Foldable Hybrid Robotics

Seminar Report submitted in the partial fulfillment of

Term Work

In
Electromechanical Workshop

By

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CERTIFICATE

This is to certify that the seminar report entitled **“Foldable Hybrid Robotics”**, has been done by **Miheer Diwan, Shubhankar Kulkarni & Khojasteh Mirza** under my guidance and supervision & has been submitted for term work evaluation for the subject **“Electromechanical Workshop”** in **“Semester V”** for the degree of Bachelor of Technology in Mechatronics of MPSTME, SVKM’s NMIMS (Deemed-to-be University), Mumbai, India.

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Name of Faculty

Date:

Place: Mumbai

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ABSTRACT

This paper presents a novel idea to tackle the situation of fitting robots in spaces with limited height access. A possible solution to such a problem was to reduce the dimensions of the robot in question, but that would also lead to gradual loss of components to make the vehicle more compact. To counter this shortcoming, our sequential approach is to reduce the mean height of the robot itself. This is done by the specially designed power train consisting of three motors in each of the four legs of the device. The reduction is achieved by accurately triggering each actuating component at the correct time to acquire the desired objective angle between the components, which depends on the application. Due to the dynamic nature of the system, the design entailed creating parts through additive manufacturing methods. For this purpose, Acronitrile Butadiene Styrene (ABS) is selected owing to its high compressive strength. Coupled with its resistance to water and very high resistance to the physical impact made it an ideal contender for being the primary material for such an application. This is combined with some conventional materials (wood) for more simple shapes to make the device more cost and weight effective. The actuators aforementioned were selected according to the weight constraints of the manufactured components to handle that amount of torque. The result showed that a DC motor with a stall torque of 50 kg-cm and a rotational speed of 30 RPM was capable of such applications. Finally, a suitable processing unit is needed to control the actuating process. Therefore, we have used a Raspberry Pi for said process.

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CHAPTER 1
INTRODUCTION

BACKGROUND OF FOLDING ROBOTS

Foldable robotics is an emerging field to combat the increasing problem of space deprivation in their operating space and are more than often bio-inspired. Researchers at MIT [1] and Harvard [2] have created systems capable of changing angles between their surfaces through piezoelectric actuation. These are both single body mechanisms, which indicates that assembly is not required. After the additive manufacturing process, the body only needs to be attached to a local DC source, making it move independently.

MOTIVATION AND SCOPE OF THE TOPIC

The main drawback to the mentioned system is that they are not intelligent. This means that one cannot pre-program them to do specific tasks and the idea of AI with onboard computers for impulsive tasks combined with such devices is far-fetched. Nor can they be operated remotely for user-specific assignments. Hence only a simple motion (generally translational) governed by a basic piezoelectric train of pulses is possible. This renders them impractical for user-specific activities. Research into this unindustrialized domain is underway, and breakthroughs are expected in the distant future. However, the main aim of our project was to take the compression and expansion to our advantage and couple them with a modular design that could be intelligent enough to be remotely controlled and eventually self-reliant and not compromise on the usefulness of the final product. This project displays the ability of the robot to manoeuvre in an obstacle-filled environment.

SALIENT CONTRIBUTION

The process adopted for this project was to create a design – simulate the said design and test its validity - create the electronic circuitry – code the microprocessor.

Khojasteh Mirza

i. Created the final CAD file for simulation on Solidworks.
ii. A static structural test was done on ANSYS to examine the strength holding capacity of the design i.e., the equivalent stress (von mises), equivalent strain, and the total deformation in the assembly.
iii. A total of six designs were created out of which three were 2-link and the other three being 3-linked. Worked on the three, 2-link mechanisms robots by researching various other papers.
iv. Iterative customization of the multiple designs to suit the motors after selecting and differentiating between various types of actuator methods (bearings/ motors/ brackets).
v. Documentation of the report.

Miheer Diwan

i. Major contributions were to develop the idea of a hybrid robotic system which would be capable of walking as well as moving with the help of wheels.
ii. Created 5 CAD designs which included robots with 2-linked as well as 3-linked legs. Made use of motion studies to make the models more dynamic and presentable.
iii. Created numerous customizations and systems for moving the legs of the robot; notable designs were the use of a Stepper motor with timing belts and pulleys.
iv. Simulated the bot in MATLAB to better understand the movement of the joints and the dynamics of the robot.
v. Created the final CAD file for the futuristic scope of our robot.
vi. Made the final presentation and helped in editing the report of our project.

Shubhankar Kulkarni

i. Major contributions were in the simulation of the robot.

ii. The complete motion planning of the robot in V-REP (previously Coppelia simulator).

iii. Creation of URDF and designing the physics model for simulating the robot.

iv. Coding of the bot in python and in Arduino to make it manipulable; working of the code is demonstrated below.

v. Worked on Path planning and obstacle avoidance of the robot and developed the code for the same.

vi. Creation the final presentation and documentation.

ORGANISATION OF THE REPORT

- Chapter 1 focuses with the overall introduction to the topi and the motivation behind it. It also discusses the prior research in the field of our topic and how we have tried to implement solutions taking inspiration from the same.
- Chapter 2 delve with the main structure of our robot. The mechanical and electronic features of our robot are highlighted here.
- In chapter 3, the applications of our bot are highlighted, and some light is shed upon how it is fit for industrial use.
- Chapter 4 encompasses the complete process and life cycle of our bot from its inception to testing
- In the latter chapters, i.e., chapters 5, 6 & 7, a brief comparison was made with existing technology and a conclusion was drawn to wrap up the project along with a summary of this report.

CHAPTER 2
FEATURES

MECHANICAL

The final design chosen was a 2-link bot to avoid unnecessary complexities as shown below.

