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

Major Project Report

Military Robot using Rocker Bogie Mechanism

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY
IN
MECHANICAL ENGINEERING

OF

VISHWAKARMA INSTITUTE OF TECHNOLOGY

Savitribai Phule Pune University

BY

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UNDER THE GUIDANCE OF
Prof. G.D.Korwar

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C E R T I F I C A T E

This is to certify that the Major Project titled **Military Robot using Rocker bogie mechanism** submitted by **Rutwik Bonde (GR. No. 1710207), Aishwarya Zambare (GR. No. 1710315) Darshana Patil (GR. No. 1710234) Omkar Dinde (GR. No. 1710555) Atharva Bahurupe (GR. No. 182165) is** in partial fulfillment for the award of Degree of Bachelor of Technology in Mechanical Engineering of Vishwakarma Institute of Technology, Savitribai Phule Pune University. This project report is a record of bonafied work carried out by him under my guidance during the academic year 2020-21.

Guide **Head**

[Prof. G.D.Korwar] **[Prof. Dr. Mangesh Chaudhari]**

Department of Mechanical Engineering, Vishwakarma Institute of Technology, Pune

Sign of External Examiner **Date: 19/06/2021**

ACKNOWLEDGEMENT

It gives us immense pleasure and satisfaction in presenting this report on "**Military Robot using Rocker bogie mechanism**". This report work has opened up new vistas of knowledge for us. We can now justifiably claim that this experience will stand us in good stead in the years to come. There are a large number of people without whose help this Unique learning experience would be a nonstarter.

We wish to express our deep sense of gratitude to our Internal Guide, **Prof. G.D.Korwar**, for his valuable guidance and useful suggestions, which helped us in completing this report work, in time. Without his co-operation, it would have been extremely difficult for us to complete this report work.

Words are inadequate in offering our thanks to **Prof. Dr. Mangesh Chaudhari**, Head of the Department, Mechanical Engineering, who has been a source of inspiration and for his timely guidance in the conduct of this report.

We are grateful to other staff members of the Department for giving important suggestions. We also like to thank Director **Dr. Jalnekar** for giving us an opportunity to make our work a success.

Needless to mention, we thank the management of the department for their encouragement and cooperation in carrying out the report work.

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ABSTRACT

The main aim of the project is to design a small terrain vehicle which is easy to handle. Also it can be used as a surveillance robot to alert people in areas with security threats like national borders, where it is difficult for humans to work. 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. One of our main aims is to develop this vehicle at a very economical cost so that these vehicles can be widely used in the military through which we will be able to save the valuable lives of our soldiers and protect our nation from the enemies. Hence we can say that the project will act as an initiative to the advancement in the defense system of our country.

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Department of Mechanical Engineering

Project Synopsis

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Academic Year : 2020-2021

Project Title : Military Robot Using Rocker Bogie Mechanism

Project Area : Robotics

Internal Guide : Prof. G. D. Korwar

Name of the External Guide:
Contact No:

Signature of Internal Guide

1. INTRODUCTION

A lot of the innovation in military robot development is taking place in the non-governing administrations; this has been the case since war vehicle development models were first conceptualized. Military and security establishments need robot frameworks as they can take on jobs that are excessively risky for individuals to do, and that are also too tedious or keep on for individuals to do. Robot frameworks likewise, hold the capacity to review organizations, territories, and for reconnaissance purposes. Here is the place robot frameworks could give a lot of administrations in serving the exact picture. It is conceivable to have swarms of robots that work together with their own particular sensors to have a much more precise locale.
Mobile robotics plays an undeniably significant job in military issues, from patrol to managing potential explosives. With appropriate sensors and cameras to perform distinctive missions robotics helps address difficulties presented by the phantom of urban fear based oppression. "Rather than having individuals draw near to dangers, for example, unattended items or vehicle bombs, robots are utilized. In the event that an administrator finishes up a risky item that may detonate, the robot could kill that article by shooting to explode it. These equivalent portable automated frameworks are utilized for killing or detonating overlooked weapons and mines after clashes stop.

1.1 PROBLEM STATEMENT

To design and fabricate a robot using a rocker bogie mechanism for surveillance and defense purposes.

1.2 OBJECTIVES

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 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.

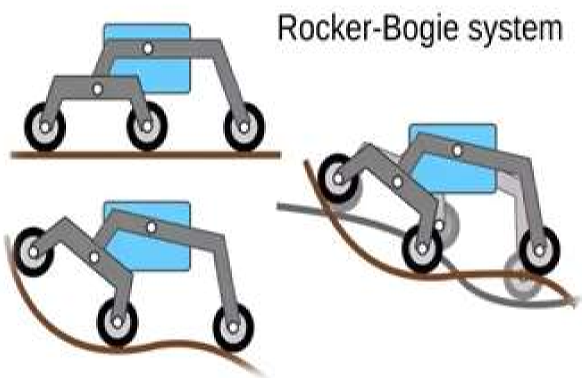
- Design and Calculations: Aim is to design two rocker bogies, one for real life applications and other for the small prototype.
- Modeling and Simulation: Aim is to model and simulate both the above designs in *Solidworks*.
- Structural Analysis and Material Selection: Aim is to analyze the parts of the models in *Ansys*.
- 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*; and implement them on the prototype, using *Arduino UNO*.

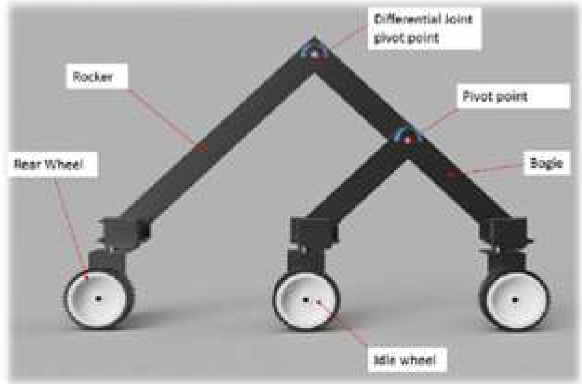
1.3 LITERATURE REVIEW

The rocker-bogie system is the suspension arrangement developed in 1988 for use in NASA's Mars rover Sojourner, and which has since become NASA's favored design for rovers. It has been used in the 2003 Mars Exploration Rover mission robots Spirit and Opportunity, on the 2012 Mars Science Laboratory (MSL) mission's rover Curiosity, and the Mars 2020 rover Perseverance. Not only in space-exploration but there also has been research on the use of rocker bogie mechanisms in disaster relief **[5]**. For Example, the flood carries the debris, soil and trees along their path damaging the road, and making them uneven. In this situation it becomes very tough to bring the aid during the post-disaster management. So in such cases rocker bogie vehicles can be used to transverse on uneven surfaces and at the same time be able to maneuver smoothly on a water surface. People have also been working on the design and fabrication of the Rocker Bogie Mechanism for stair climbing **[1], [2];** and survey **[4]**. Some research also explained the use of rocker bogie in defense **[2]** and surveillance **[7]**. We also read about a modern approach for surveillance at remote and border areas using multifunctional robots based on current 3G technology used in defence and military applications **[6]**. The robotic vehicle works both as an autonomous and manually controlled vehicle using the internet as a communication medium. In many research papers we found that many people have made separate robots for surveillance and defense, whereas in our project we look forward to combining surveillance as well as defense. Also, we have seen very few papers in which people have used rocker bogie mechanisms for defense. Rocker bogie mechanism has various advantages that other drives and mechanisms, such as simple four wheel drive, do not have. Hence we propose to use rocker bogie in our military robot. One of the disadvantages of this mechanism is its inability to take a proper turn, and a lot of research is still going on the rocker bogie to find different methods to produce proper turn of the rocker bogie. In this project, (on the prototype) we will take turns just by increasing the rpm of one side and decreasing the rpm of the other side.

2. 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.

