assist the soldiers at places such as country border lines and other places where soldiers are needed to be deployed for defense purposes. The robot is basically a six wheeled rocker bogie mechanism equipped with various sensors, for surveillance; and will have a small gun actuated by a motor, for defense. The robot is totally autonomous except for the gun part, as the gun only needs to be actuated when a command is given to it. The sensor that are mounted on this robot are the ultrasonic sensors for robot locomotion around the obstacles, PIR sensors for motion detection, Gas sensor for detecting harmful gases and smoke, Temperature and Humidity sensor to know the on spot temperature and humidity, Vibration sensor to detect vibration in the nearby area, Soil Moisture sensor to indicate the amount of moisture in soil, and then finally the rain sensor to detect the rain. We have shown these sensors for our robot because these sensors are can really be helpful in every possible way to the soldiers. Finally, to sum up our aim is to use Rocker Bogie mechanism for the military robot and equip it with all the above mentioned sensors and components so that it can assist or replace our soldiers on the deployment area.

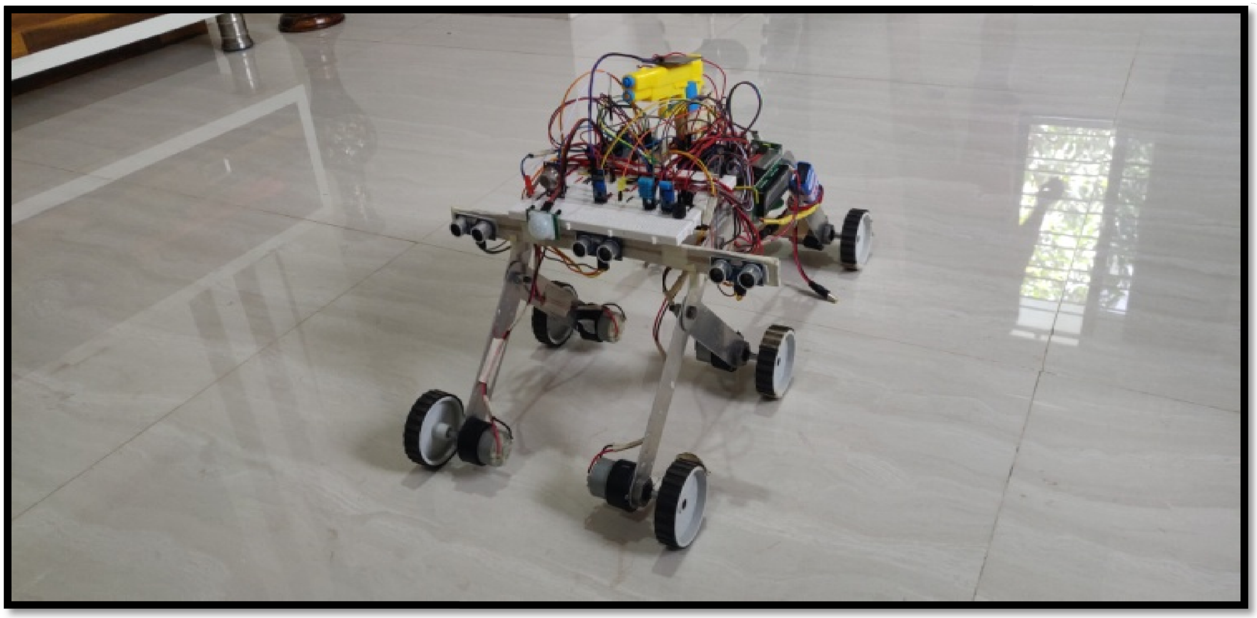


Fig. 1. Military Robot using rocker bogie mechanism

ASSUMPTIONS

Throughout this project we assume that the robot will be partially controlled by a control center which is far away from the deployment area of the robot. But we haven't specifically stated or shown how the communication will take place between the robot and the control center, on the prototype. We also assume that the robot will give all the feedback to the control center; and the control center will then inform their soldiers about the information given by the robot. We haven't installed any communication device on our robot, but as stated above we assume the communication between the robot and the control center. We assume that all the sensors' data is sent and can be seen at the control center. The control center can control the trigger of the gun, present on the robot.

ROCKER BOGIE MECHANISM

The Rocker bogie system is the suspension arrangement. The primary mechanical feature of the Rocker Bogie design is its drive train simplicity, which is accomplished by two rocker arms. Basic Rocker Bogie has six wheels. The term "rocker" describes the rocking aspect of the larger links present on each side of the suspension system and balances the bogie as these rockers are connected to each other. In the system "bogie" refers to the conjoining links that have a drive wheel attached at each end. Besides the pivot point between the rocker and the bogie, we have also given the mechanism, a differential pivot point as shown in the figure (2), which increases the mobility of the robot and makes two sides of the robot (left and right) independent.

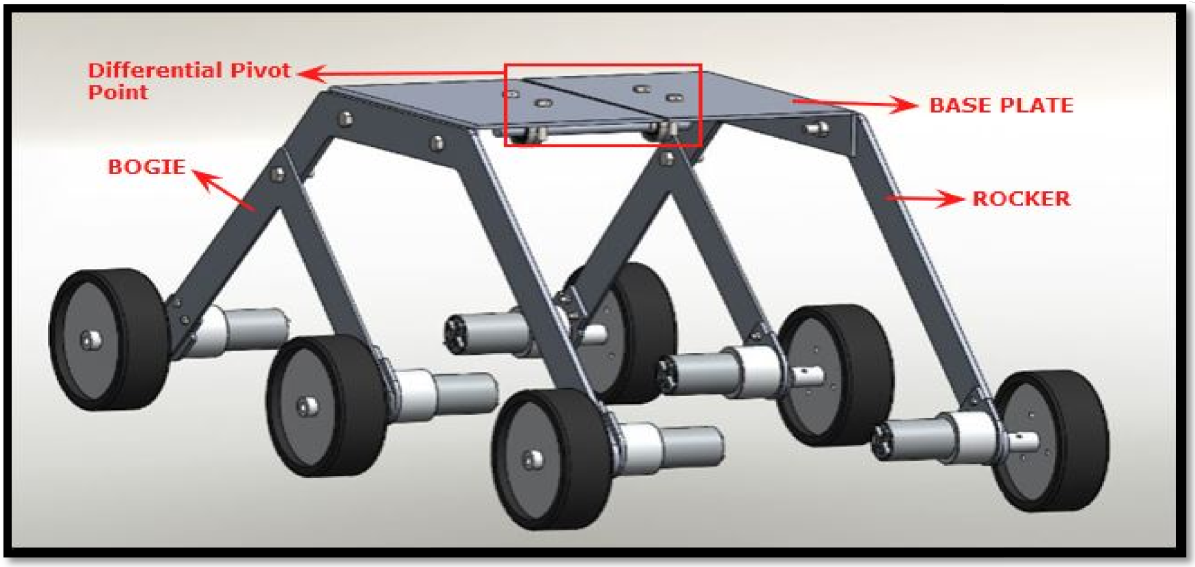


Fig. 2. Rocker bogie structure (Not implemented on the prototype)

Due to covid lockdown we did not get some of the mechanical components like bearings and machined rods, hence we had to shift to other design shown in figure (3). In the implemented design (figure 3) we did not include the differential point.

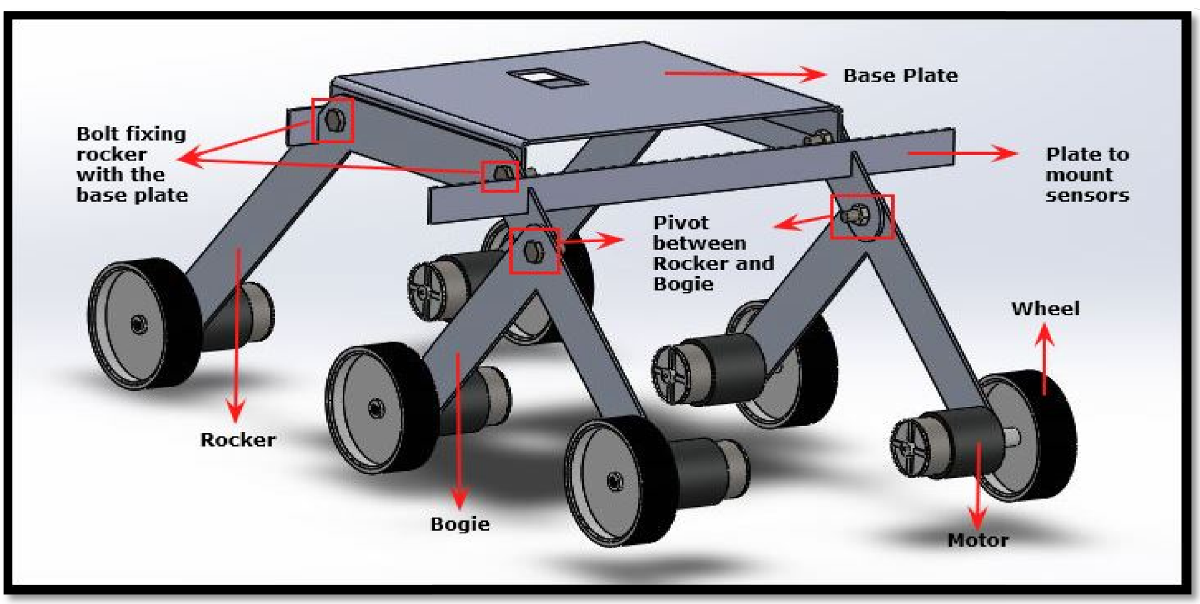


Fig. 3. Rocker bogie structure (Implemented on the prototype)

Why to use Rocker Bogie Mechanism?

The rocker bogie mechanism can climb obstacles twice the size of the wheel diameter. There is an independent movement of rocker on either side of the bogie due to the exact flexibility provided by the differential pivot point. Moreover, the front and back wheels have individual drives for climbing, enabling the rover to traverse obstacle without slipping. The payload is distributed over its six wheels uniformly and each wheel always remains in contact with the ground, which makes it very stable. The design reduces the main body motion by half as the jerk experienced by any of the wheel is transferred to the body as a rotation and not as translation like conventional suspensions. Finally, the design is very simple, flexible, and reliable.

Obstacle climbing ability of Rocker Bogie Mechanism

In the below four figures (4), (5), (6), (7); we can see that how the rocker bogie mechanism overcomes an obstacle double the size of its wheels. The relative motion between the rocker and the bogie is very important, and due to which the robot climbs the obstacle without affecting its own stability.