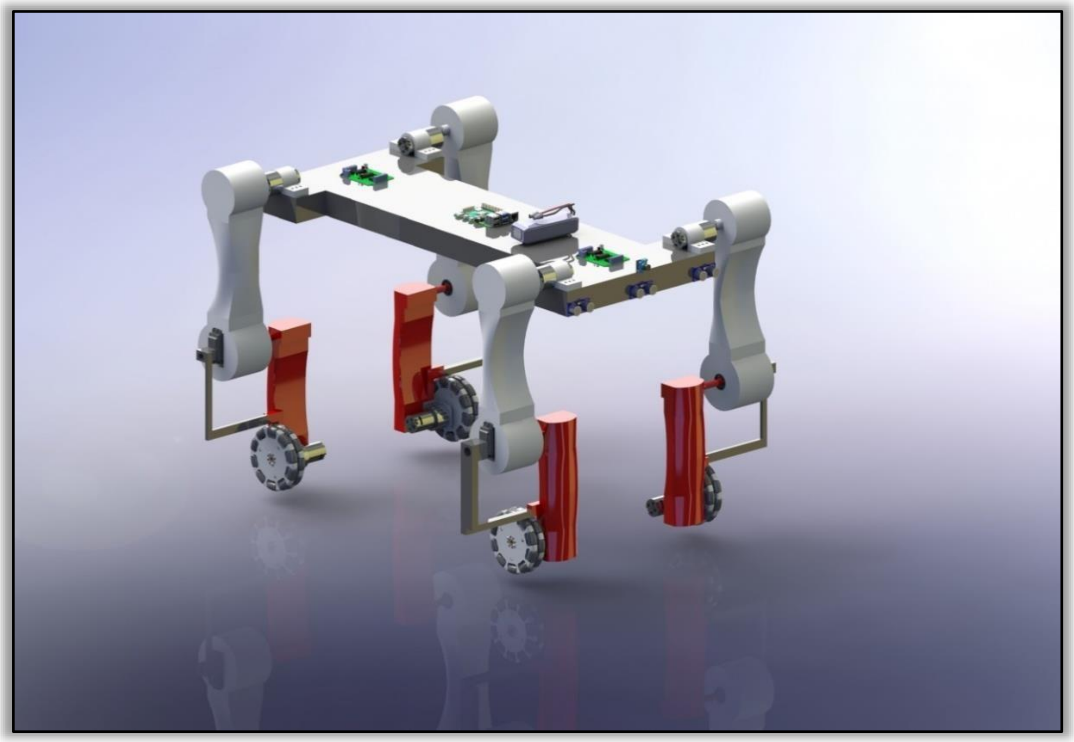


Figure 1. Mechanical Design

All designs were curated on Dassault Systems SOLIDWORKS 2019 Student Edition. The main components are highlighted in the illustration below. The robot has three main phases of operation, mainly decided by the variation of angle between link 1 and link 2.

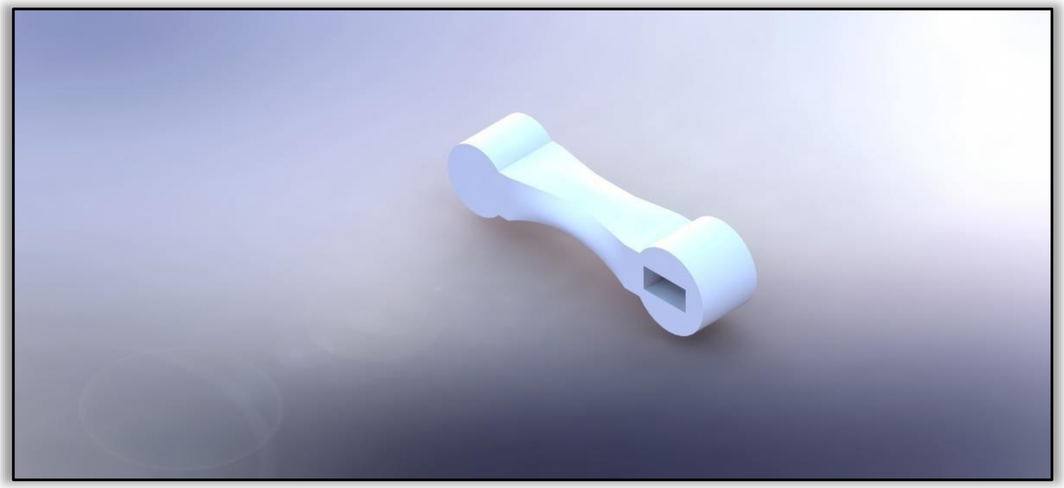


Figure 2. Link 1

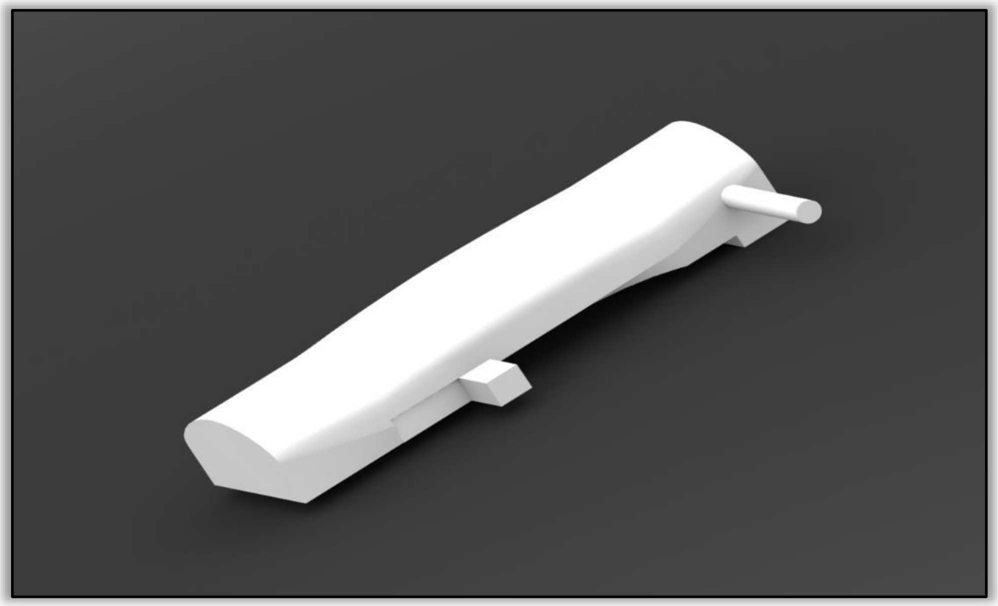


Figure 3. Link 2

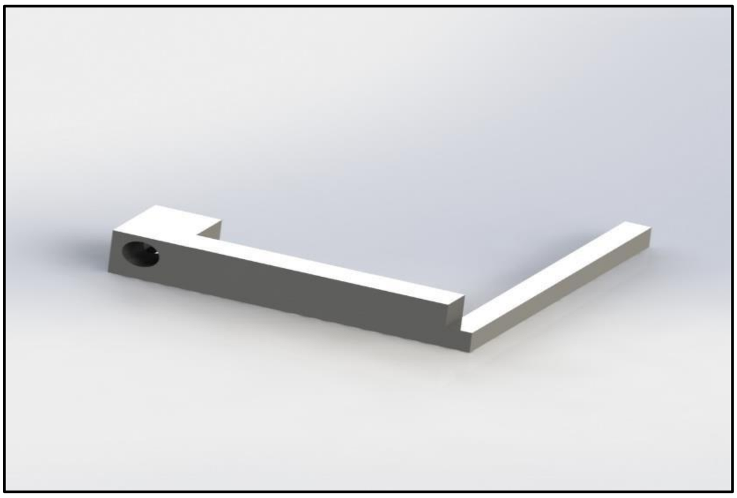


Figure 4. Connecting Link

Steady mean position

The mean position of the robot is achieved when the angle between link 1 and link 2 is held at a constant 90-degree value.