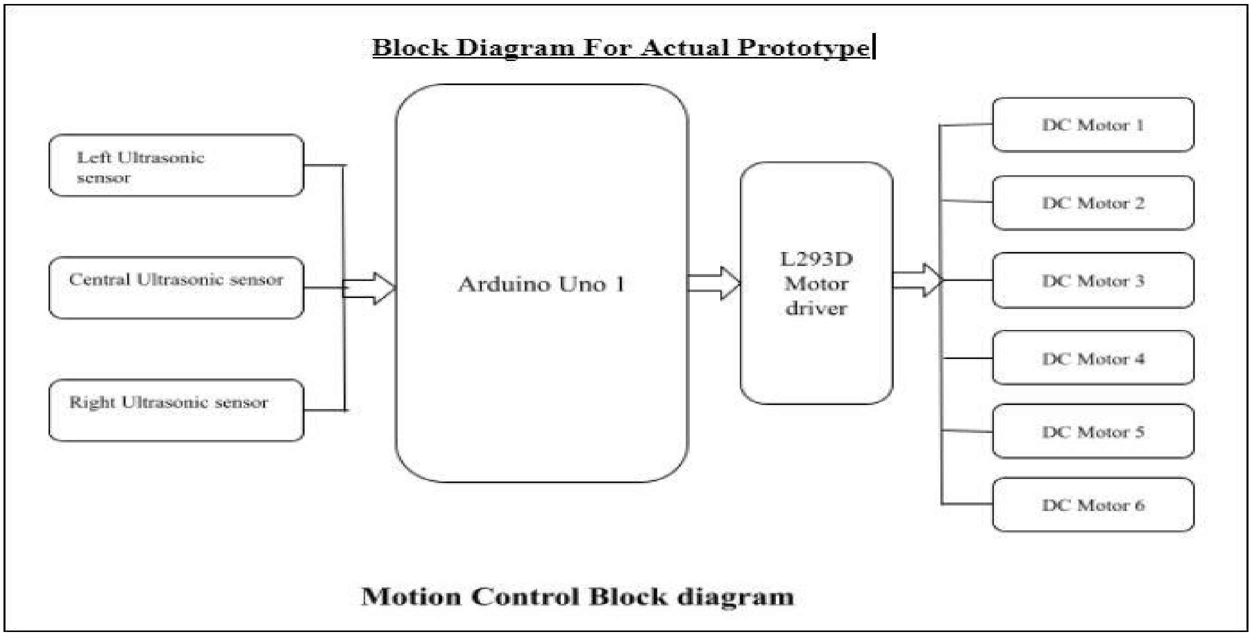


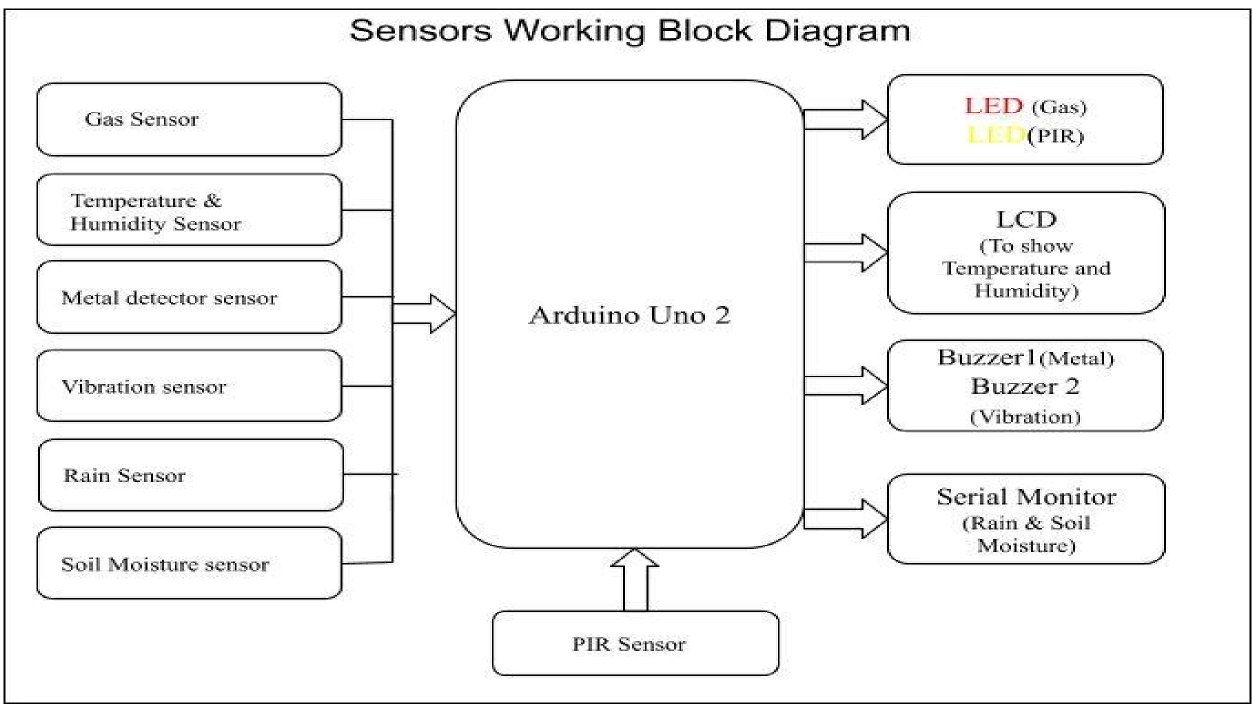


Why to use Rocker Bogie Mechanism?

- Allows to climb obstacles twice the size of the wheel diameter
- Independent movement of rocker on either side of the bogie
- The front and back wheels have individual drives for climbing, enabling the rover to traverse obstacle without slip
- The design is very simple and reliable
- Distribution of the payload over its six wheels uniformly
- 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, not as translation like conventional suspensions

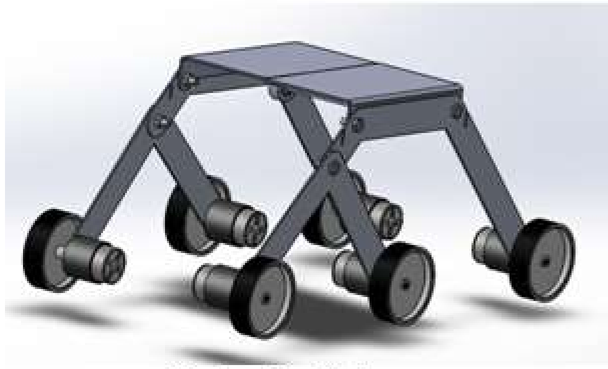
3. BLOCK DIAGRAM





4. Components

- Rocker Bogie Frame



Rocker Bogie Frame

- Wheels - Wheels are used to support the rover load, transmit traction and provide braking forces to the road surface, absorb road shocks, and help in changing and maintaining the direction of travel. The wheels are made of plastic with rubber gripping at the surface to provide traction. Six wheels are used in the rover and connected at the end of six links of rocker and bogie.

Wheel

- Electronic components

A. Arduino Uno ATmega 328-

Arduino is a computer designed specifically for controlling hardware which in this rover is used for controlling the motors. Arduino consists of both a physical programmable circuit board, a piece of software, or IDE (Integrated Development Environment) that runs on a computer and which is used to write and upload computer code to the physical board.