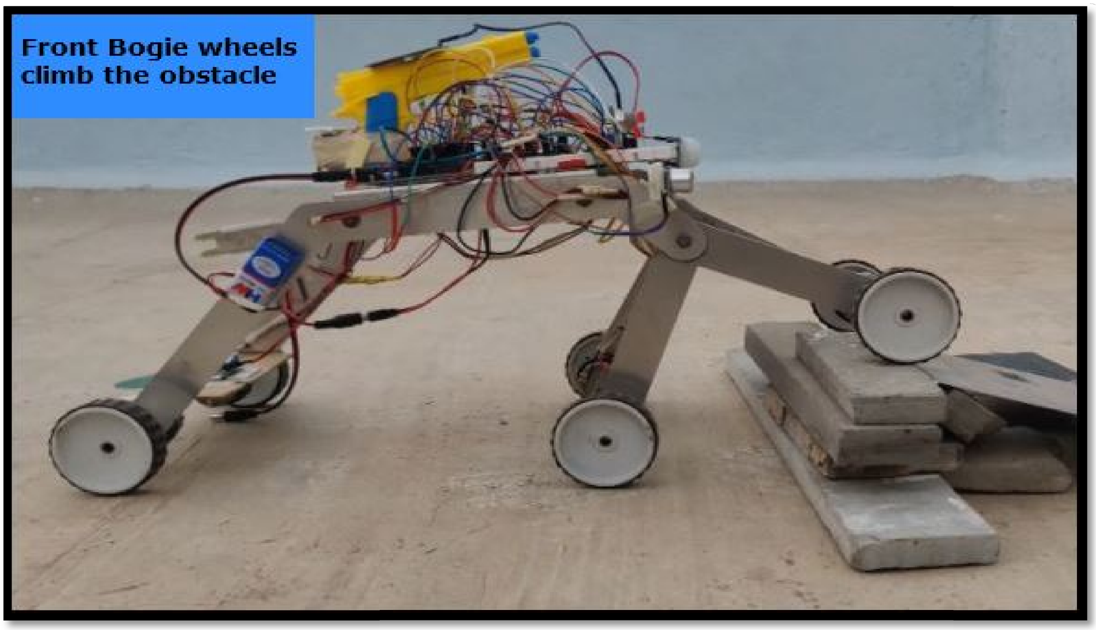


Fig. 4. Front bogie wheels climbed the obstacle

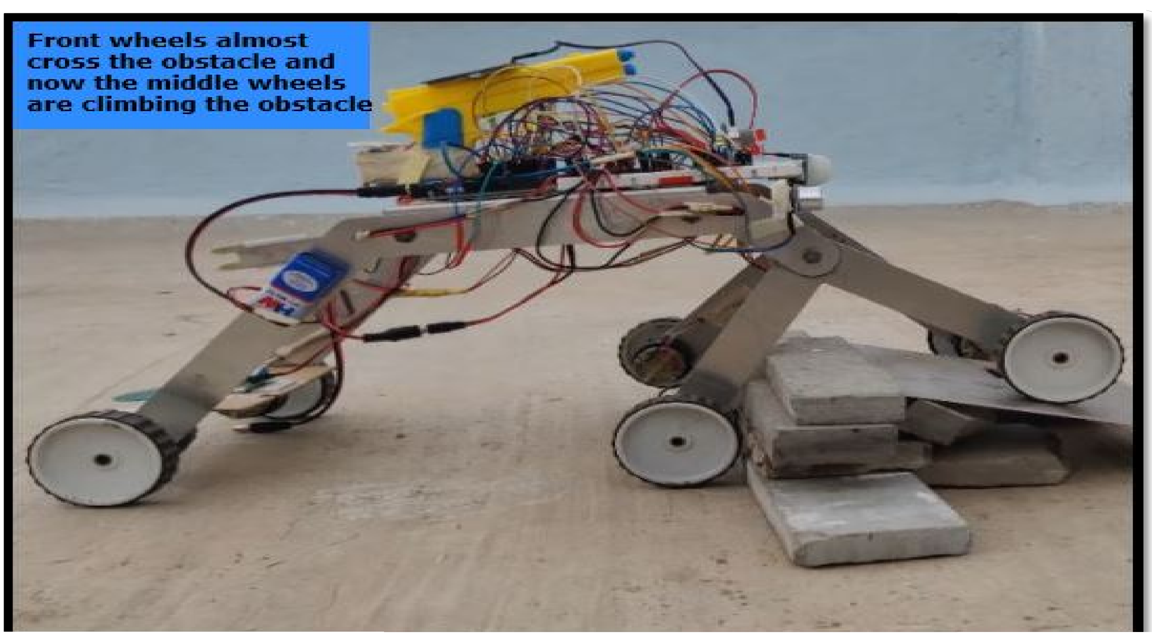


Fig. 5. Middle wheels climbing the obstacle

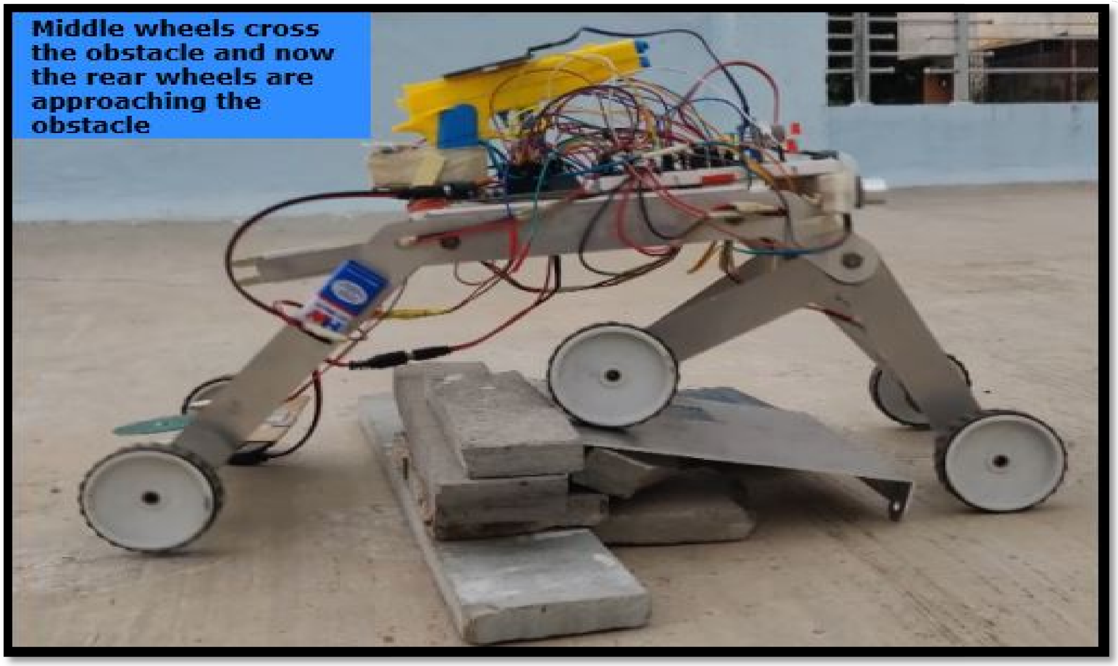


Fig. 6. Middle wheels cross the obstacle and rear wheels approaching it

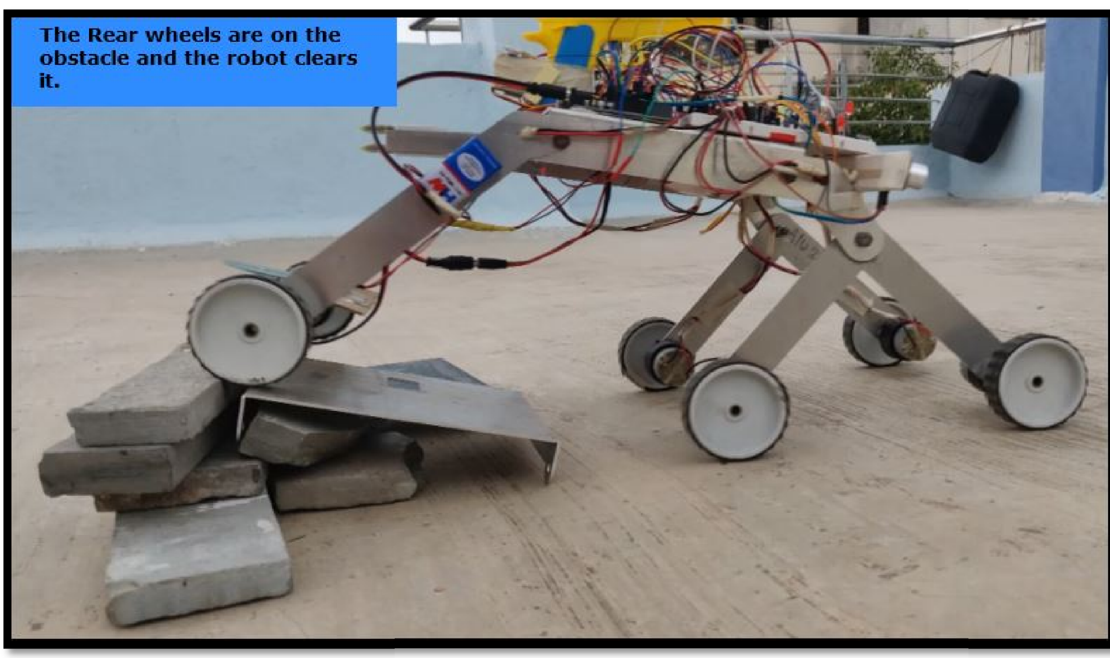


Fig. 7. Rear wheels are on the obstacle and the robot clears it

MODEL OF THE ROBOT

The robot model mainly consists of bogie link, rocker link, a base plate to mount equipment's, wheels for locomotion, and motor to drive wheels. Bogie link and rocker link are connected to each other through provide pivot joint, which acts as suspension and helps to overcome the obstacles. Bearings are mounted on base plates from the bottom side and the rod is inserted through two bearings to provide differential pivot joint between left and right rocker links. The differential pivot joint (figure (8)) gives extra mobility to the mechanism and helps the wheels to stay in contact with the ground. The figure (9) shows all the structure details of the robot. Figure 9 also shows some sensors, microcontroller (Arduino UNO), battery, etc.