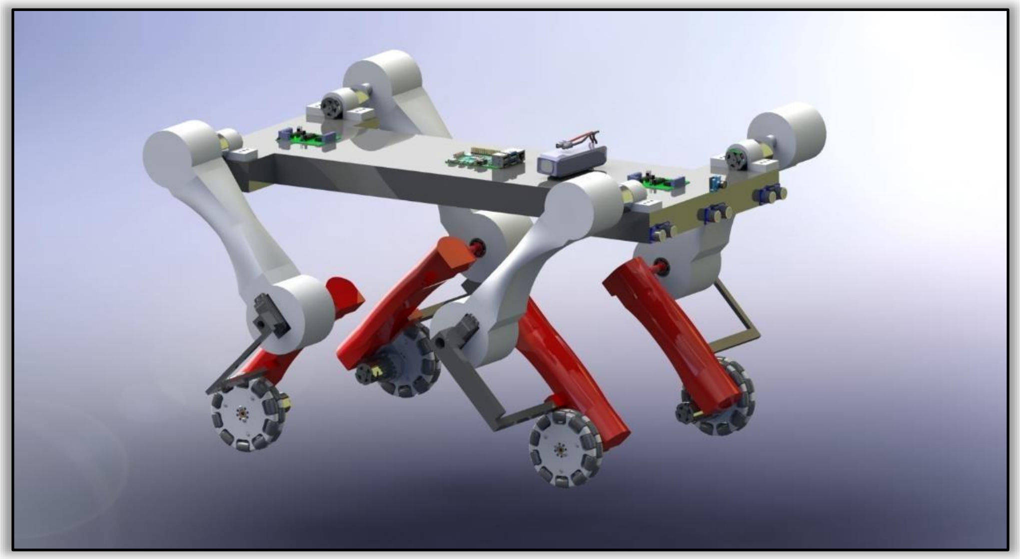


Figure 5. Mean Position

Complete compression – minimum height mode

In this mode, the distance on the Z-axis is minimum, which translates to: 15.43mm, the distance between the lower surface of the chasis and the ground being at its least value.

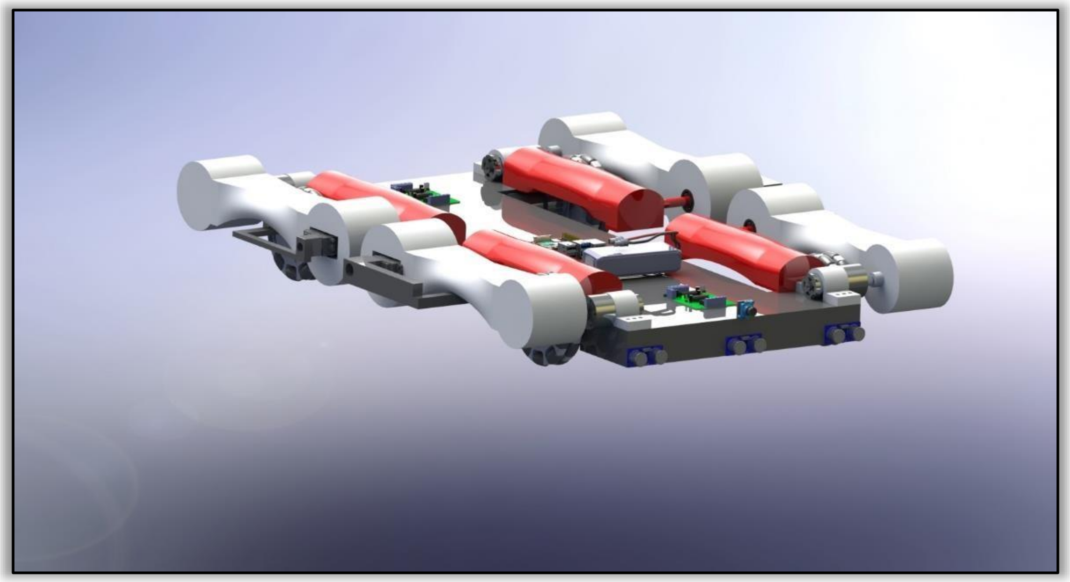


Figure 6. Complete Compression

Complete expansion - maximum height mode

This configuration is the exact opposite of complete compression, and hence the height of the robot is increased to its maximum allowable value which is approximately 410mm (414.53mm) by making the angle between link 1 and link 2 equal to 180 degrees.

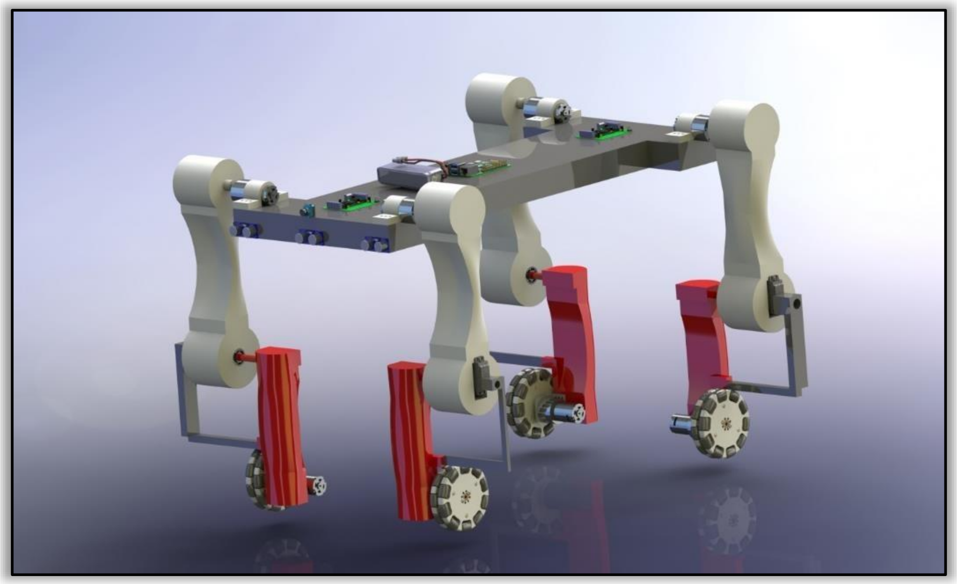


Figure 7. Complete Expansion

DOF Calculation

The degree of freedom one assembly of the leg was calculated, and this assembly was mimicked at the other three links in the bot. The simplified model for the degree of freedom is shown below.