Technical Specifications-

Operating Voltage: 5 Volts

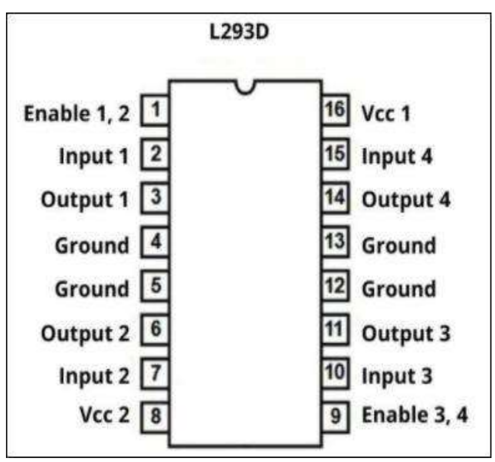
Input Voltage: 7 to 20 Volts

Digital I/O Pins: 14 (of which 6 can provide PWM output)

Analog Input Pins: 6

B. DC Motor
A **DC motor** is any of a class of rotary electrical motors that converts direct current electrical energy into mechanical energy. The most common types rely on the forces produced by magnetic fields.

C. L293D motor driver
It is a 16 pin IC which has supply voltage of 5V and 600 mA output current capability with pulsed current 1.2 A. It allows DC motors to drive in either direction and can control a set of 2 DC motors simultaneously. It has internal ESD protection and high noise immunity inputs. It has 2 voltage pins, one is used to draw current for working of L293D and other is for applying voltage to motors.



D. 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.

Ultrasonic Sensor

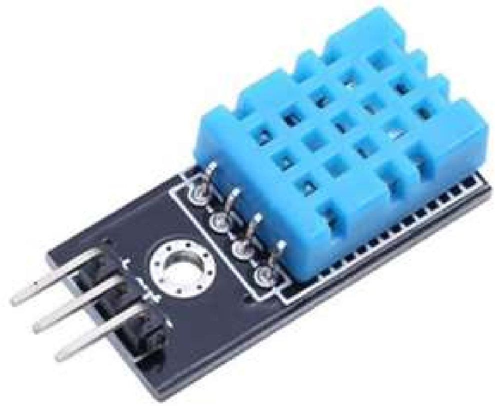
E. PIR Sensor

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.

PIR SENSOR

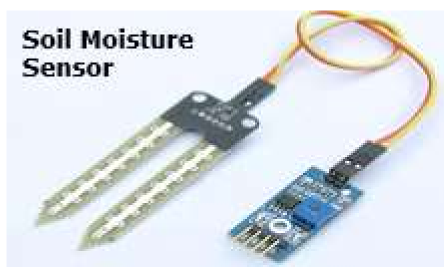
F. Temperature sensor

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.



Temperature and Humidity Sensor

G. 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.



H. 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 conversation 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.

Rain Sensor Module

I. Metal Detector 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.

J. 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.

K. 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.

L. Jumper Wires

There are three types of jumper wires:

1) Male to male
2) Male to female
3) Female to female

- Pistol auto 9mm 1A-

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

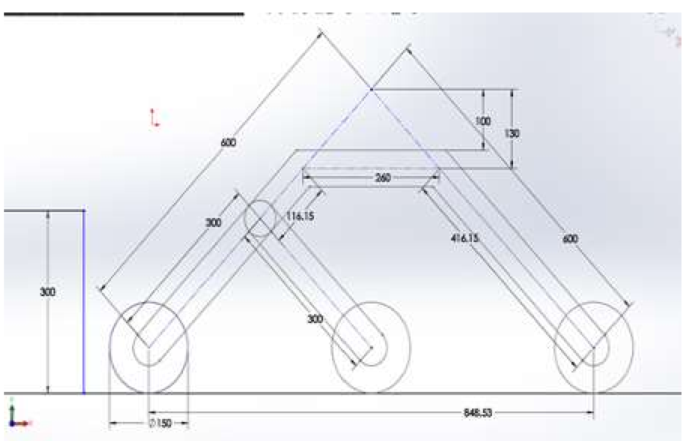
5. Calculations

- ❖ Design of Rocker Bogie Mechanism
- ❖ Drive Wheel Motor Torque Calculations
- ❖ Spring Calculation

5.1 Rocker Bogie Geometry

By considering length of Obstacle 200 mm & Radius 50

INPUT	VALUE	UNITS
Length of mechanism	665.685	mm
Height of obstacle	200	mm
Slope angle	45	
Radius of front wheel	50	mm
Radius of rear wheel	50	mm
Gun length	250	mm
Velocity	150	mm/sec
AM=MN	200	mm
AN	282.8427125	mm
NC	282.8427125	mm
BM	200	mm
BC	400	mm
Height without Considering Radius	207.8427125	mm
Total height	257.8427125	mm
Wheel base	565.6854249	mm



5.2 TORQUE CALCULATIONS:

Drive Wheel Motor Torque Calculations

1. No. of wheels in UGV : X
2. Gross vehicle weight (GVW) : Y
3. Radius of each wheel (Rw) : Rw
4. Max. gradient of slope (α) :
5. Max. linear velocity (Vmax) :
6. Surface friction co-eff. (Crr) : (Crr of sand is considered)

Step One: Determine Rolling Resistance Rolling Resistance (RR)

is the force necessary to propel a vehicle over a particular surface.

Rolling Resistance (RR) - GVW x Crr

Step Two: Determine Grade Resistance

Grade Resistance (GR) is the amount of force necessary to move a vehicle up a slope or grade. This calculation must be made using the maximum angle or grade which is the max gradient of slope , the vehicle will be expected to climb in normal operation.

Grade Resistance (GR) - GVW x Sin α

Step Three: Determine Acceleration Force Acceleration Force (Fa)

the force necessary to accelerate from a stop to maximum speed in a desired time.

Acceleration Force (FA)- (GVW x Vmax) / 32.2 ft/s2 x 1s)

32.2 ft/s^2 is acceleration due to gravity (9.8 m/s^2) if Vmax is in ft/s

Step Four

Total Tractive Force (TTE) - RR+GR+FA

Total Tractive Effort 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.

Step Five

Wheel Torque (Tw) - TTE x Rw x RF

Tw = wheel torque

TTE = total tractive effort

Rw = radius of the wheel/tire

RF = resistance factor

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%).

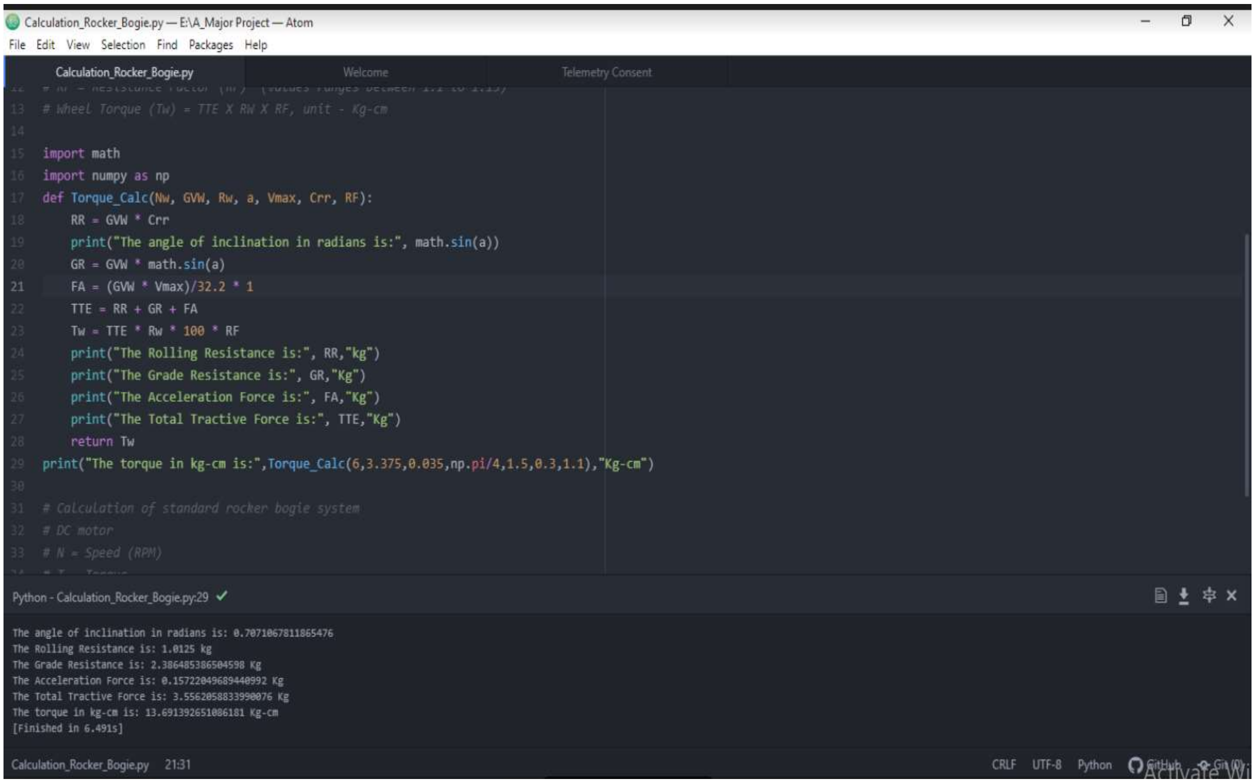
Below calculations are for 0.01 coefficient of friction which is for Good concrete.