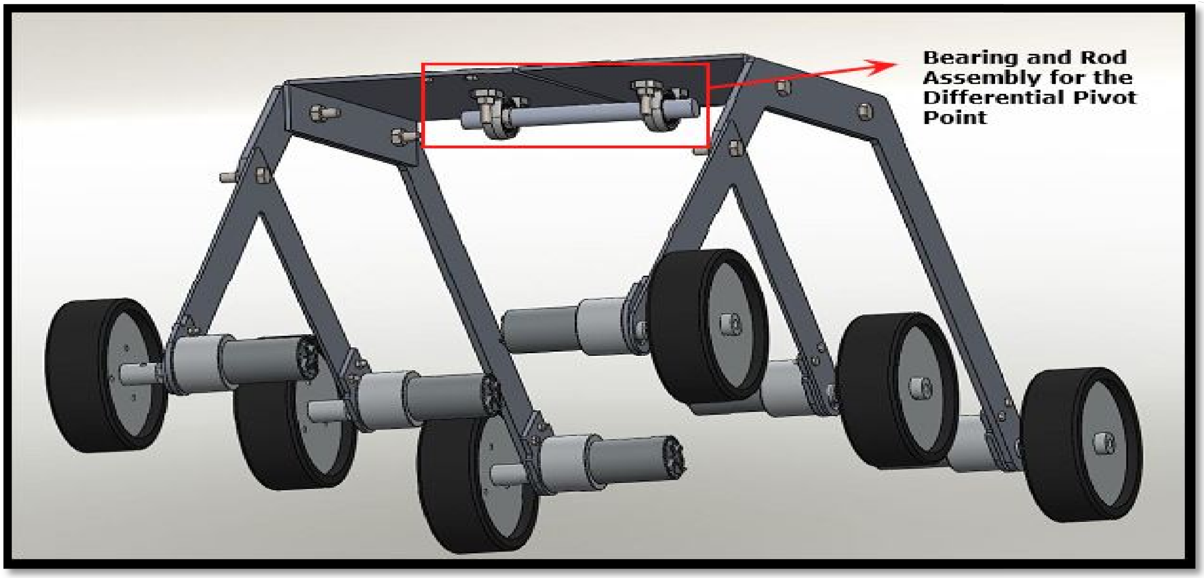


Fig. 8. Differential pivot point

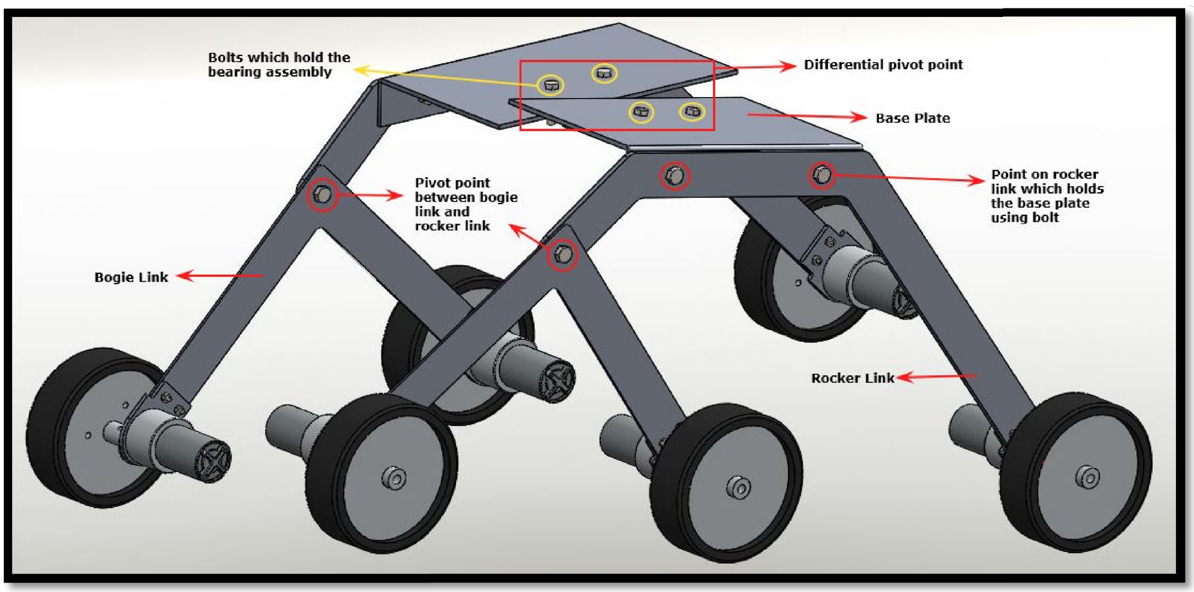


Fig. 9. Details of the rocker bogie structure

Model of the Robot Implemented on the Prototype

As mentioned earlier, due to covid lockdown we could not include differential point in our prototype as we did not get some of the mechanical components like bearings and machined rods, hence we had to shift to other design, as shown in figure 10. The implemented model also shows some electronics components and sensors like Ultrasonic Sensors, PIR Sensors, Gas Sensor, Temperature and Humidity sensor, Arduino UNO, Battery, Breadboard, Motor, etc.

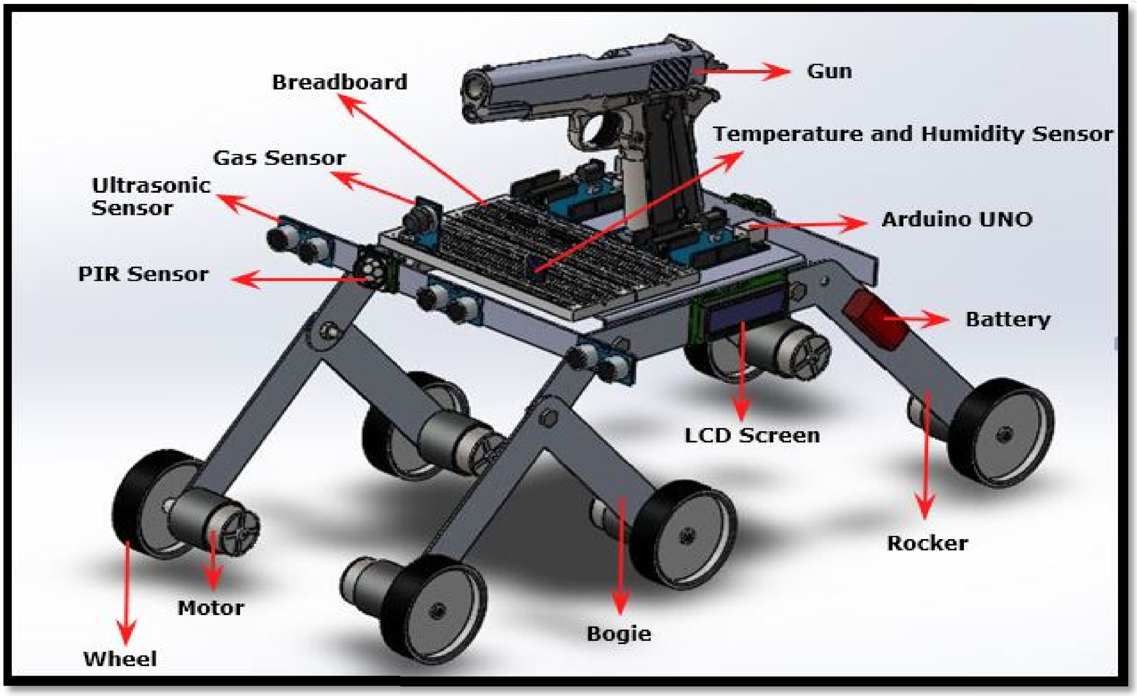


Fig. 10. Complete robot model with some electronics and sensors mounted

DESIGN OF THE ROCKER BOGIE MECHANISM

For designing the Rocker bogie mechanism we provide a theoretical algorithm in which we considered height of the obstacle as input. Refer the figure (11) for the algorithm given below. The Algorithm given below is based on the input height of the obstacle, which means the algorithm starts with the input as the height of the obstacle.

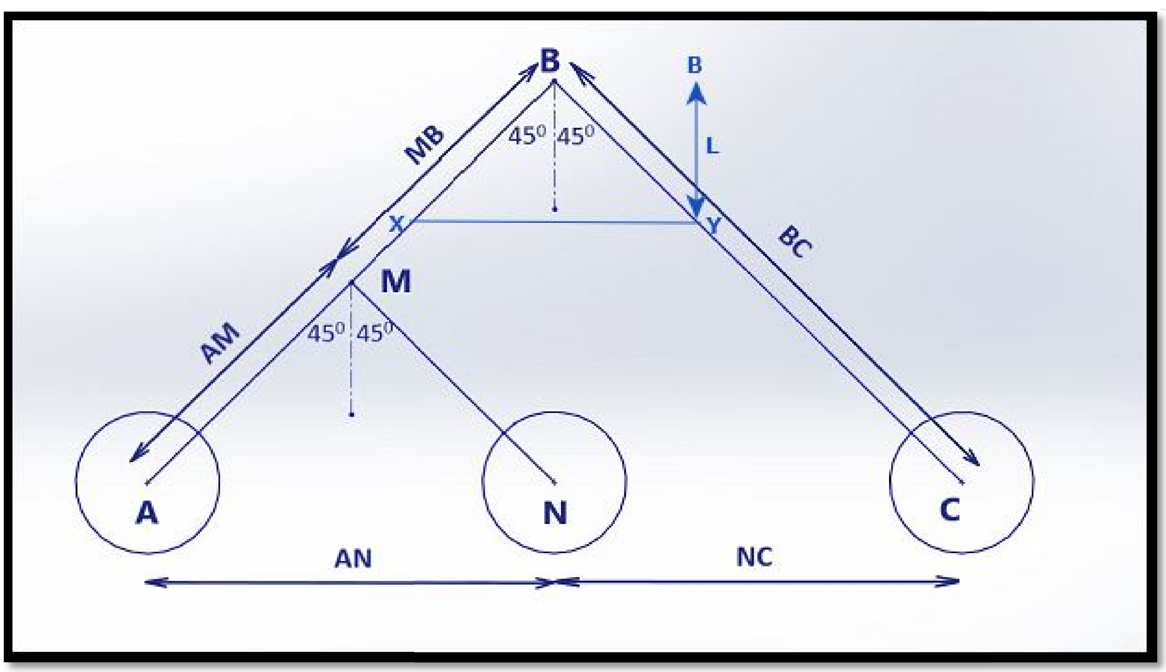


Fig. 11. Dimensional design of rocker bogie

Algorithm for Designing the Rocker Bogie Mechanism

1: Decide a height H of the obstacle, according to the requirements of particular application.
2: Consider height of obstacle as input for bogie length (AM and MN) and the diameter of the wheel, i.e. set the bogie length equal to height of obstacle and the diameter of wheel as half the height of the obstacle.
3: Keep the middle wheel at the midpoint of wheel base to achieve maximum stability, i.e. AN = NC, as shown in the figure.
4: Pivot bogie with rocker at point M such that AM = MB.
5: As all links are perpendicular to each other, using Pythagoras theorem we can find AN, and therefore NC.
6: Now that we have got all the dimensions, we can insert a link XY, as shown in the figure (11), to get a horizontal platform at the top, to mount equipments and circuits. But for that we need to simulate a 2D structure to calculate the distance from upper point B to the link XY. For that, take a block of the height H, place the bogie wheels on the block and bring the rocker wheel in contact with the block as shown in the figure (12); and then decide the dimension of L, keeping in mind that there should be some clearance C between the middle wheel and the link XY; some gap between the obstacle and the rocker link as shown in the figure (12).

The figure (13) shows sample dimensions of the robot for the obstacle with the height of 200mm.
The table below shows the sample calculation for obstacle height 150 mm, 200 mm, and 300 mm. (Dimensions in mm)

Obstacle Height (mm)	**Radius of wheel (Rw)**	**Bogie Length (AM)**	**Rocker Length (BC)**	**Wheel base (AC)**	**Total height (BN)**	**L (B to XY)**
150	**37.5**	**150**	**300**	**424.3**	**250**	**60**
200	**50**	**200**	**400**	**565.6**	**332**	**90**
300	**75**	**300**	**600**	**848.5**	**500**	**130**