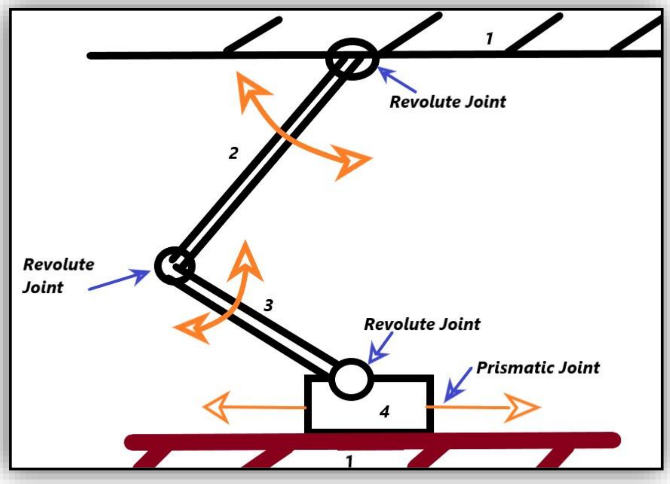


Figure 8. DOF Calculation

According to Grübler Kutzbach Criteria,

$f = 3(L-1) - 2J - h$ ....(1)

Where: *f = degree of freedom,*

L= number of links = 4

J= number of lower pairs = 4

h = number of higher pairs = 0

In our system, we have three revolute or pin joint pairs (1-2, 2-3, 3-4) and one sliding or prismatic pair (1-4). Substituting these values in equation (1), we get *f=1,* which is a single degree of freedom system. An SDOF system is one whose motion is governed by a single, second-order differential equation. Only two variables, position and velocity are needed to describe the trajectory of the system.

The parts of the final assembly were created with a loft operation due to its complex shape Fig. 9 and Fig. 10. This was done to ensure the structural integrity of the component under high compressive stress while still being capable of having a 0-degree angle between link 1 and 2, as seen in Fig. 11 and Fig. 12**.**