INPUT	**VALUE**	
No. of wheels in UGV	6	
Gross vehicle weight (GVW)	3.374	Kg
Radius of each wheel (Rw)	50	mm
Max. gradient of slope	45	
Max. linear velocity (Vmax)	150	mm/sec
Surface friction co-eff. (Crr)	0.01	Good Concrete
RF	1.1	
CALCULATIONS	**VALUE**	
Rolling Resistance (RR)	0.05061	Kg
Grade Resistance (GR)	2.38577828	Kg
Acceleration Force (FA)	0.05159021407	Kg
Total Tractive Force (TTE)	2.487978494	Kg
Wheel Torque (Tw)	13.68388172	Kgcm

Torque calculations for different surface conditions

Surface	**Surface Coeff of Friction**	**RR**	**TTE**	**Tw**
Concrete	0.015	0.05061	2.487978494	13.68388172
Asphalt	0.017	0.057358	2.494726494	13.72099572
Wood	0.0053	0.0178822	2.455250694	13.50387882
Snow	0.031	0.104594	2.541962494	13.98079372
Dirt	0.031	0.104594	2.541962494	13.98079372
Mud	0.0923	0.3114202	2.748788694	15.11833782
Grass	0.065	0.21931	2.656678494	14.61173172
Sand	0.17	0.57358	3.010948494	16.56021672
			Average	14.39507874

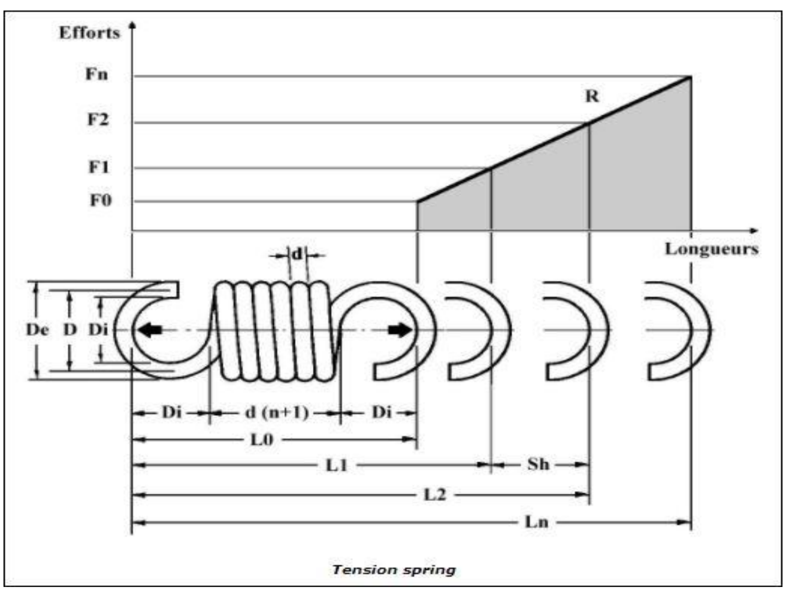
We also did this Calculations using Python Program. This program takes input values from the user like gross vehicle weight, radius of wheels, surface coefficient, Resistance factor, Velocity, etc. and directly it provides the value of the Wheel Torque(Tw).



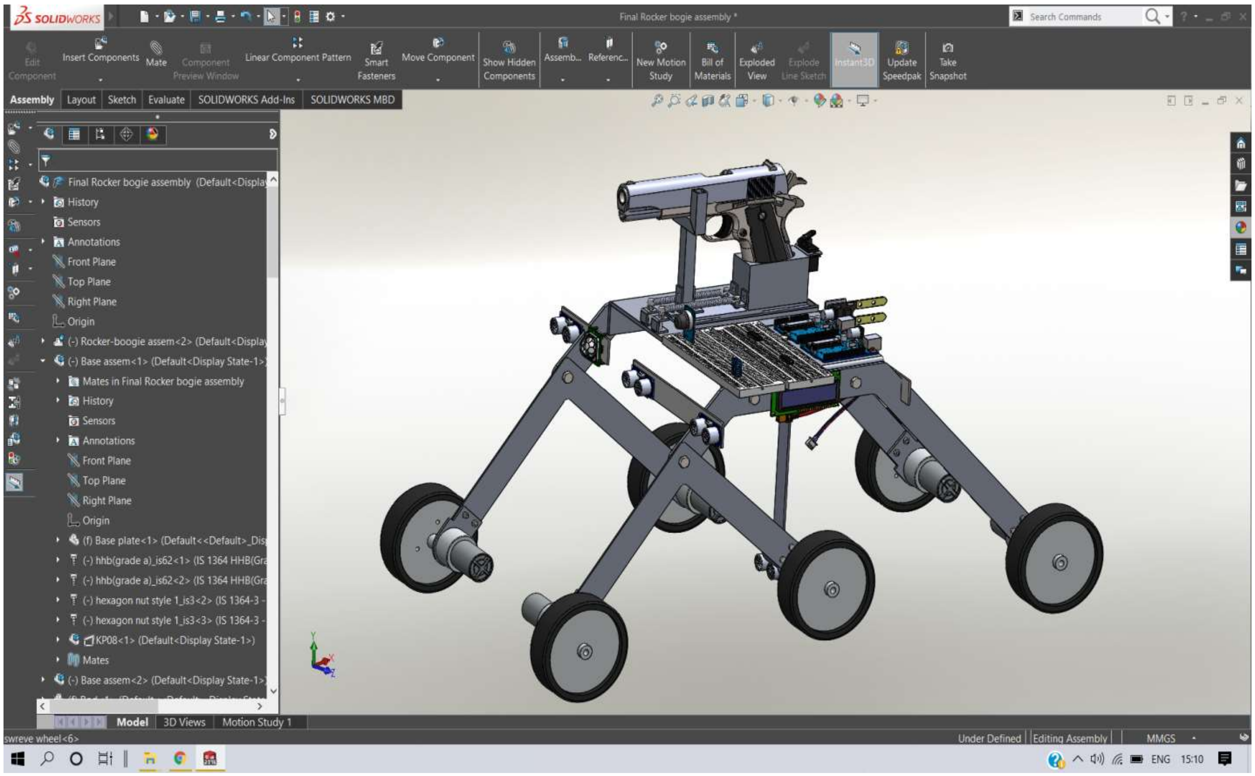
5.3 SPRING CALCULATION:

Input	Formulae	Value	Unit
Gun weight W		2	Kg
Modulus of rigidity, G		73000	N/mm2
Ultimate tensile strength UTS		900	N/mm2
spring index, C		6	
Deflection of spring, δa		10	mm

Permissible shear stress, τ		513	N/mm2
	Calculations		
Load on each spring, P	W*gSinx+ Fb	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