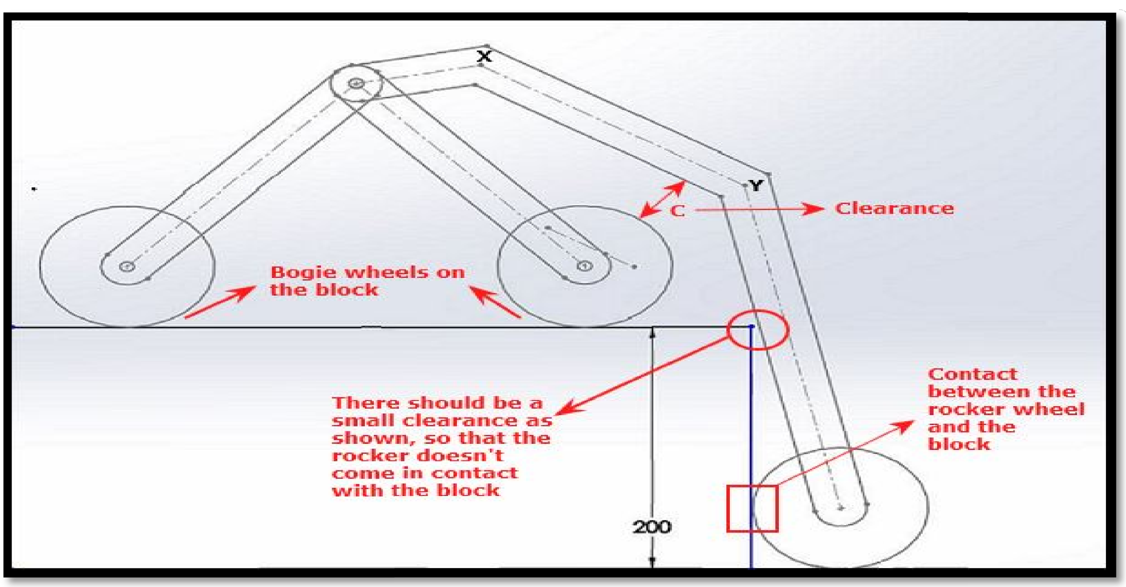


Fig. 12. Bogie Wheels on the obstacle and rocker wheel on the ground

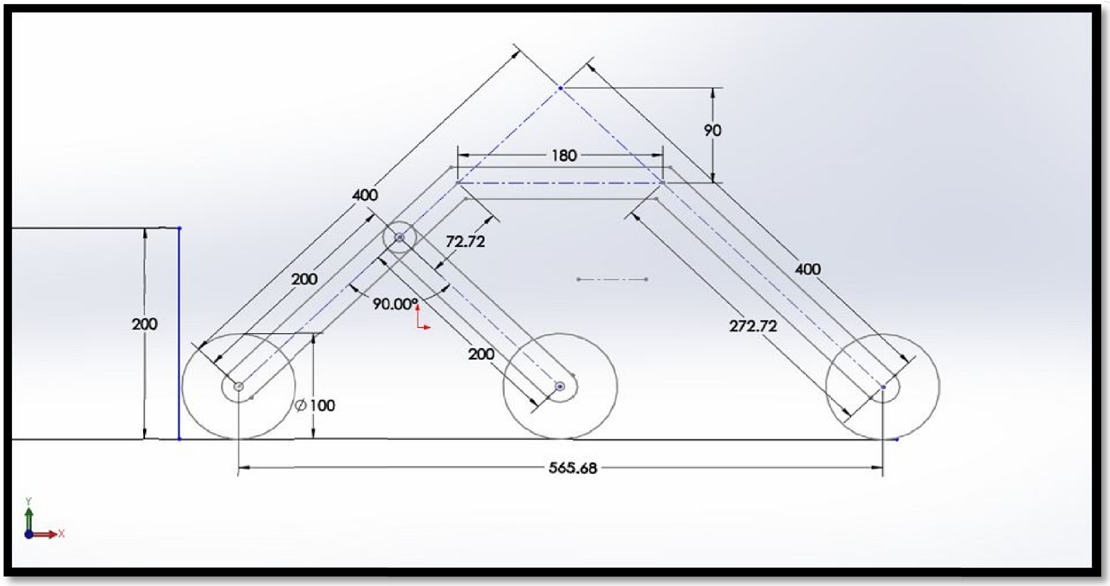


Fig. 13. Sample design dimensions, to overcome 200mm obstacle

Torque Calculations for Rocker Bogie Mechanism

Before actually calculating the Torque required by each motor on each wheel, let's understand some technical terms.

Rolling Resistance (RR) – It is the force necessary to propel a vehicle over a particular surface.

Grade Resistance (GR) – It is the amount of force necessary to move a vehicle up a slope or grade.

Acceleration Force (FA) – It is the force necessary to accelerate from a stop to maximum speed in a desired time.

Total Tractive Force (TTF) – It is the net horizontal force applied by the drive wheels to the ground. If the design has two drive wheels, the force applied per drive wheel (for straight travel) is half of the calculated TTE.

Resistance Factor (RF) – The resistance factor accounts for the frictional losses between the caster wheels and their axles and the drag on the motor bearings. Typical values range between 1.1 and 1.15 (or 10 to 15%).

Algorithm: Pseudo Code for Torque Calculations for motor on each wheel of Rocker Bogie Mechanism

```
GVW ← Gross Vehicle Weight
Nw← Number of wheels
Rw← Radius of each wheel
α← Max. gradient of slope
Vmax← Max. linear velocity
Tw ← Wheel Torque
Crr← Surface friction co-eff.
RR ← GVW x Crr
GR ← GVW x Sinα
FA ← (GVW x Vmax)/9.8 x 1s
TTF← RR + GR + FA
TFw ← RR + GR + FA/Nw
Tw ←TFw x Rw x RF
Print("The wheel torque is:", Tw)
```

Analysis of the Rocker Bogie Structure

1) Bogie

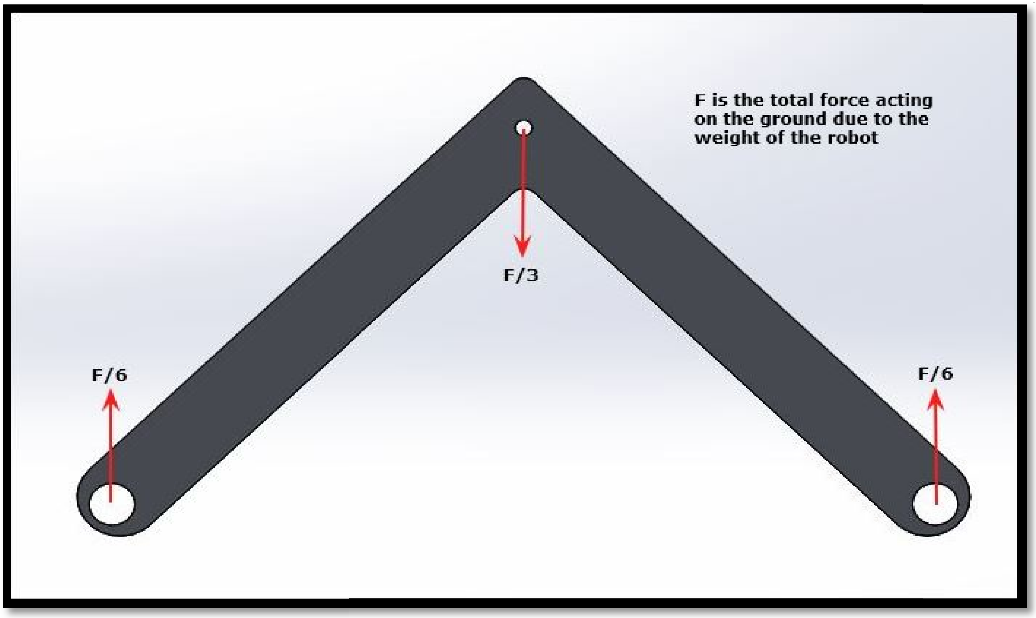


Fig. 14. Forces acting on the bogie

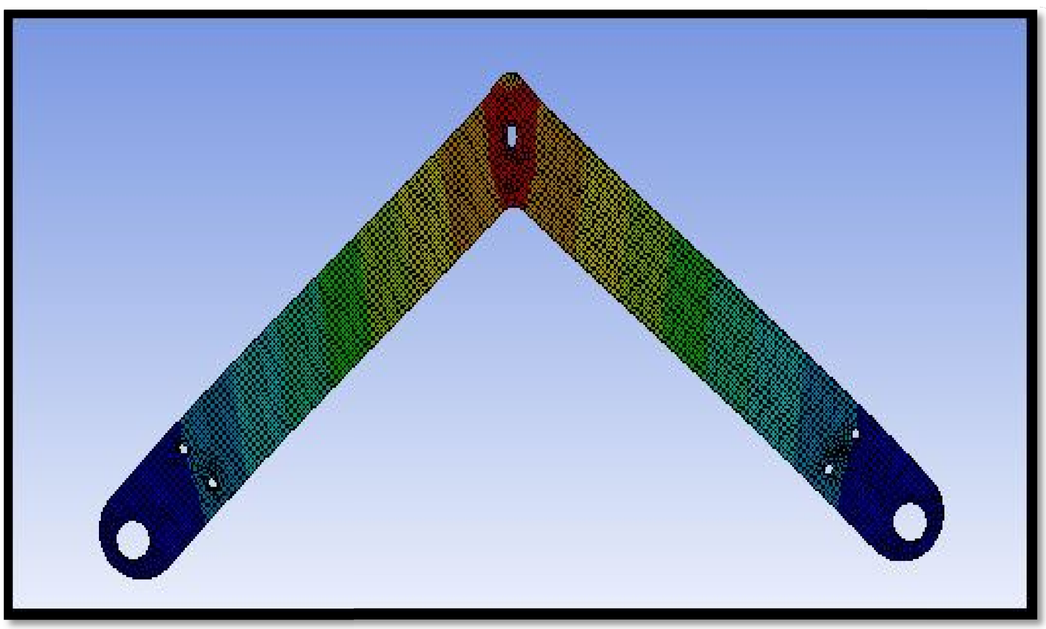


Fig. 15. Deformation in the bogie link (Red = Max; Dark Blue = Min)

The total force acting on the ground is F (force exerted by robot's total weight on the ground) as a reaction to which, the ground exerts a force on the wheels. This force F gets distributed on six wheels as F/6. Therefore at each wheels the ground exerts a reaction force of F/6 as shown in figure (14). The top point in the figure, where the rocker is pivoted to the bogie, the force of F/3 acts in downward direction. The bogie is the most stable part of the mechanism as the forces balance each other. In the figure (15), we can see the bogie analysis in which the red zone is the maximum deformation zone and the dark blue zone is minimum deformation zone.