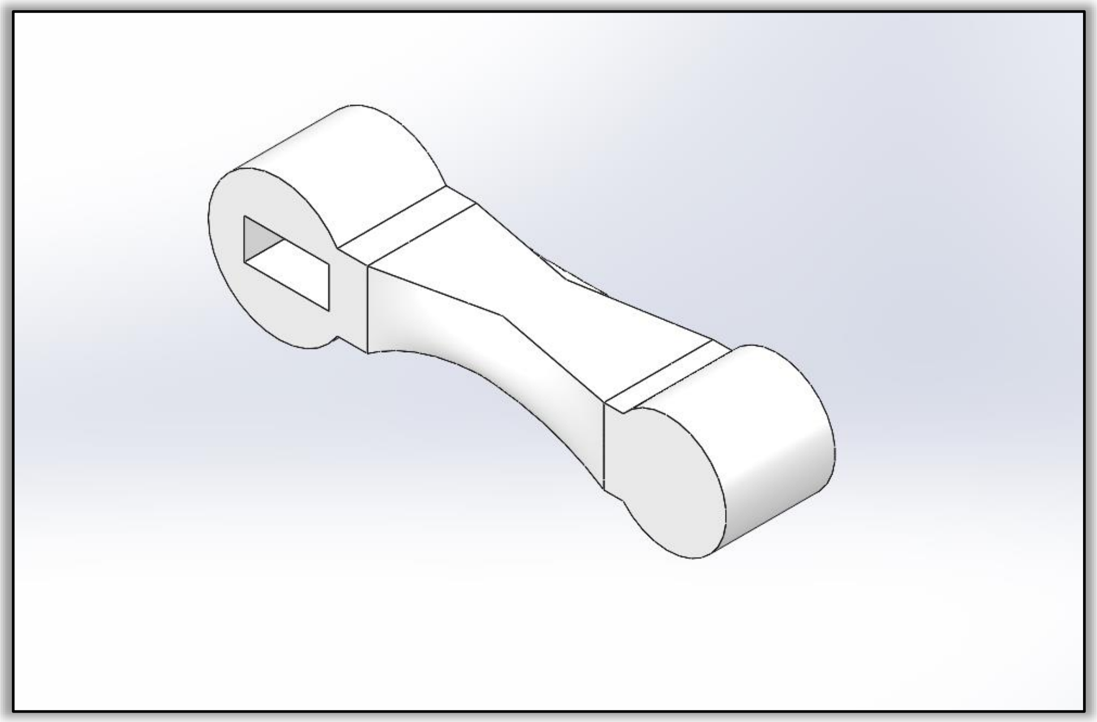


Figure 9. Link 1 Isometric View

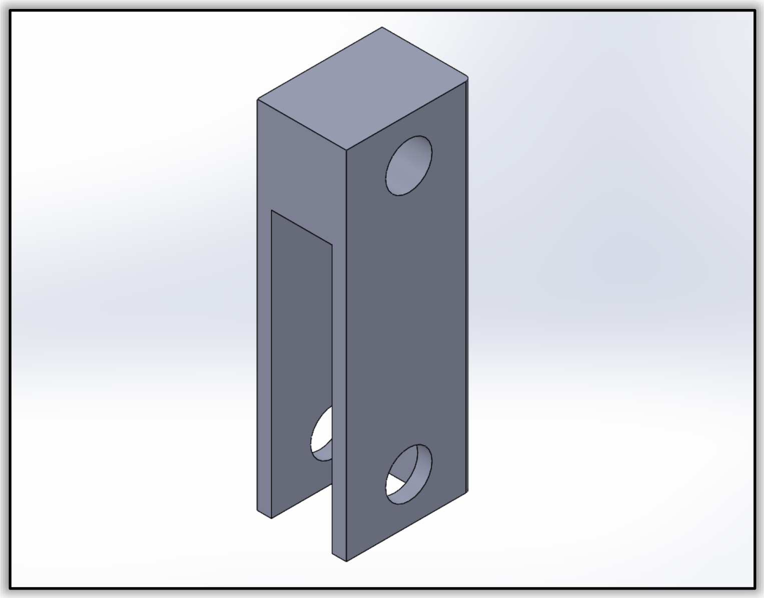


Figure 10. Link 2 Isometric View

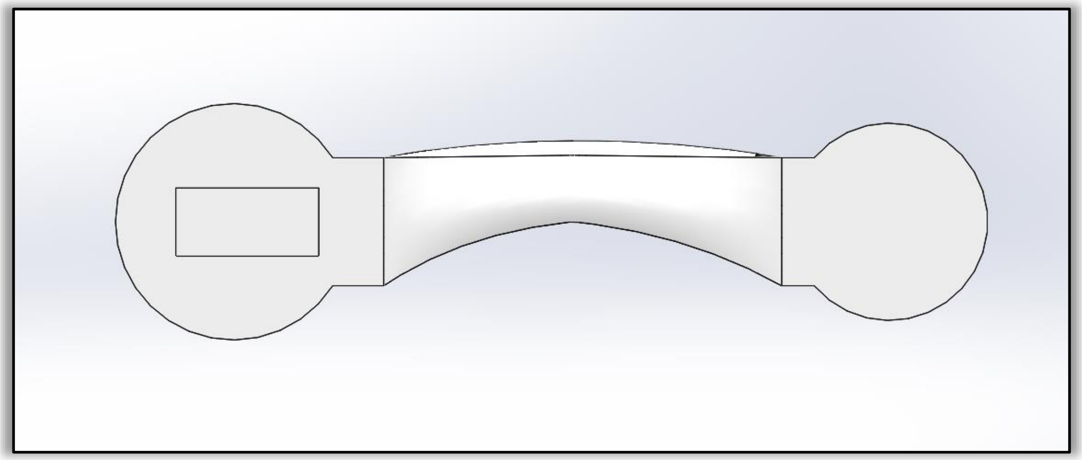


Figure 11. Link 1 Lofted View

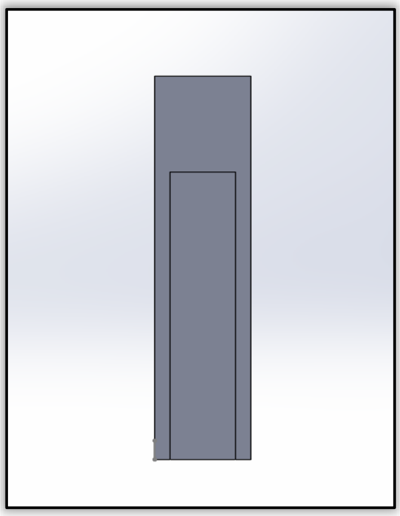


Figure 12. Link 2 Lofted View

Static Tests

Each component underwent 3 tests – total deformation, stress and strain test. For link 1 the data is as shown below:

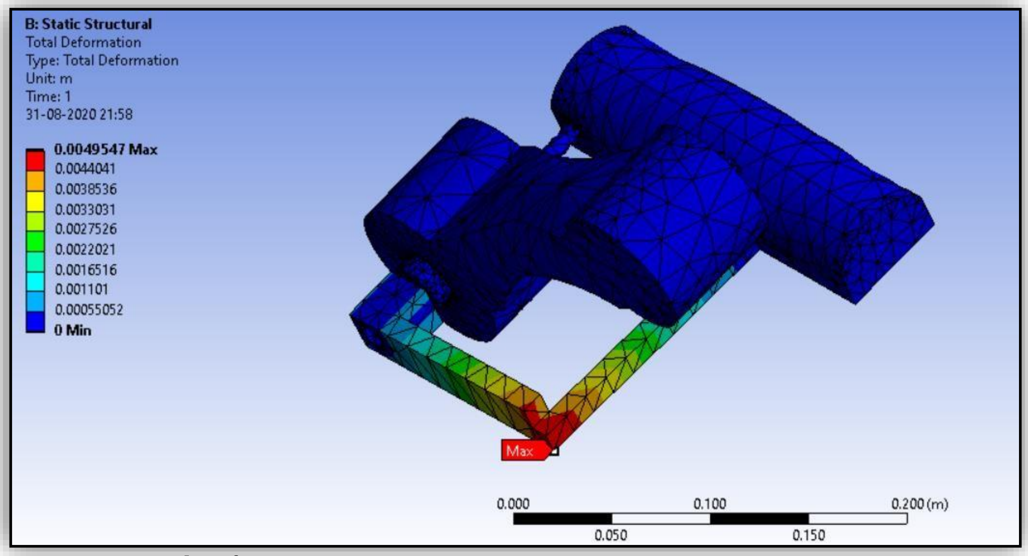


Figure 13. Total Deformation Test

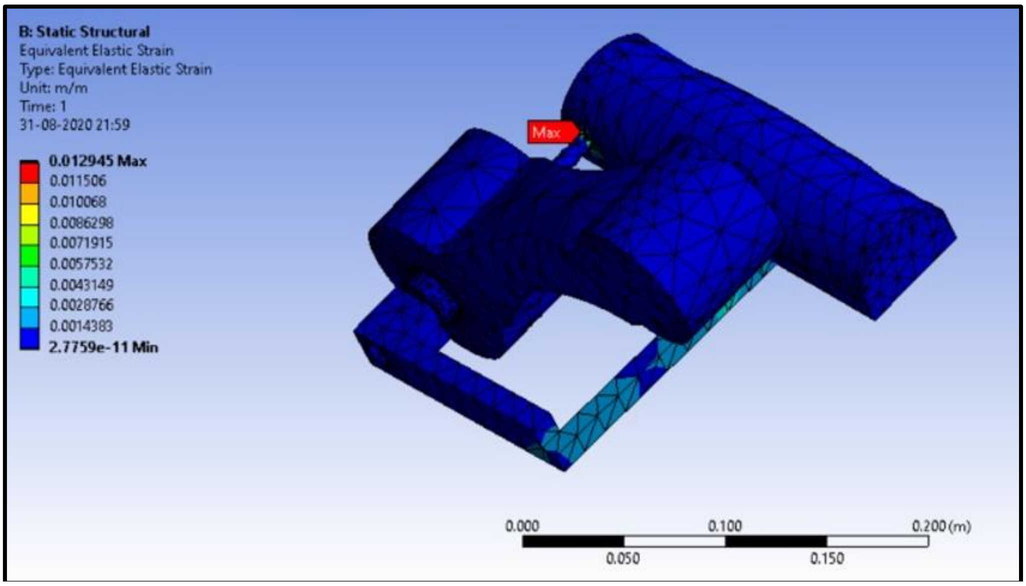


Figure 14. Strain Test

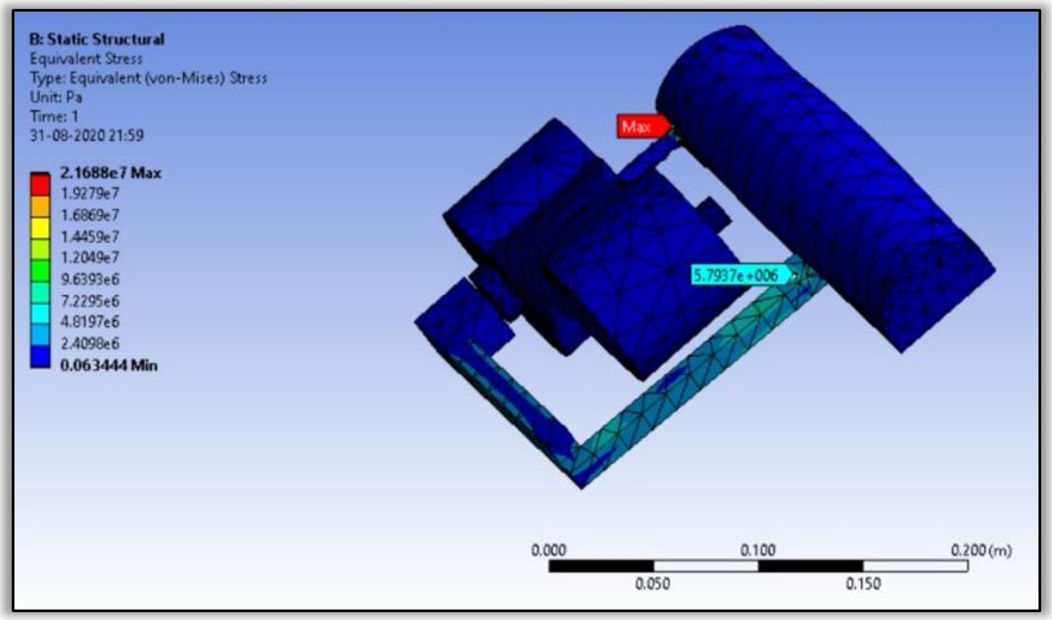


Figure 15. Stress Test

Here it should be noted that the Yield stress for ABS plastic is 48e+6 according to experimental data. The data from the simulation shows that the maximum stress in the assembly is 2.16e+7 which translates to 21.6e+6 which is roughly half the value of the yield stress point. Which is safely below the yield stress value and hence the body will not undergo any major deformation and will not show plastic deformation.

ELECTRONICS

The following components were used:

- Raspberry Pi 4
- 8 x 12V 60 RPM Johnson DC Motor
- 4 x MG 995 Servo Motor
- 2 x Motor Driver

PROGRAMMING

Physics Model

To consider all the forces of the robot, one must simulate a model wherein the entire robot is respondable and can interact with each of its parts like the real world. Hence, a skeleton is created to enable all interactions whilst the robot is in motion.

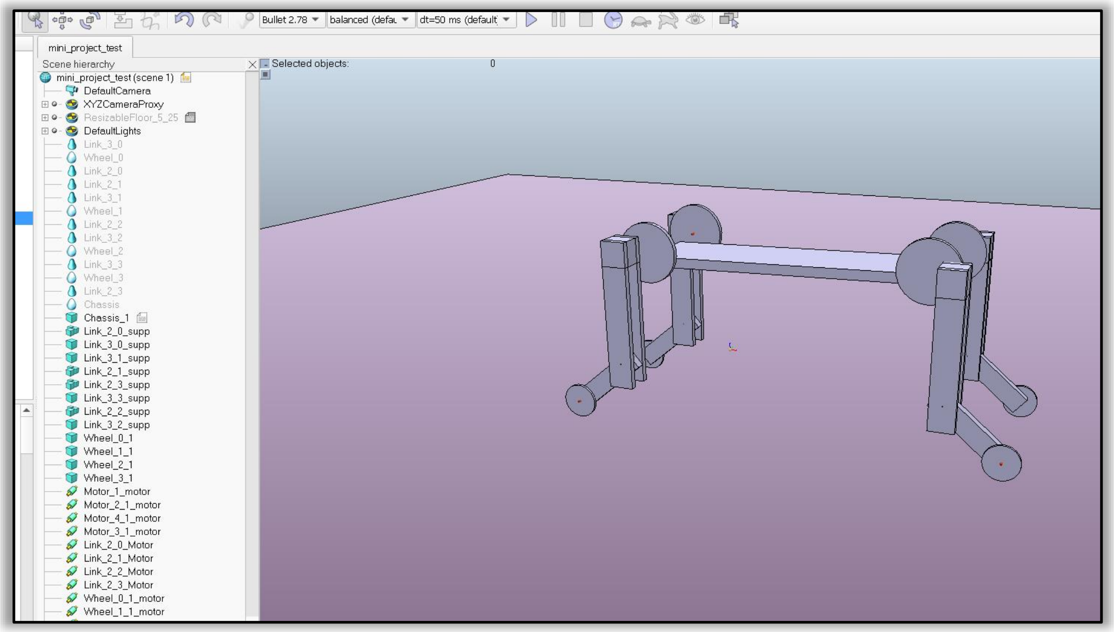


Figure 16. Physics Model

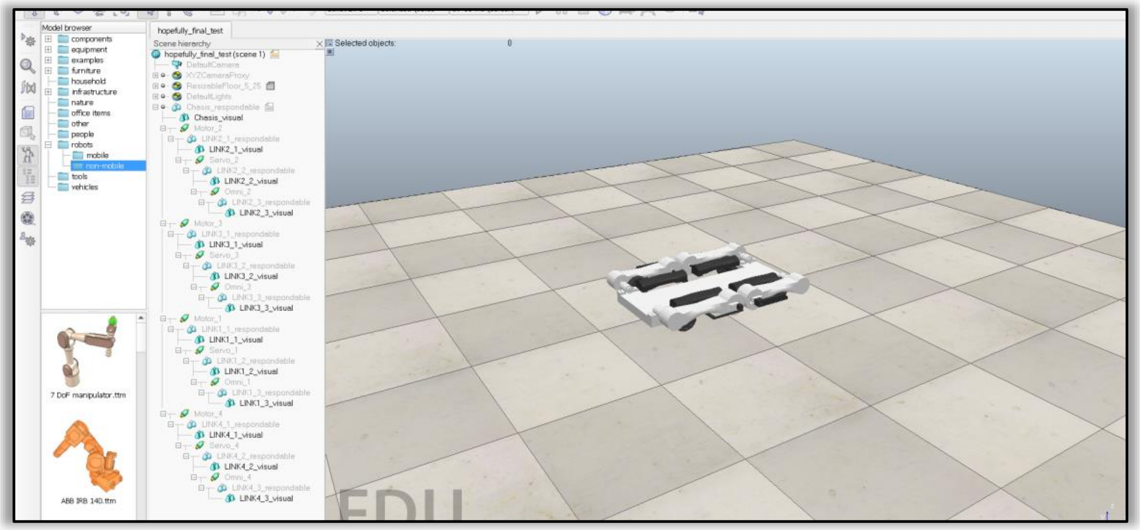


Figure 17. Final Model CoppeliaSim

Detecting an obstacle

If an obstacle is encountered by the robot, two approaches are followed. In the first approach, the robot checks the availability of a gap big enough to fit the robot. If so, it will go through the object. If this is not satisfied, the height of the robot is gradually increased using motors. After its highest position is reached and the robot is still not able to overcome the obstacle, the second approach is used. In the second approach, the robot will return to its original position and turn right to explore alternate paths to reach the goal.