6. CAD MODEL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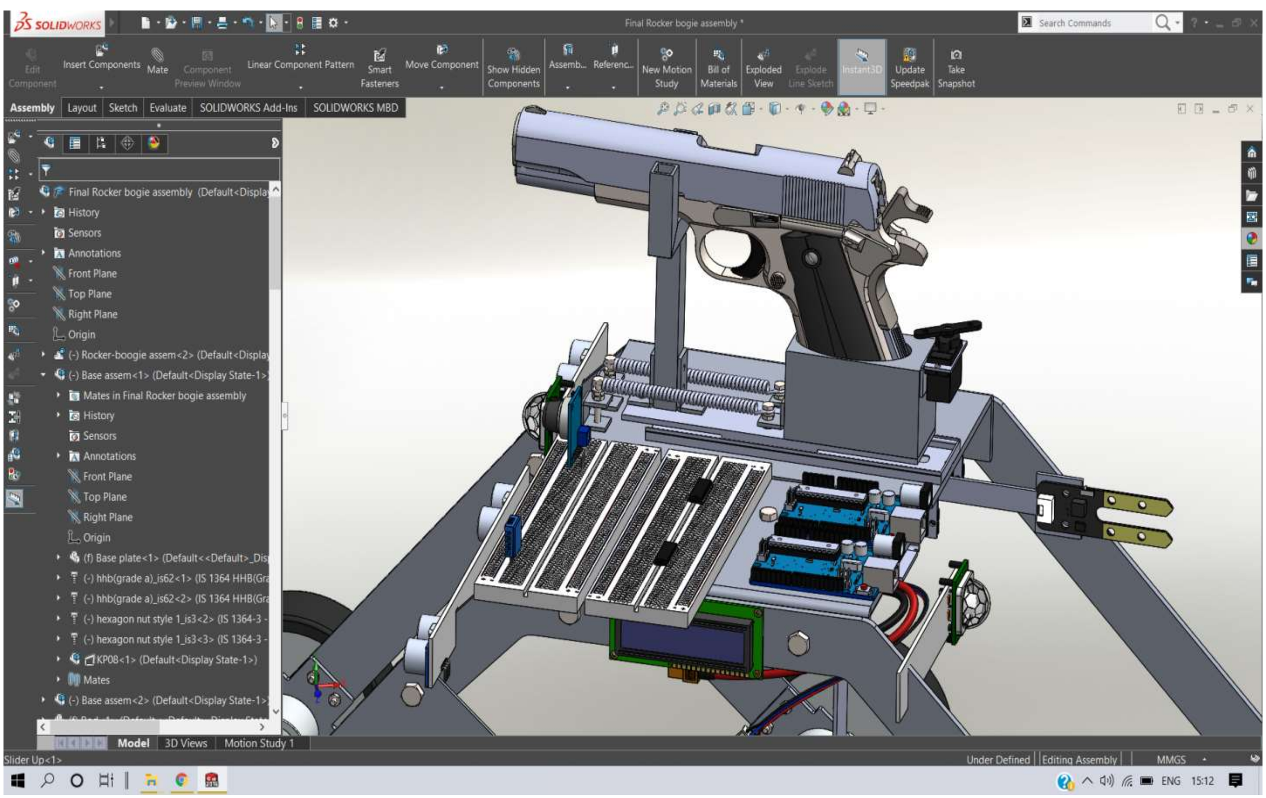
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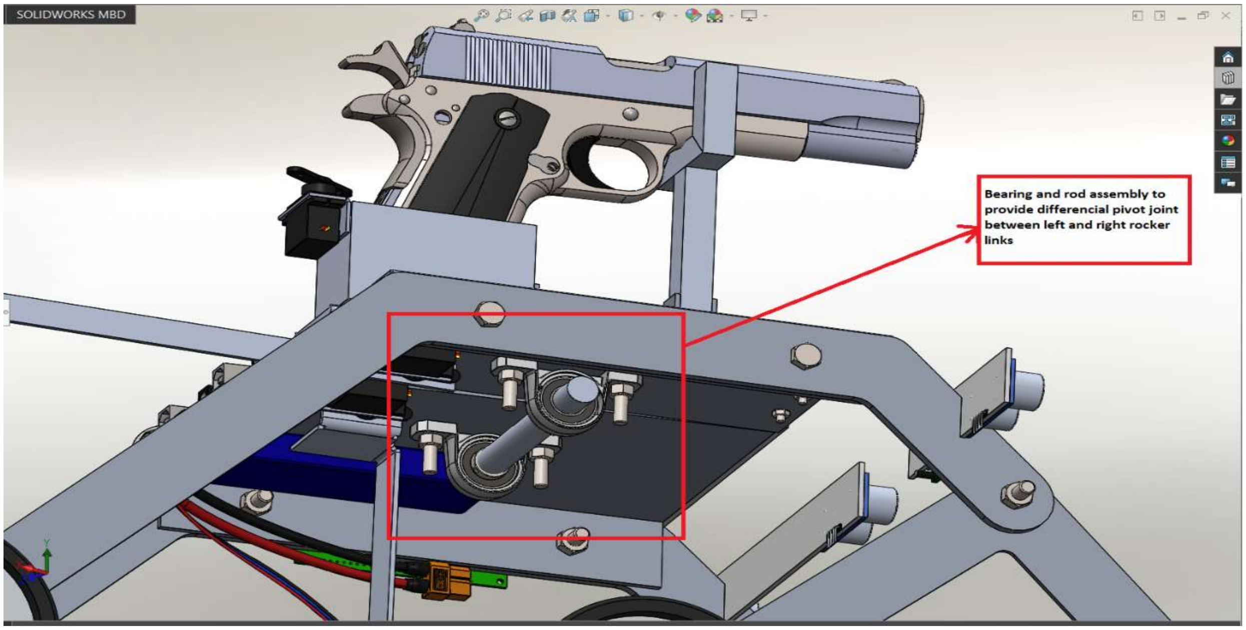
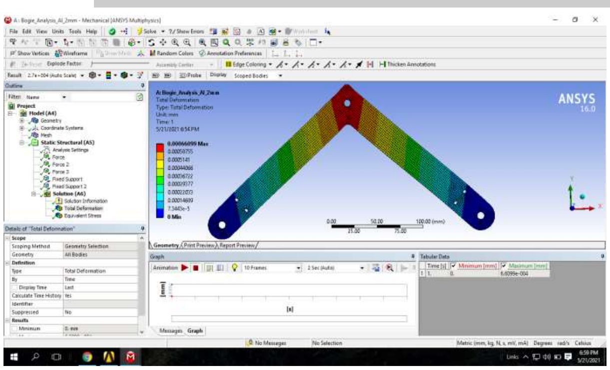


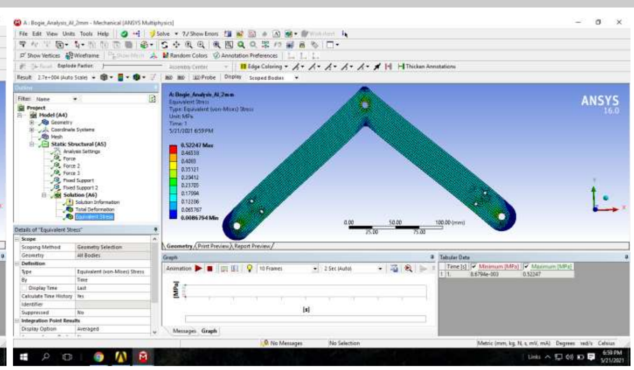
- Modeling and simulation of the robot was done in solidworks.
- To provide a differential pivot joint between left and right rocker links, bearing and rod assembly was mounted at the bottom side of the robot.
- For defence purposes, a gun actuated by servo is mounted on the base plate of the robot. A Y-shaped link structure and block with cavity is used to mount the gun in a vertical position. After gun fire, the robot will experience a jerk. So to minimize that jerk the gun assembly is mounted on the slider. An extension spring is used to regain the position of the gun after firing a bullet.
- Simulation of robot locomotion is carried out by using motion analysis in solidworks. For motion analysis following input commands are provided:

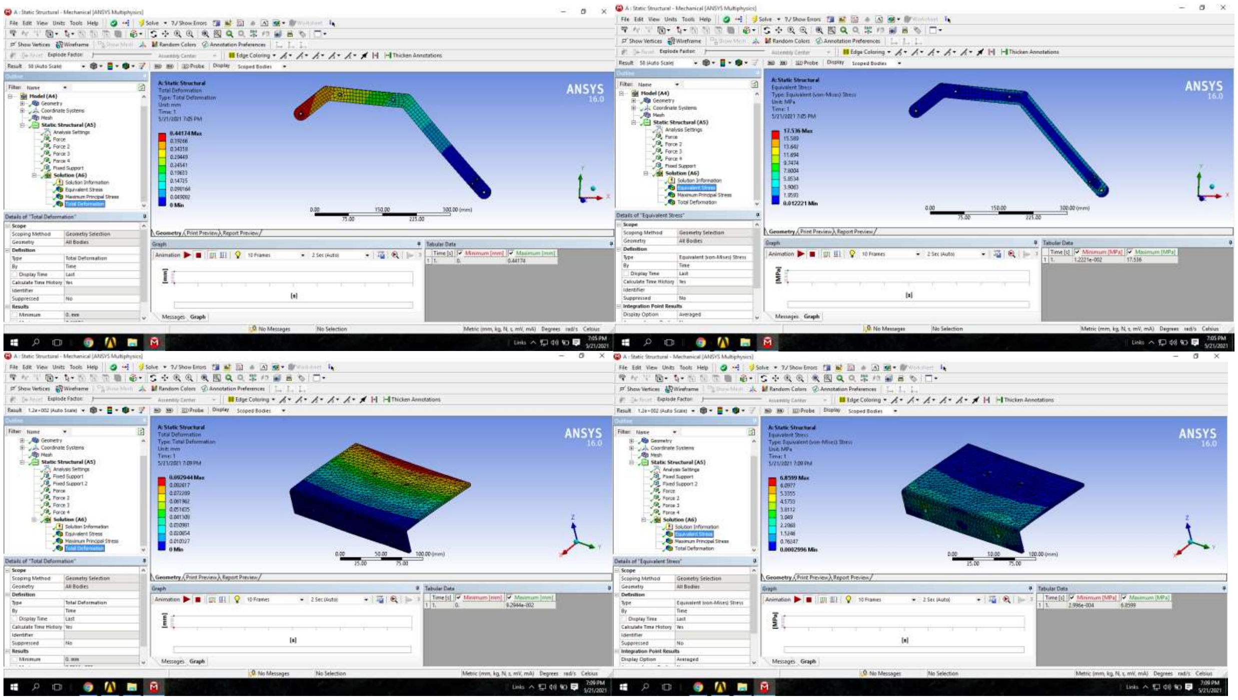
1. Solid body contact between all the wheels and ground
2. Gravity in downward direction
3. Rotary motor to all the wheels(100 RPM)

7 Analysis and Observations

7.1 Analysis in ANSYS





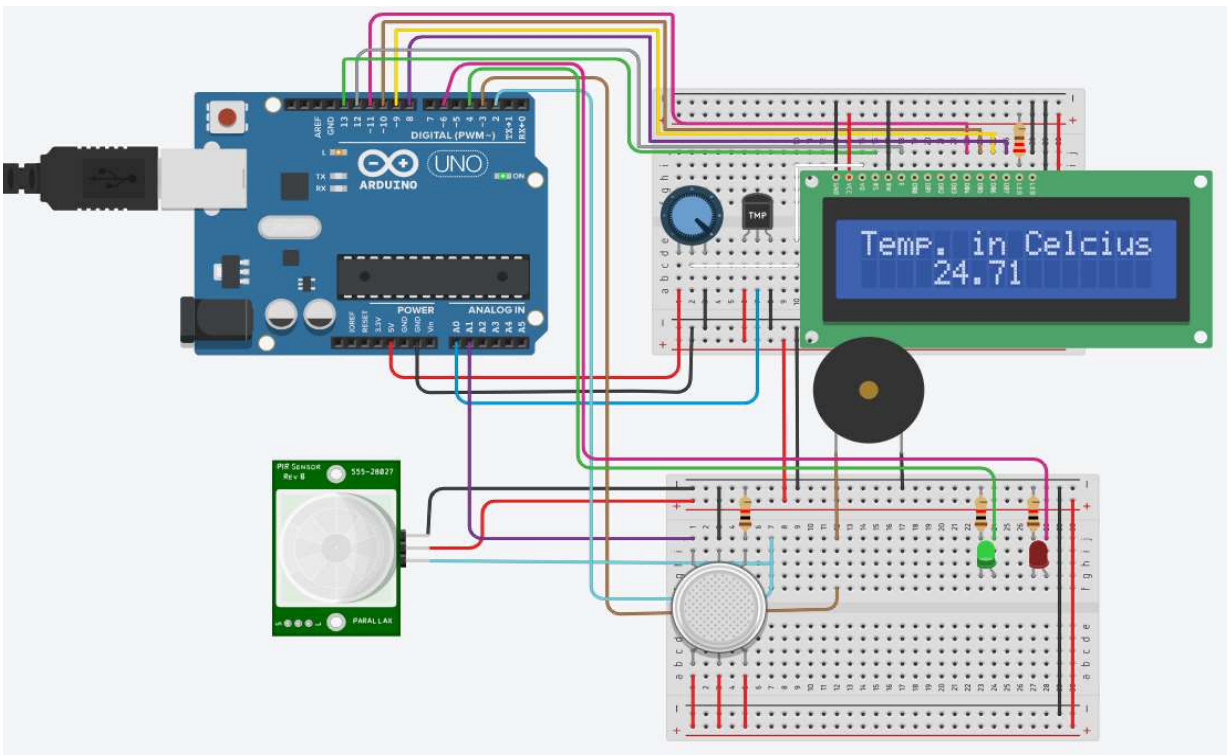


	Material	Thickness (mm)	Max Deformation (mm)	Max Equivalent (mpa)	Min Equivalent (mpa)
Base Plate	AL	2	0.78245	25.81300	0.00801
	AL	3	0.23448	12.66800	0.00293
	AL	4	0.10016	7.39260	0.00032
	MS	1	2.18050	104.430	0.01364
Rocker Link	AL	2	0.87157	12.12700	0.01439
	AL	3	0.58102	8.08230	0.00967
	AL	4	0.43575	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

The analysis of the bogie link, rocker link, and base plate was done in the Ansys. Each of the three parts was analyzed with three different thickness for Aluminium metal and 1mm thickness for Mild Steel, as shown in the above tables. So after the analysis and comparison between all thickness and materials for each part, we decided to choose 2mm Aluminium for bogie link, 4mm Aluminium for rocker link, and 3mm Aluminium for base plate. Aluminium being a very light metal, suits our mechanism and design.