2) Rocker

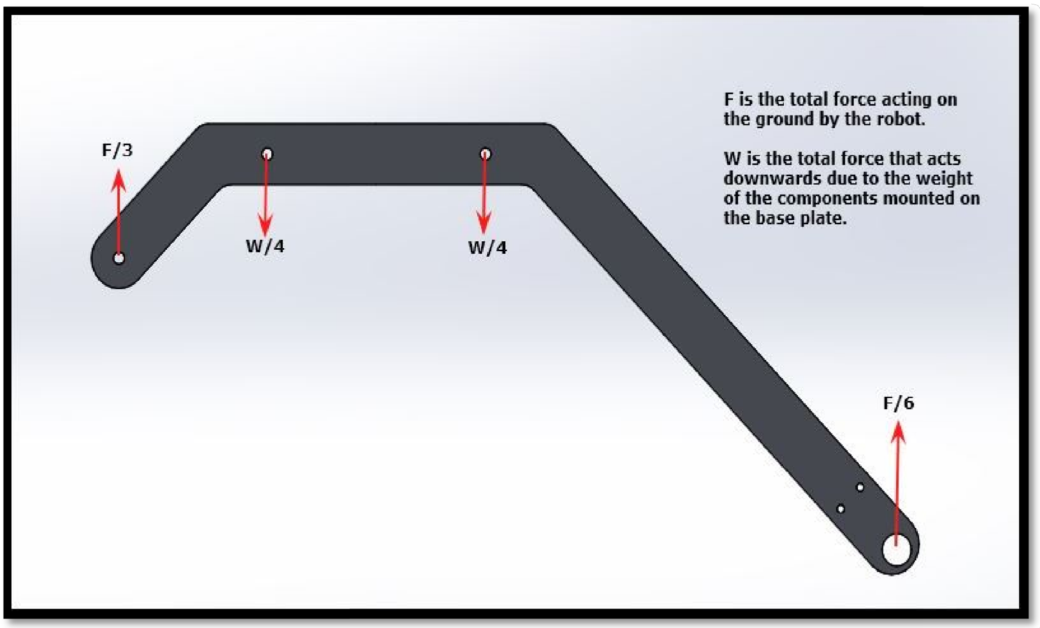


Fig. 16. Forces acting on the rocker link

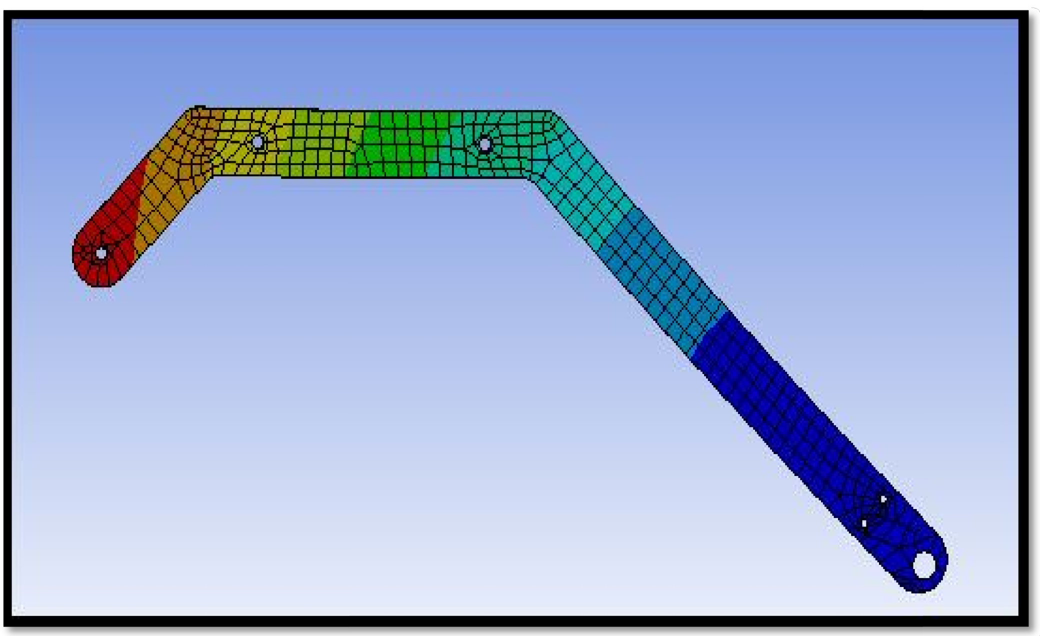


Fig. 17. Deformation in the rocker link (Red = Max; Dark Blue = Min)

F/3 reaction force acts on the rocker's first hole, as shown in figure (16). F/6 force acts as a reaction force from the ground on the rocker wheel. W/4 force acts on two holes on the rocker, where the base plate is attached. W is the total force that acts downwards due to the weight of the components mounted on the base plate. The force W gets divided on four holes as W/4, two holes on each rocker. In the figure (17), we can see the rocker analysis in which the red zone is the maximum deformation zone and the dark blue zone is the minimum deformation zone.

3) Base Plate (Only designed not implemented)

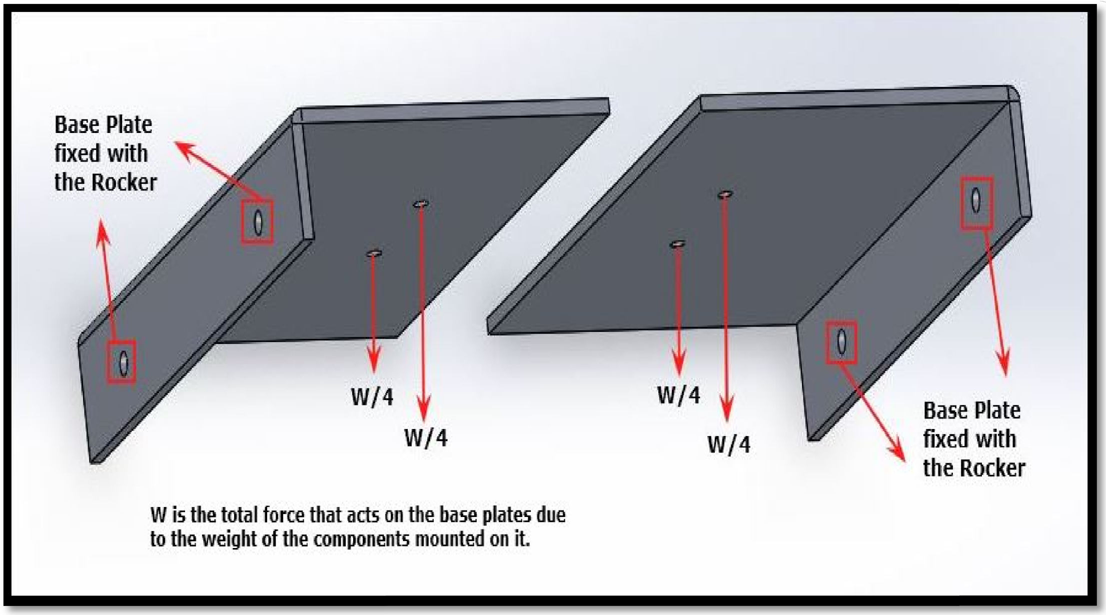


Fig. 18. Forces acting on the Base plates

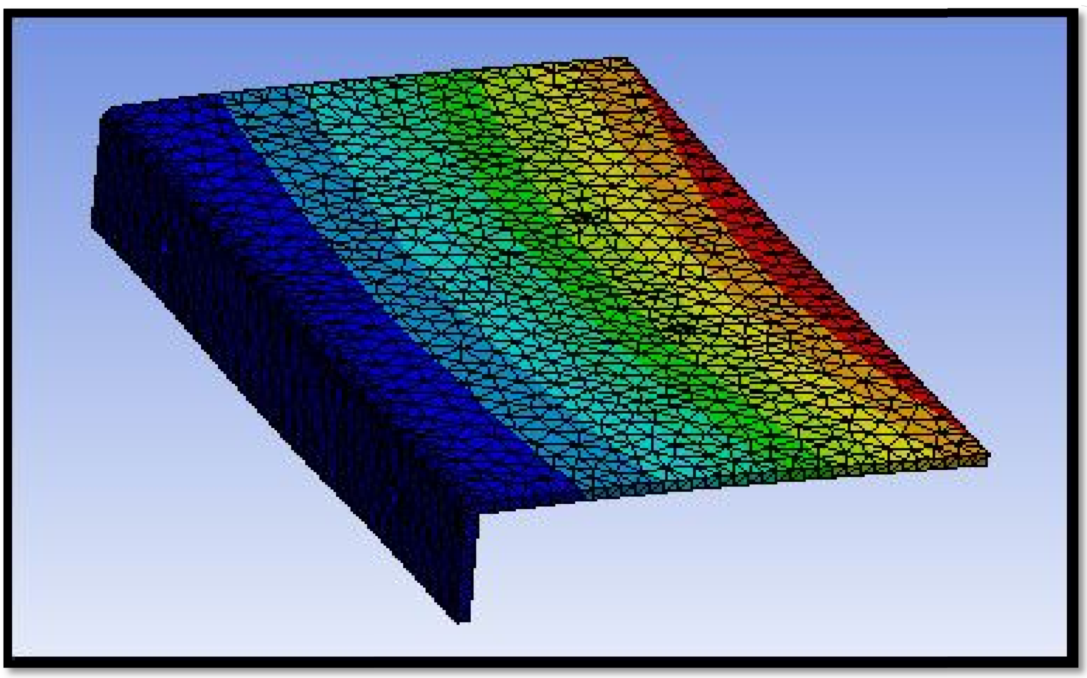


Fig. 19. Deformation in the base plate (Red = Max; Dark Blue = Min)

In the figure (18), at the center of the base plates, on the holes, W/4 force acts downwards. Those are the holes on which the bearing and rod assembly is mounted. The base plate is fixed with the rocker with the holes on the side as shown in figure (18), on the base plate. In the figure (19), we can see the base plate analysis in which the red zone is the maximum deformation zone and the dark blue zone is the minimum deformation zone.

4) Base Plate (Designed and implemented)

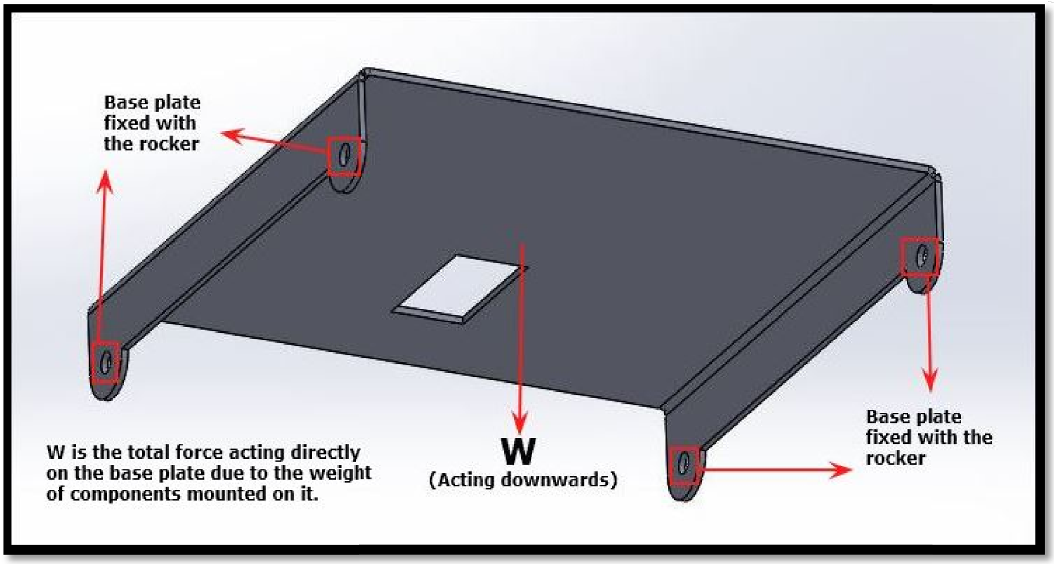


Fig. 20. Forces acting on the base plate

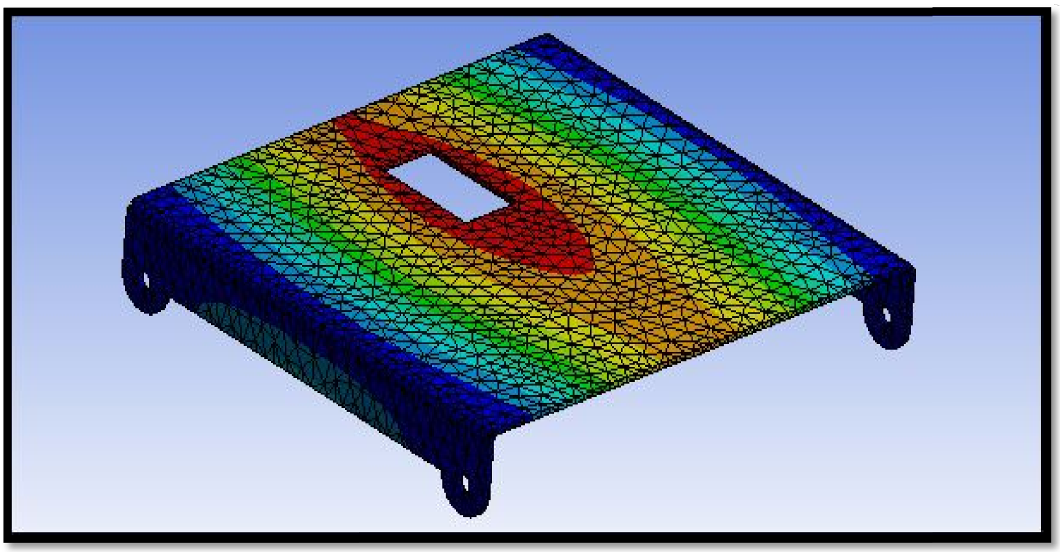


Fig. 21. Deformation in the base plate (Red = Max; Dark Blue = Min)

In the figure (20), at the center of the base plate, W force acts downwards. In the figure (21), we can see the base plate analysis in which the red zone is the maximum deformation zone and the dark blue zone is the minimum deformation zone.