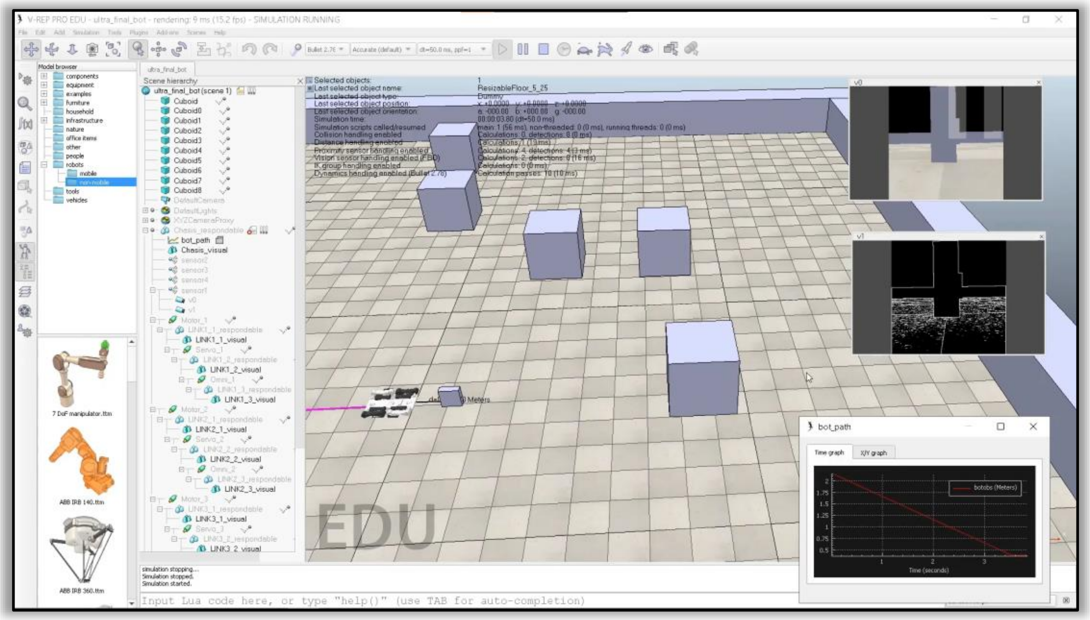


Figure 18. Detecting an Obstacle

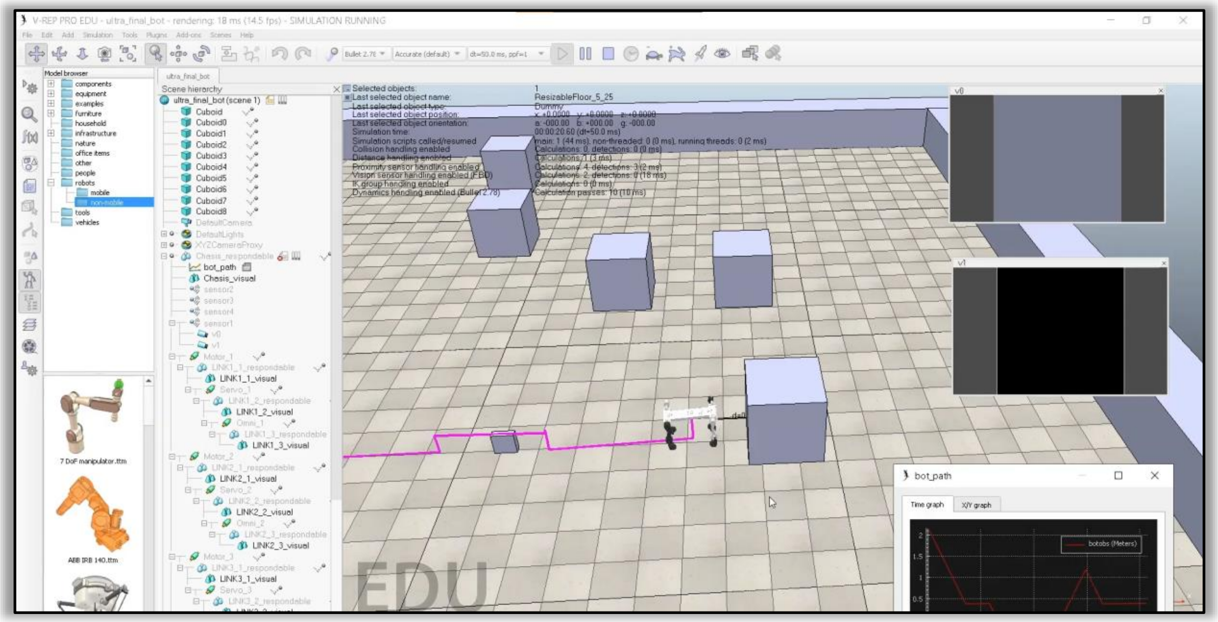


Figure 19. Detecting a Non-Overcomable Obstacle

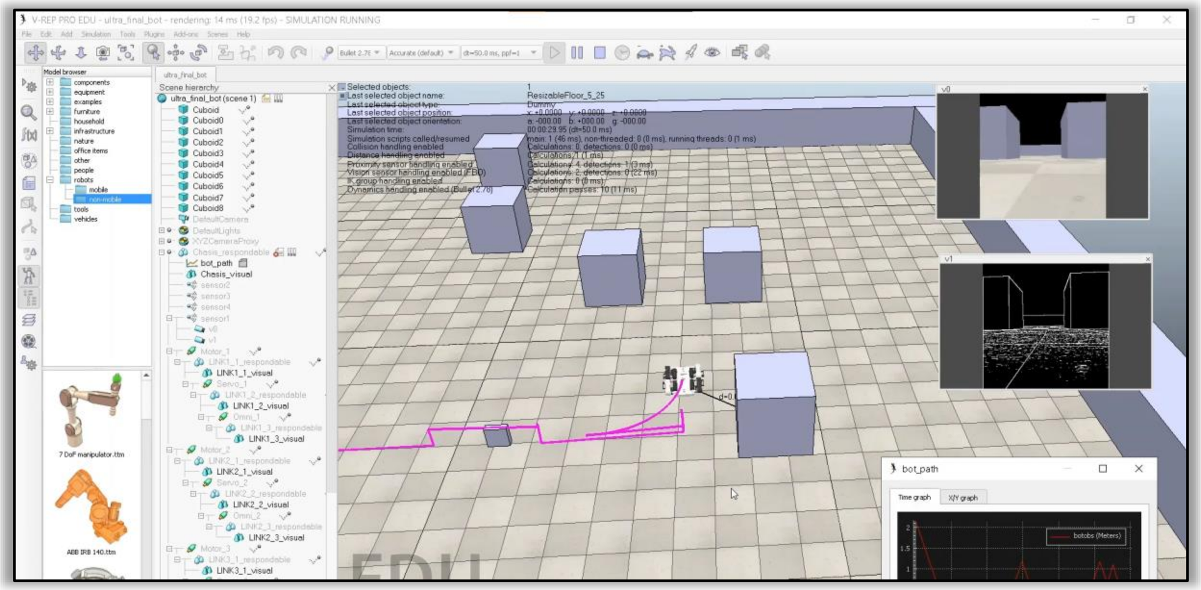


Figure 20. Obstacle Evasion

Robot Elevation

To increase and decrease the height of the robot, 4 high torque DC motors are being used synchronously. These motors have been PID tuned in MATLAB so that they can turn the required angle whilst holding the angle.