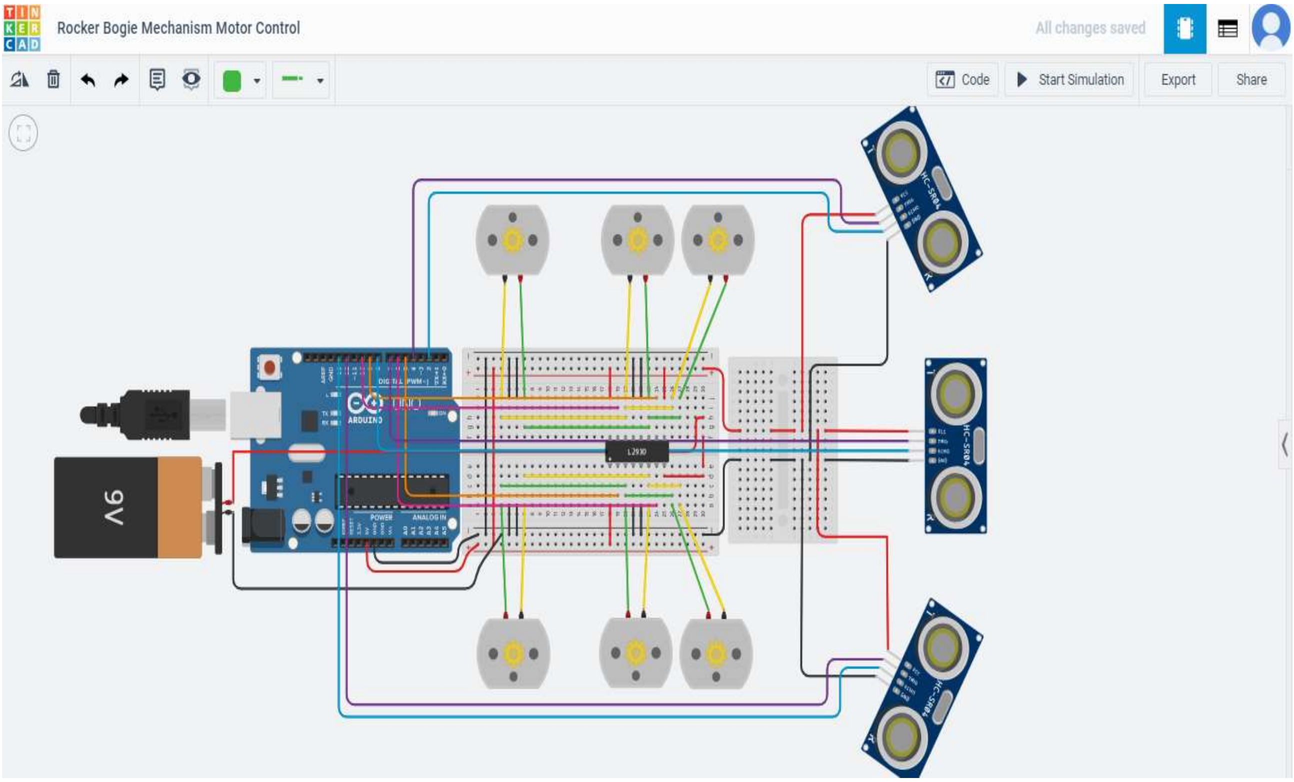
8. SIMULATION

8.1 SENSOR CIRCUIT SIMULATION



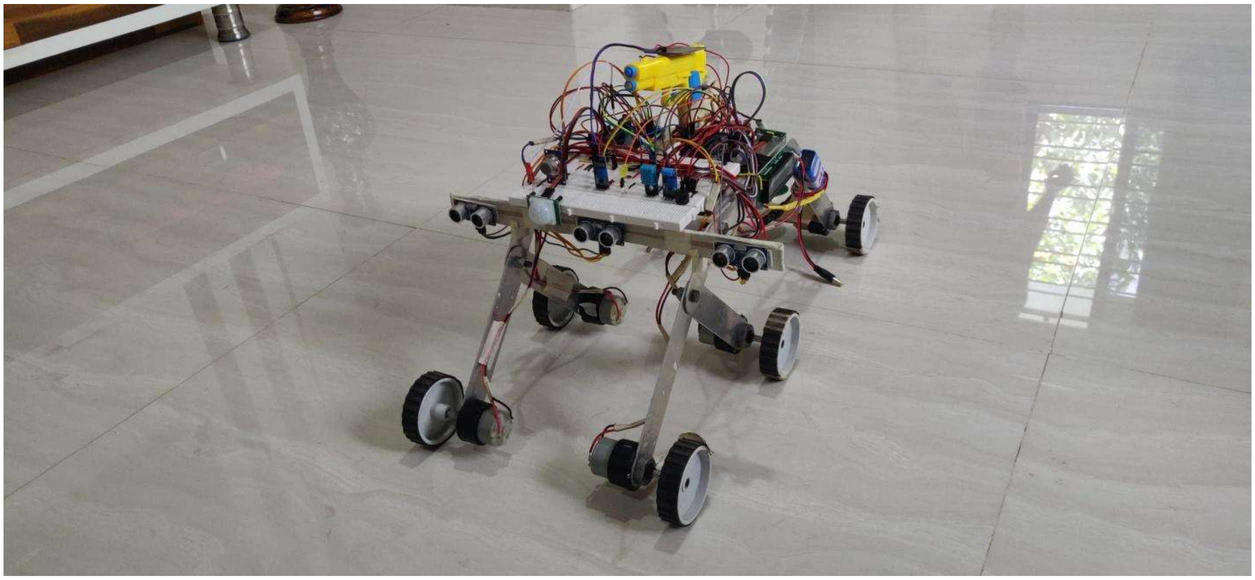
In the above figure we can see that sensors are simulated in TinkerCad. In the above simulation the readings from the temperature sensor (black) are displayed on the Liquid Crystal Display (LCD). The output for the passive infrared sensor (green) is the buzzer. When the PIR sensor detects any motion in front of it, the buzzer starts buzzing. Then we have the gas sensor (white), so when the gas sensor detects any gas or smoke the Red Led glows, whereas if there is no gas nearby then the Green Led continuously glows.

8.2 Robot Locomotion circuit simulation

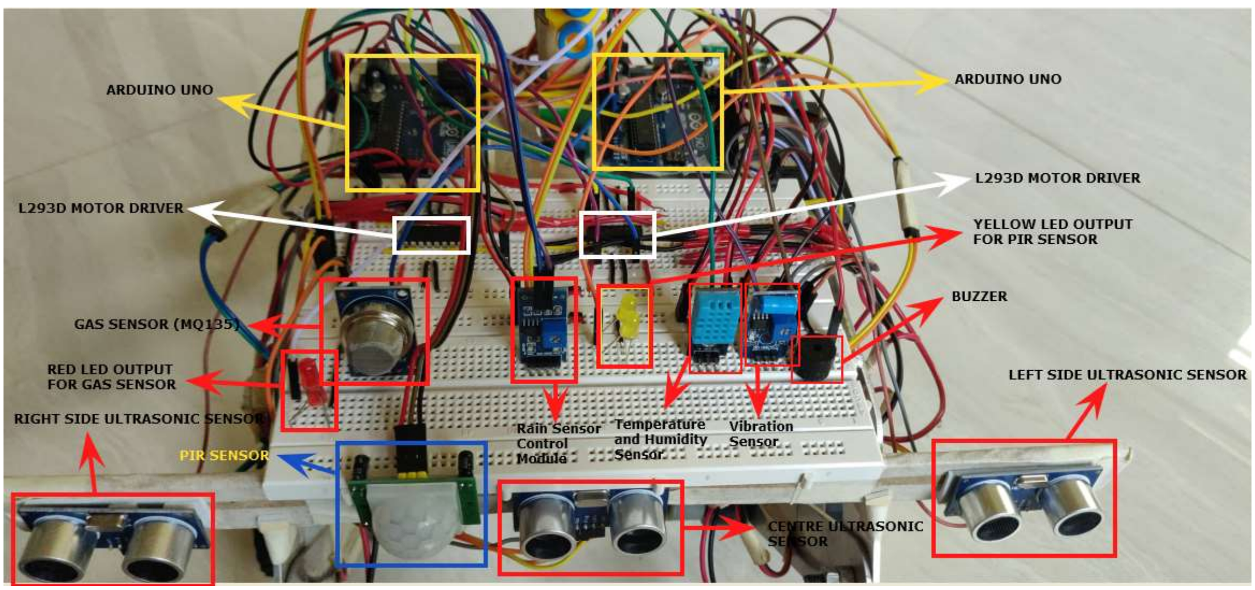


- For locomotion of the robot, we have used three ultrasonic sensors (Left, Center, and Right).
- So basically, when the left ultrasonic sensor detects an obstacle, the robot takes a right turn.
- When the right ultrasonic sensor detects an obstacle, the robot takes a left turn.
- When the center ultrasonic sensor detects an obstacle, the robot moves backwards.
- When the left and center ultrasonic sensor detects an obstacle simultaneously, the robot takes a right turn.
- When the right and center ultrasonic sensor detects an obstacle simultaneously, the robot takes a left turn.
- When all the left, center, and right ultrasonic sensors detect an obstacle simultaneously, the robot moves backwards.