The Table below shows the results of analysis done in Ansys. The analysis was done considering the total force of 45N (F) acting on the ground by the robot, out of which 27N (W) is directly acting on the base plate. The force was decided considering weight of all the components including sensors, battery, gun, etc. So accordingly we did the analysis with the force distribution shown above. We set a limit for maximum deformation; we decide that we will choose that thickness, whose deformation is less than 0.5mm. We also looked for uniformity in the material. So according to the results, we decided to use base plate of 3mm AL, Rocker link 4mm AL, and Bogie link 2 mm AL.

	Material	Thickness (mm)	Max Deformation (mm)	Max Equivalent (MPa)	Min Equivalent (MPa)
Base Plate	AL	2	0.78245	25.81300	0.00801
	AL	3	0.23448	12.66800	0.00293
	AL	4	0.10016	7.39260	0.00032
	MS	1	2.18050	104.430	0.01364
Rocker Link	AL	2	0.87157	12.12700	0.01439
	AL	3	0.58102	8.08230	0.00967
	AL	4	0.43575	6.05930	0.00730
	MS	1	0.61829	24.2520	0.02945
Bogie Link	AL	2	0.00076	1.70000	0.00165
	AL	3	0.00050	1.37570	0.00041
	AL	4	0.00037	1.02340	0.00029
	MS	1	0.00053	4.1547	0.00129

Manufacturing

We only needed to manufacture three parts, the bogie using laser cutting; the rocker using laser cutting; and the base plate using laser cutting and bending. We assembled the robot structure using nuts and bolts. The wheels were attached to the motor shaft through a small bolt in holes already present on both wheels and shafts. Motor used had special thread and nut arrangement, which made the assembly even easier.

Sensor implemented on the Robot

Assumption: It is assumed that the robot is controlled from a control center, situated far away from the deployment area and the sensor data is also received at the control center.

A. Ultrasonic Sensor

Ultrasonic sensors measure distance by using ultrasonic waves. The sensor head emits an ultrasonic wave and receives the wave reflected back from the target. Ultrasonic sensors measure the distance to the target by measuring the time between the emission and reception.

The Ultrasonic sensor in the robot will control the complete locomotion. The three ultrasonic sensors on the robot will detect obstacle in-front of it; and based on the feedback of the obstacles from the sensor, the locomotion will be controlled. For example, if the left ultrasonic sensor detects the obstacle the robot will take a right turn and when right ultrasonic sensor detects the obstacle the robot will take a left turn; whereas if the middle ultrasonic sensor detects the obstacle the robot will move back.

Ultrasonic Sensor

B. PIR Sensor

Passive Infrared sensor can detect animal/human movement in a requirement range. PIR is made of a pyroelectric sensor, which is able to detect different levels of infrared radiation. The detector itself does not emit any energy but passively receives it. It detects infrared radiation from the environment. Once there is infrared radiation from the human body particle with temperature, focusing on the optical system causes the Pyroelectric device to generate a sudden electrical signal.

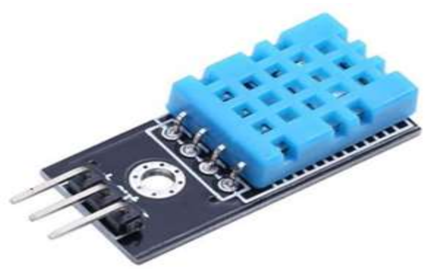
The PIR sensor can be useful to the robot we it stationary and not moving like at nights. So when the robot detects any movement in its proximity, it will sense the movement and give a feedback to the control center.

PIR SENSOR

C. Temperature Sensor

A temperature sensor is a device, typically, a thermocouple or resistance temperature detector, that provides temperature measurement in a readable form through an electrical signal.

The temperature on the robot will give the exact and current temperature and humidity of the location of the robot.

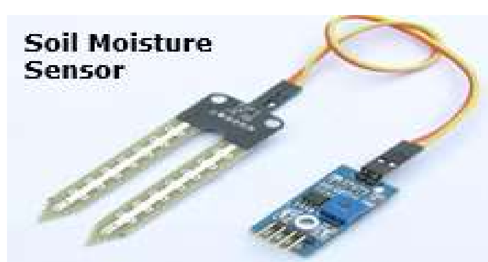


Temperature and Humidity Sensor

D. Soil Moisture Sensor

The Soil Moisture Sensor is used to measure the water content of soil. This makes it ideal for performing experiments in courses such as soil science, agricultural science, environmental science, horticulture, botany, and biology.

The use of soil moisture sensor in the robot is that it can give the feedback of whether the soil is wet, dry, semi-wet, etc. This feedback is very useful, it can be used by the control center to inform their soldiers to choose the correct path which is suitable for them to walk on or run on.



E. Rain Detector Sensor

A rain sensor or rain switch is a switching device activated by rainfall. There are two main applications for rain sensors. The first is a water conservation device connected to an automatic irrigation system that causes the system to shut down in the event of rainfall. The second is a device used to protect the interior of an automobile from rain and to support the automatic mode of the windscreen wipers.

The rain sensor on the robot will give the feedback of the amount of rain falling in that particular area. This feedback can be used by the control center to inform their soldiers about the rainfall.

Rain Sensor Module

F. Motion Detection Sensor

A metal detector is an instrument that detects the presence of metal nearby. Metal detectors are useful for finding metal inclusions hidden within objects, or metal objects buried underground.

The metal detection sensor on the robot will give the feedback of any metal, weapons, explosives, etc; present underground. This feedback can be used by the control sensor to inform their soldiers about the weapons, explosive, and other harmful things in a particular area. So with this information soldiers can save their lives and may also deactivate the weapons or explosives.

Metal Detector

G. Gas Sensor

Gas sensors (also known as gas detectors) are electronic devices that detect and identify different types of gases. They are commonly used to detect toxic or explosive gasses and measure gas concentration. Gas sensors are employed in factories and manufacturing facilities to identify gas leaks, and to detect smoke and carbon monoxide in homes.

The gas sensor on the robot is very useful because it can detect harmful gases and smoke in the nearby area, which can be used to alert the soldiers about the possible danger of these harmful traps; so that they can take possible action on spot.

Gas Sensor

H. Vibration Sensor

The vibration sensor, which is useful for a variety of different fields, has the ability to detect vibrations in a given area. This can help to alert someone to trouble with a system, and you will even find these types of sensors in use with security systems today. They have quite a few different uses.The vibration sensor on the robot can give useful feedback to the control center regarding the possible vibrations in that particular area due an earthquake or even the hard marching of the enemies. The control center can inform their soldiers regarding the possible position of their enemies or even of an earthquake; using this information.

GUN ON THE ROBOT FOR DEFENSE

The gun on the robot is used for the defense purpose. We assume that the gun will only be actuated on the command given from the control center. Whenever the control center things that there is something wrong or bad happening only at that time the control center will actuated this gun. Basically the gun is actuated by a servo motor attached to it at the back. The servo horn is attached to the trigger of the gun using any mechanical arrangement like a string. So when the servo horn moves the string also moves with it in the opposite direction of the trigger, pulling it.

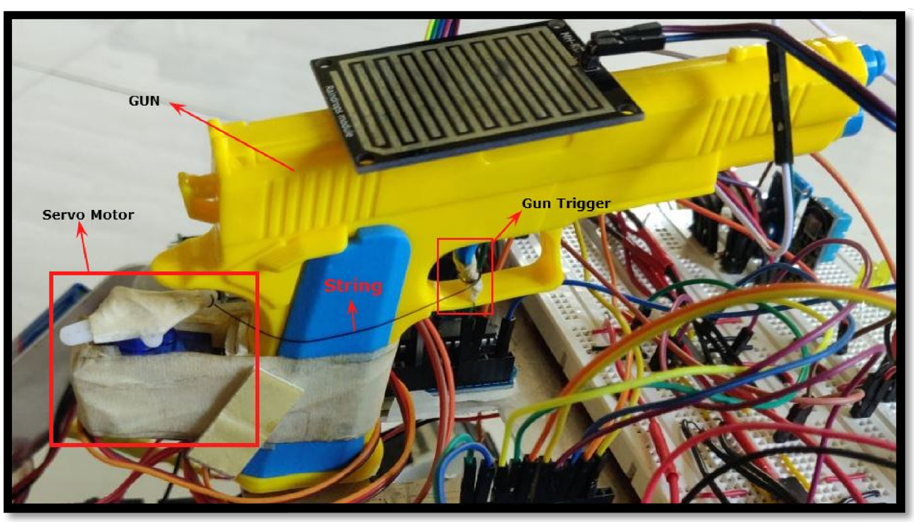


Fig. 22. Gun trigger attached to the servo motor horn using a string

In reality with actual gun, when the bullet is fired, there is a reaction force that acts in opposite direction of the bullet. Although we implemented a simple plastic gun on the prototype without thinking anything about the reaction force, we also designed (but did not implement) an arrangement for real gun. To prevent the reaction force of the gun to directly affect the robot structure, we made a gun holding assembly on a slider as shown in figure 23. Further, after the reaction, to bring the gun back to its original position we implemented an extension spring. The spring also keeps the gun in position when the robot is on an inclined plane.

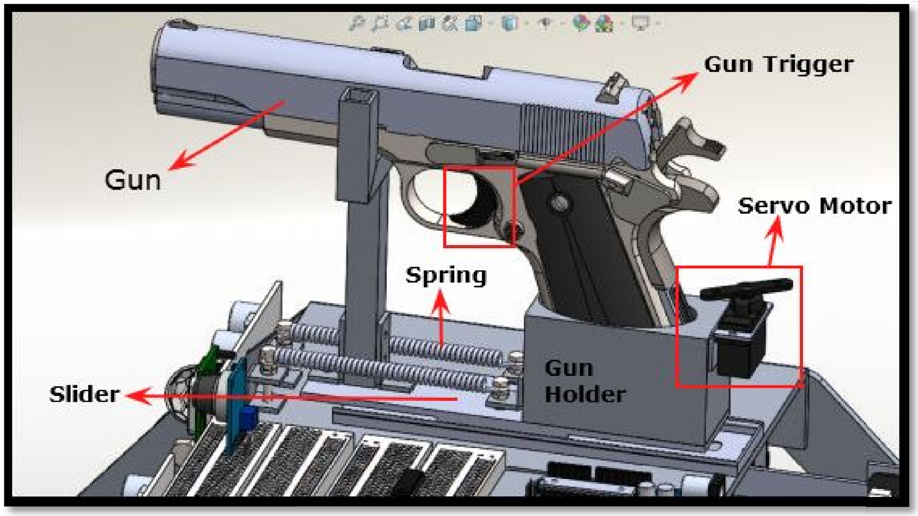


Fig. 23. Gun assembly mounted on the slider, and the spring position

For experimentation purpose (did not implement) we considered the following gun:
Pistol auto 9mm 1A: The Pistol Auto 9mm 1A also known as IOF 9mm pistol is a semi-automatic pistol uses 9×19mm Parabellum ammunition.

Height	150	mm
effective range	50	m
length	205	mm
With magazine empty	0.935	Kg
With magazine loaded	1.075	Kg
bullets	13	

When gun actuates, the gun experiences reaction force which pushes gun in backward direction. To stabilize the position in field operations, we decided to use springs and slider for mounting gun, as shown in figure (23), so that it will regain its original position.

To calculate this force first we have to calculate reaction force on gun by using momentum equation.
Initial momentum = Final Momentum
Final momentum is Bullet momentum – Gun momentum, which will be equal to zero, because initially assembly is at rest. By using momentum equation we can find the recoil velocity of gun, which is the velocity at which gun will move in backwards direction. Velocity of bullet is mentioned in data book.
Reaction Force = Change in momentum / (time required to fire 1 bullet)

Here, for this gun we considered 2 bullets can be fired per second. So 0.5 sec required for one bullet.