9. Prototype



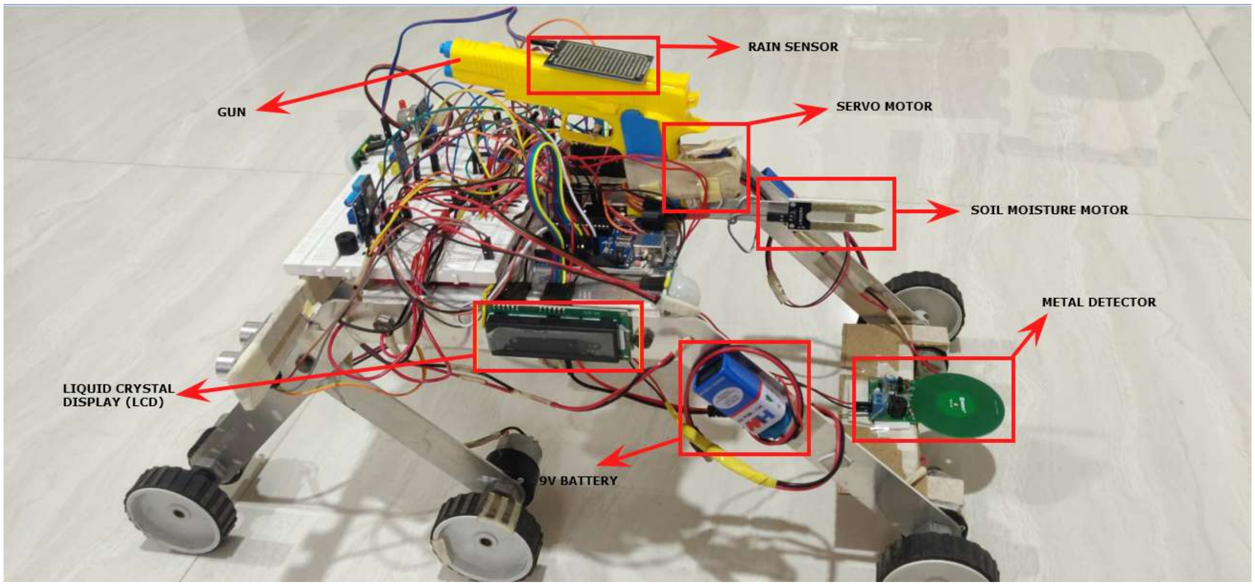
10. Electronic Circuits and Sensors



The above circuit shows the following components:

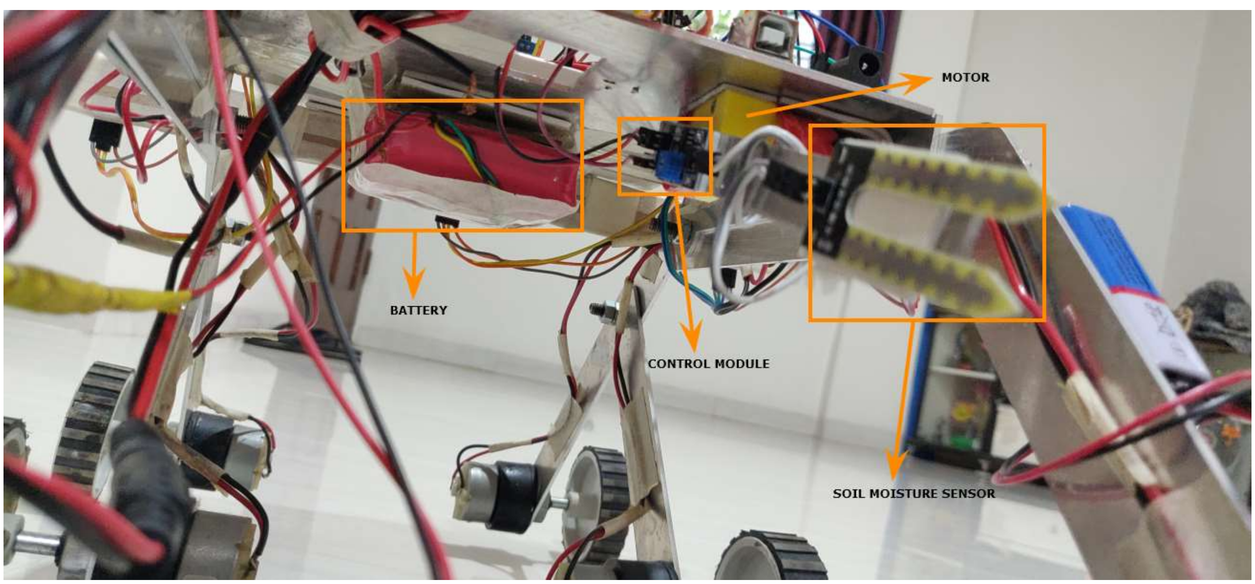
- 3 Ultrasonic Sensor
- PIR Sensor with Yellow LEDs as Outputs
- Gas Sensor with Red LEDs as Outputs
- Temperature and Humidity Sensor
- Vibration Sensor with Buzzer as Output
- 2 L293D Motor Drivers
- 2 Arduino UNO

- Rain Sensor Control Module



The above image shows the following components:

- Rain Sensor
- Liquid Crystal Display (LCD)
- 9V Battery
- Soil Moisture Sensor
- Metal Detection Sensor
- Gun actuated by a Servo Motor



The above image shows the following components:

- 12V, 2600mah, Battery
- Soil Moisture Sensor

- Control Module
- L-shaped BO Dc motor (controls the position of soil moisture sensor)

11. Arduino Programming

1) Locomotion Code
2) Sensor Code

12. Cost Report

Sr.no	Components	Cost / Piece	Quantity	Total Cost (Rs)
1	Robot Structure	-	-	500
2	Wheels	25	6	150
3	DC Motors (100 rpm)	155	6	930
4	Arduino UNO	619	2	1238
5	BreadBoard	102	2	204
6	Ultrasonic Sensor	150	3	450
7	PIR Sensor	146	2	292
8	Gas Sensor	125	1	125
9	Temperature Sensor	199	1	199
10	Soil Moisture Sensor	180	1	180
11	Rain Sensor	140	1	140
12	Metal Detector	313	1	313
13	Plastic Gun	60	1	60
14	Servo Motor (9G)	129	1	129
15	L shaped Dc BO Motor	120	1	120
16	LCD	225	1	225
17	Jumper Wires	2.5	40	100

18	Li-ion Battery	1047	1	1047
19	9V Battery	25	2	50
	Total Cost			**6452**

Total Cost - 6500/

13. CONCLUSION

- We propose a robot which can perform tasks of surveillance as well as defense.
- We propose to use a rocker bogie mechanism for the robot due to its flexible, simple and reliable design.
- We also use 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.

14. MISTAKES AND INSIGHTS

1) Mistake: We directly inserted the motor pins into the arduino board digital pwd pins. So when we switched on the circuit, the motor drew excess current through the arduino board, due to which the board just burnt off.
Insight: We learned the use of motor drivers, which can be helpful in providing excess current to the motors.

2) Mistake: We tried to make a metal detector, but we made a mistake that we used pure copper wire and made turns which touched each other. Due to which the magnetic flux became zero.
Insight: We learned that, in order to make Average length of the coil minimum and at the same time have the maximum magnetic flux; we should use enamel copper wire.

15. References

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