Bullet Velocity	396	m/sec
Bullet weight	0.01076923077	Kg

Recoil Velocity	3.967084079	m/sec
no of bullets fired per second	2	
Force	8.529230769	N

The Bullet offers around 8.5 N force which is smaller than gun assembly weight which is 2 Kg i.e. 19 N. So gun will not move in backward direction in standard case i.e. on horizontal surfaces. But on inclined surfaces there can be slight movement in gun assembly, if weight component of gun and reaction force acts in same direction. In this case, springs can be helpful in regaining positions.

Tension Helical springs is used for this application, with material SAE-AISI 6150 (G61500) Chromium-Vanadium Steel whose modulus of rigidity 73000 MPa and permissible shear stress 513 MPa.

By referring Machine Design book by V.B.Bhandari, we followed all standard design steps for spring calculations, and got the values required for Designing.

Gun Weight W	2	Kg
Modulus of rigidity, G	73000	N/mm2
Ultimate Tensile Strength	900	N/mm2
Spring Index, C	6	
Deflection of Spring, δa	10	mm
Permissible Shear Stress, τ	513	N/mm2

Load on each spring, P	(W*gSinx+ Fb)/2	12	N
Wahl factor, K	k = (C+ 0.5) / (C- 0.75)	1.238095238	
Wire diameter, d (mm)		1	mm
Mean coil diameter, D	D=C*d	6	mm
No. of active coils, N	N = G d4 / (8 R D3)	35	
Total no. of coils, Nt	Nt = N	35	
Actual deflection, δ	δ =(8 P D3 N)/(G d4)	9.941917808	mm
Free length (mm)	L0 = 2 Di + n (d +1)	80	mm
Pitch, p	L0/(N-1)	2.352941176	mm
Spring constant, R	R = G d4 / (8 N D3)	2.836137554	N/mm

This spring can handle up to 40 N forces which is much higher than our real life application force.

ROBOT LOCOMOTION

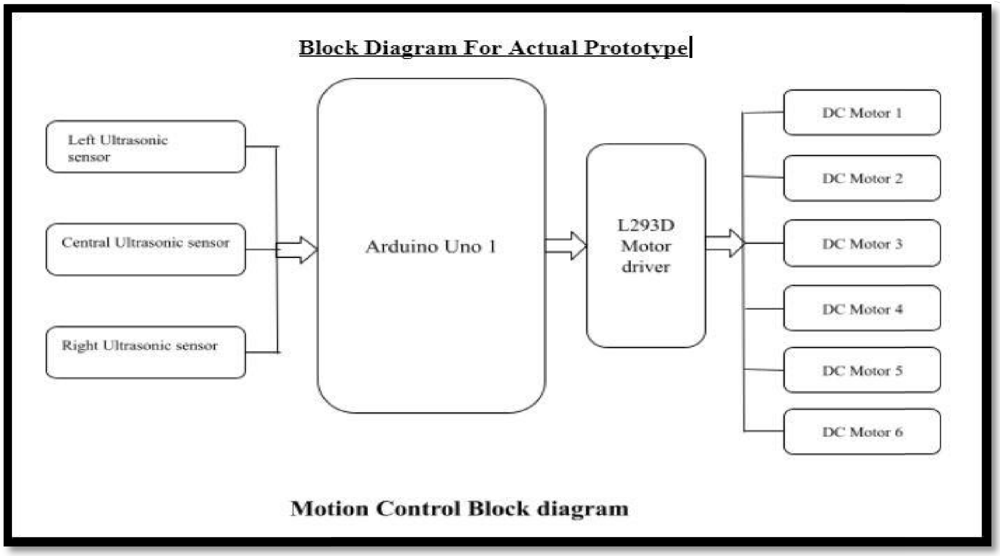


Fig. 24. Robot locomotion control block diagram

The figure (24) represents the block diagram for robot locomotion control. Locomotion of robot is based on the feedback given by the three ultrasonic sensors mounted at front of robot, at left, center and right side. These three sensors collect data and helps in actuation of six motors with six wheels. All the feedback that comes from the sensors goes through microcontroller (Arduino) and then with the help of motor driver (L293D), the required current is given to the respective motors. All six motors are connected to single motor driver, three left side motors to one channel and other three right side motors to the second channel.

The feedback control works as follows:

- When the left ultrasonic sensor detects an obstacle, the robot takes a right turn.
- When the right ultrasonic sensor detects an obstacle, the robot takes a left turn.
- When the central ultrasonic sensor detects an obstacle, the robot moves backward.
- When the left and central ultrasonic sensor detects an obstacle simultaneously, the robot takes a right turn.
- When the right and central ultrasonic sensor detects an obstacle simultaneously, the robot takes a left turn.
- When all the three; left, central, and right ultrasonic sensors detect an obstacle simultaneously, the robot moves backwards.

Algorithm for Robot Locomotion

Algorithm: Pseudo Code for Robot Locomotion

```
int trig1, trig2, trig3;
int echo1, echo2, echo3;
function ULTRASONIC (trig, echo)
            trig(LOW);
            delay(2);   // delay in microseconds
            trig(HIGH);
            delay(2);  // delay in microseconds
            trig(LOW);
            delay(2);  // delay in microseconds
time = pulseIn (echo, HIGH);
           distance = (time*0.034/2);
```

```
return distance
function end
function MOTORS_PWM (LF, LB, RF, LB)
        Left_Side_Motors_Forward(LF);
        Left_Side_Motors_Backward(LB);
        Right_Side_Motors_Forward(RF);
        Right_Side_Motors_Backward(LB);
function end
Ultra-one ← ULTRASONIC (trig1,echo1);
Ultra-two ← ULTRASONIC (trig2,echo2);
Ultra-three ←ULTRASONIC (trig3, echo3);
if ((Ultra-one <= 100) && (Ultra-two <= 100) && (Ultra-three <= 100)) // 100cm
{
MOTORS_PWM (0, 255, 0, 255);
print("GO BACK");
}
else if ((Ultra-one <= 100) && (Ultra-two <= 100))
{
 MOTORS_PWM (255, 0, 100, 0);
print("RIGHT TURN");
}
else if ((Ultra-two <= 100) && (Ultra-three <= 100))
{
MOTORS_PWM (100, 0, 255, 0);
print("LEFT TURN");
}
else if (Ultra-one <= 100)
{
 MOTORS_PWM (255, 0, 100, 0);
print("RIGHT TURN");
}
else if (Ultra-two <= 100)
{
MOTORS_PWM (0, 255, 0, 255)
print("GO BACK");
}
else if (Ultra-three <= 100)
{
MOTORS_PWM (100, 0, 255, 0);
print("GO BACK");
}
else
{
MOTORS_PWM (255, 0, 255, 0);
print("GO BACK");
}
```

The figure (25) shows how the circuit with microcontroller looks like. Actually, the circuit shows us how the motors are connected to the motor driver L293D. The circuit also shows the placement of all the three ultrasonic sensors; left, central, and right, etc.

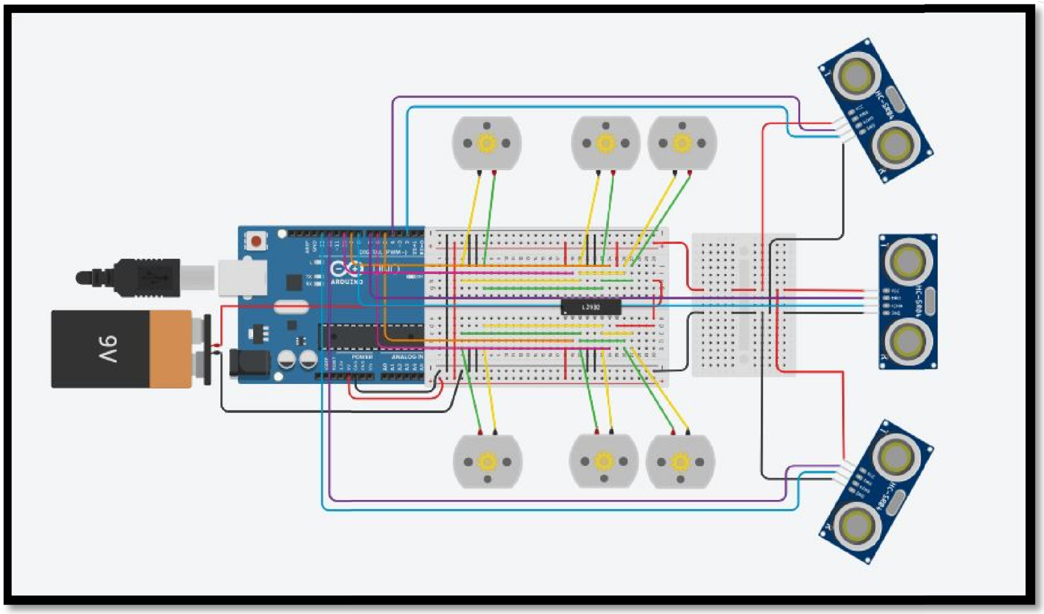


Fig. 25. Circuit of the motor control using feedback from ultrasonic sensors (TinkerCad Circuit)

ROBOT SENSOR WORKING BLOCK DIAGRAM

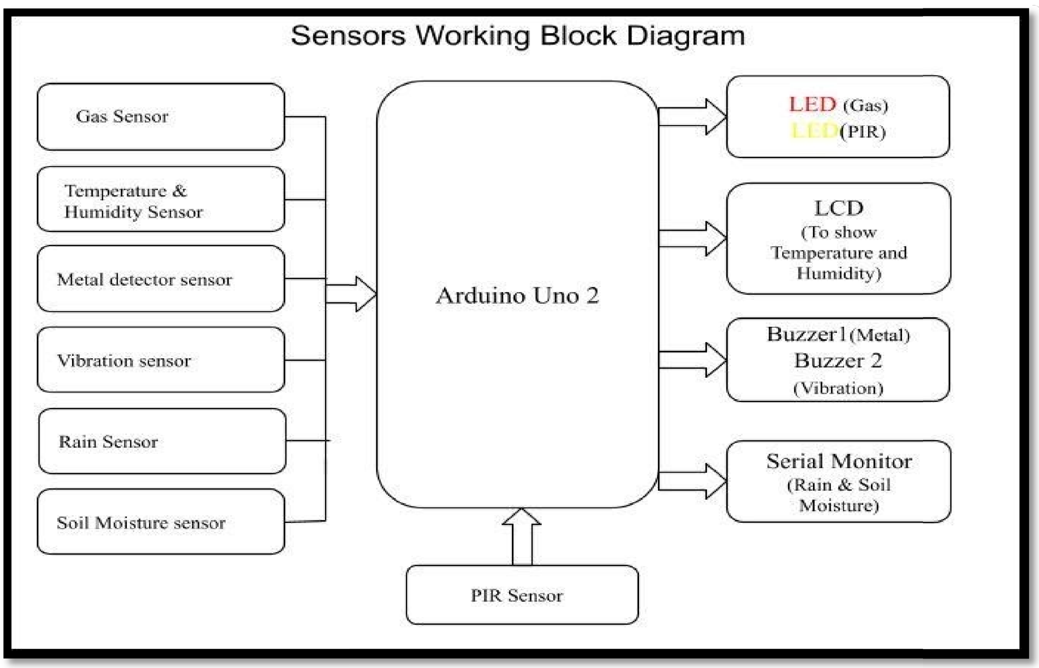


Fig. 26. Sensors working block diagram

As stated earlier, we assume that there is a control center, far away from the deployment area, to which the robot provides the data. We also assume that, all the outputs shown on the right side in figure (26) (LED, LCD, Buzzer, Serial Monitor, etc), are not only present on the robot but are also present at the control center i.e. if a red LED glows on the robot, then at the same time the red LED at the control center will also glow.

The block diagram, in figure (26), helps us understand the working of the sensors on the robot. In the robot, to predict the real surrounding, we implement different sensors for different purpose. Gas sensor is used to detect harmful gases in the area; so if there are any such gases in the nearby area, then the red LED will glow on the robot as well as at the control center. To detect the human or animal activity around the robot 2 PIR sensors are placed in the front and at the back on the robot. When any such presence of human or animal activity is detected the yellow LED, on the robot and at the control center, starts blinking. This will be helpful for soldiers, because this data will allow soldiers to decide their routes. Temperature and Humidity sensor detect the on spot temperature and humidity, and its values are shown on a LCD screen. Metal detector sensor helps in finding metallic objects like guns, bombs, weapons, etc.; which will be helpful for the soldiers to know the position of hidden weapons. Vibration sensor shows its output through a buzzer. Rain sensor helps in determining rain activity and helps robot to switch off all circuit operations or cover the circuits to avoid any problems or short circuits. Soil moisture sensor measures the moisture content in the soil and informs the control center through a serial monitor. The figure (27) shows some sensors with their outputs, motor drivers and the microcontrollers (Arduino UNO).

COMPONENTS ON THE ROBOT:

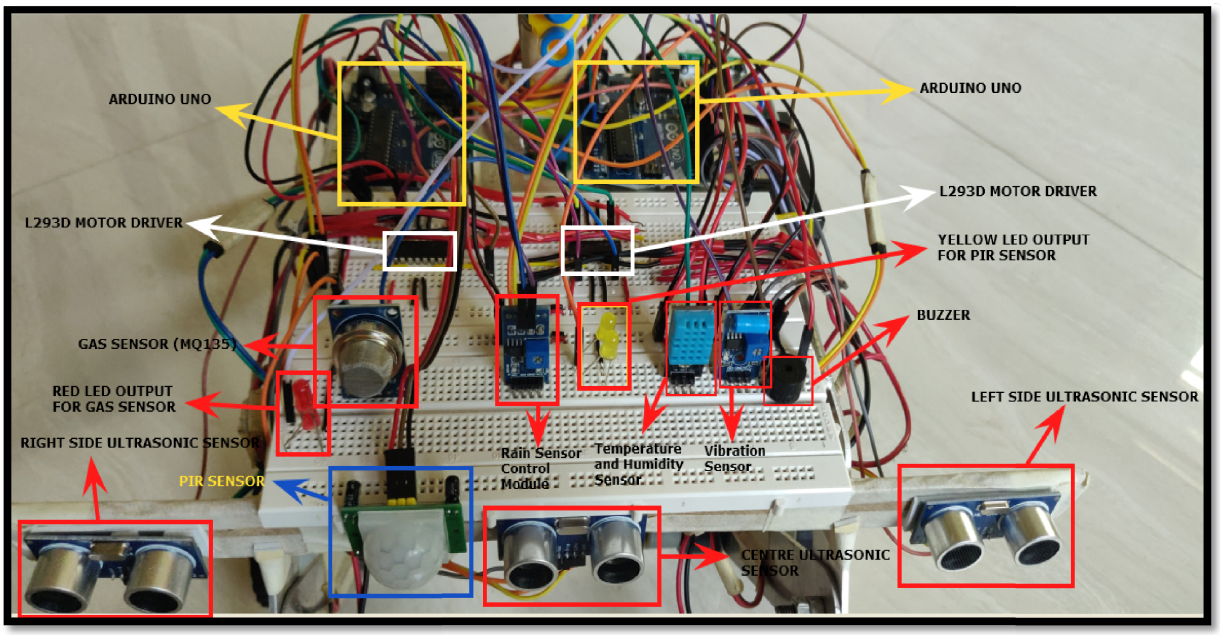


Fig. 27. Components on the Robot

Components in Figure 27:

- Right, Center, Left Ultrasonic Sensors (Locomotion Control)
- Passive Infrared Sensor (PIR Sensor)
- Red LED (Output for Gas Sensor)
- Gas Sensor
- Rain Sensor Control Module
- Yellow LED (Output for PIR Sensor)
- Temperature and Humidity Sensor
- Vibration Sensor
- Buzzer
- 2 L293D (One for robot locomotion motors, and other for movement of soil moisture sensor)
- 2 Arduino UNO (One for complete robot locomotion and other for all sensor working)
- Breadboards and jumper wires

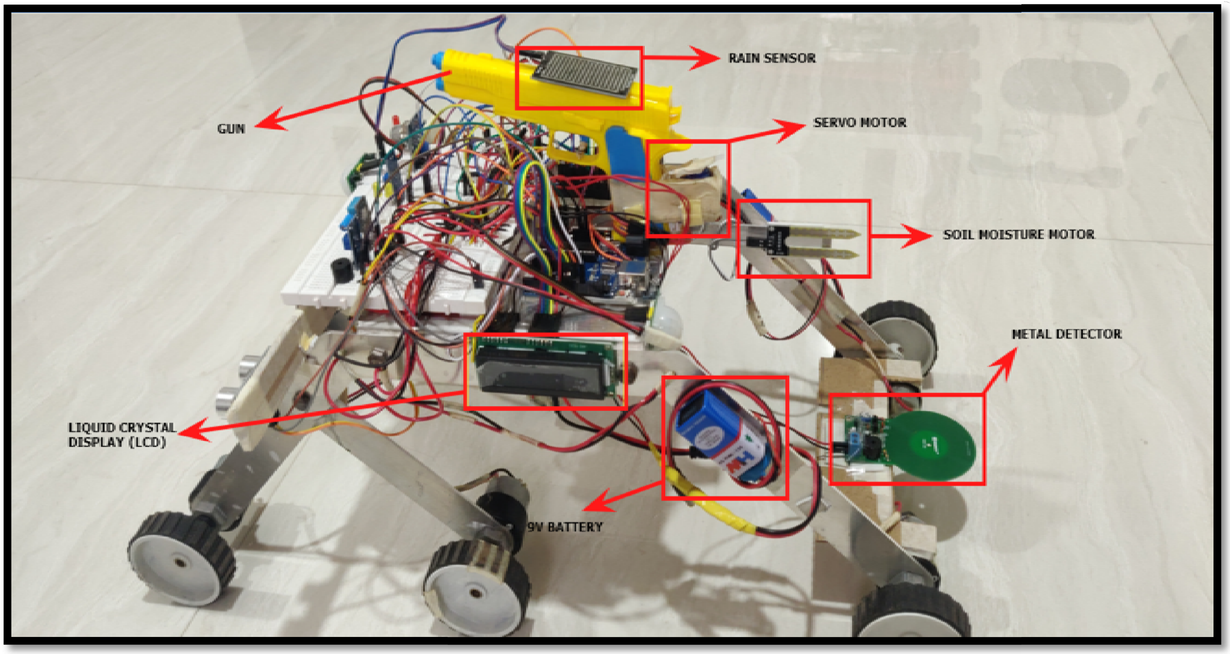


Fig. 28. Components on the Robot

Components in Figure 28:

- Plastic Gun
- Rain Sensor
- Servo motor (to actuate the trigger)
- Soil Moisture Sensor
- Metal Detector
- 9v Battery (to give external power to Arduino Uno)
- Liquid Crystal Display (LCD) (to display temperature and humidity)

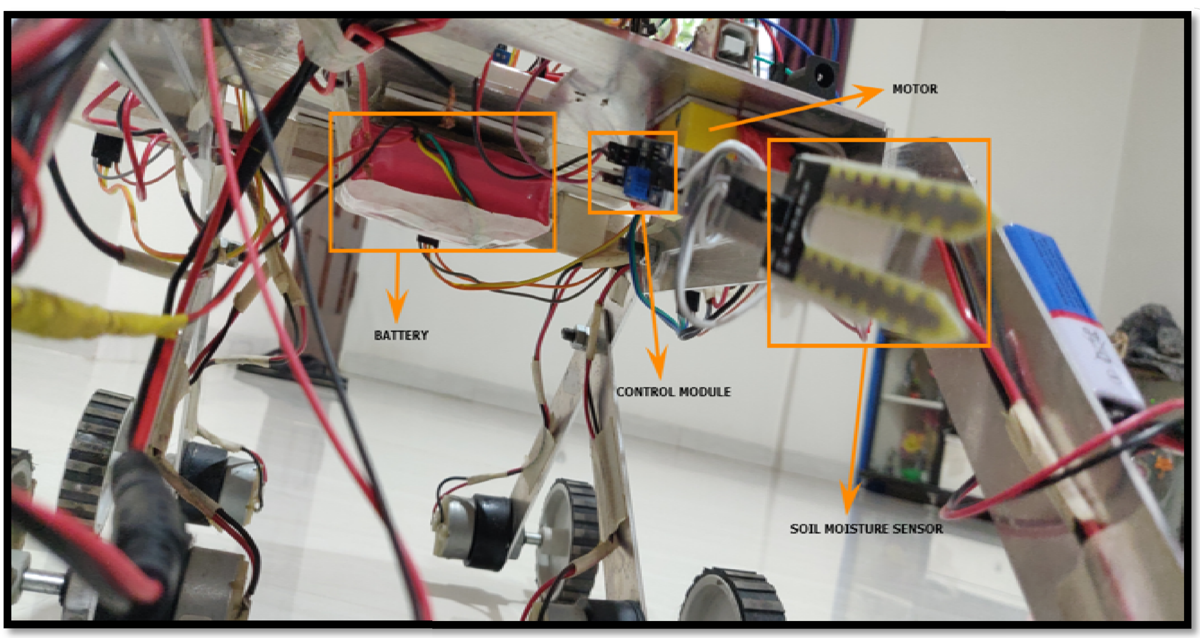


Fig. 29. Components on the Robot

Components in figure 29:

- Battery to power the Motor Drivers
- Control Module for soil moisture sensor
- Soil Moisture Sensor

CONCLUSION

- We propose a robot which can perform tasks of surveillance as well as defense.
- We use rocker bogie mechanism for the military robot due to its flexible, simple and reliable design.
- We give a theoretical algorithm for the designing of the rocker bogie mechanism based on the obstacle height.
- We also provide an algorithm (pseudo code) for the calculation of motor torques.
- We propose an algorithm for the locomotion of the robot based on the feedback from the ultrasonic sensors and avoiding obstacles in the path.
- We use and explain the function of various sensors like ultrasonic sensor, PIR sensor, Vibration sensor, Temperature and Humidity sensor, Soil Moisture sensor, Rain sensor, Metal Detection sensor, and Gas sensor; for surveillance purpose and a gun actuated by a servo motor for defense purpose.

VIDEOS OF THE ROBOT:

We request you to please go through all the videos given below, we have uploaded the robot videos on the YouTube:

1) https://youtu.be/2ESD7JcYutI
2) https://youtu.be/LqSaApODrN8
3) https://youtu.be/F07tPX4c9do
4) https://youtu.be/pN0s_VPVQO8
5) https://youtu.be/s1wOZ7--Rig
6) https://youtu.be/CmPwAD8L_d4
7) https://youtu.be/RqnsHBB9SFA
8) https://youtu.be/cFYl3zm0GSk
9) https://youtu.be/6xZhIy8C-1A
10) https://youtu.be/BN15Y-_ak4