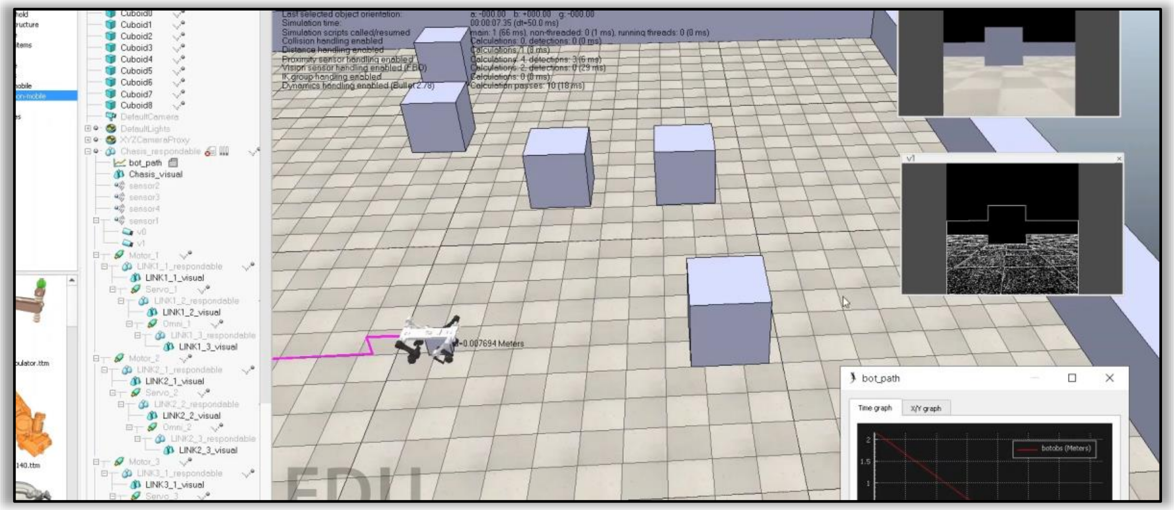


Figure 21. Overcoming an Obstacle

CHAPTER 3
APPLICATIONS

GOING THROUGH INACCESSIBLE LOCATIONS

Our robot, on account of its ability to increase and decrease its height, can fit into small places such as manholes and pipes. A camera can be mounted on the robot to get real time video fed back at the monitoring station. Other sensor can also be mounted on the robot to increase its versatility. For example, to find a crack inside a pipe, the most important methods used, which can fit to a mobile robot for pipe inspection are: computer vision systems (camera), magnetic field measurements and acoustic detection (microphone). And since our device is modular, it leaves plenty of space for more additions and changes.

SERVICE ROBOT

By putting a robotic arm onto our mobile robot, it can be tasked with picking and manipulating objects. Further if object recognition is enabled on the vehicle in the near future, the robot can be a truly versatile solution for helping in factories and major manufacturing industries. The robot can be sent to a fixed location where it will detect an object and transport it back without any human intervention.

CHAPTER 4
METHODS

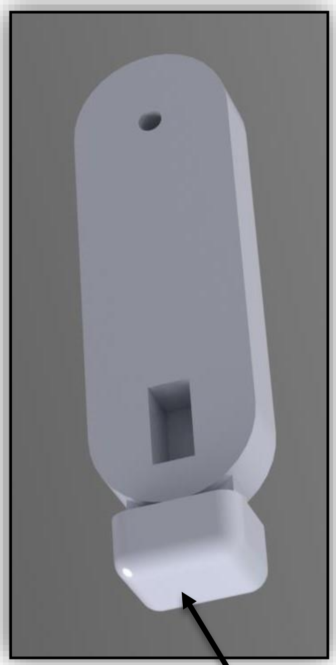
LIFE CYCLE OF THE PROJECT AND DEVELOPMENT

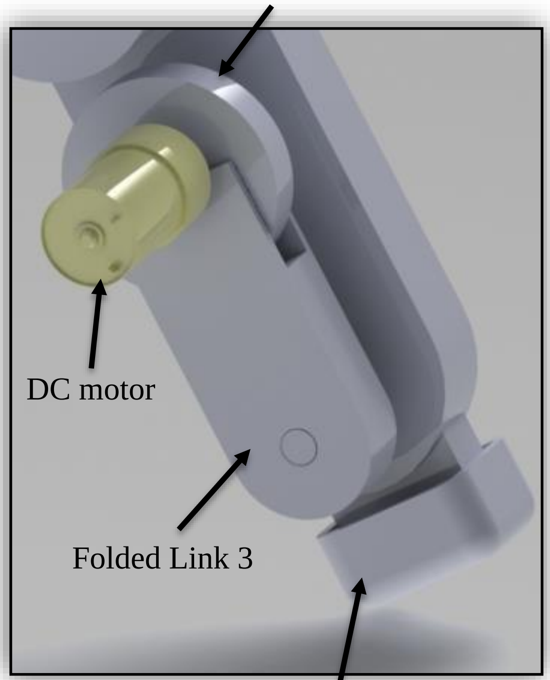
- The project initially was culminated through a group discussion to overcome suspension problems in mobile vehicles. The focus quickly shifted on how to create a system capable of overcoming obstacles without going around them or without changing the path which traditional systems do. A rough idea was created, and the design process was initiated.
- The CAD modelling defined the first major segment of our project. The assembly was divided into two main categories. A 3-link prototype and a 2-link version. For simplicity and ease of simulation the 2-link robot was selected while the 3-link version was kept as a standby.
- In the second phase, the chosen assembly was improved, the weight and dimensions were finalized, and, on that basis, electronic components were chosen. After computing the amount of static and dynamic forces acting on the body through free body diagrams, we ran a structural test on each component to check their capabilities. Once we were convinced that the design can manage the required forces, the design was finalized.
- The third major phase of the project involved simulating the behavior of the robot. By creating a virtual environment and adding obstacles and defining the behavior of our robot, we were able to accurately display the movements and visually confirm that our robot was following the movements we intended.
- The fourth phase saw the programming and circuit layout in proteus and tinkercad. Through this we were able to show the movement of the motors

according to our desired algorithm. For the motors on the chasis, a PID controller was designed in MATLAB to control the position of the motors.

FUTURE CONCEPT

- The future concept of the bot is a hybrid, improved version of the current bot.
- A CAD model showing the prospects of the robot was created.
- While retaining its feature to alter its height, the bot can now change its mode of locomotion from wheels to walking on feet/hooves. This is done by modifying an existing link and adding a third one.
- The robot will also be equipped with advanced obstacle detection systems which will improve this feature exponentially.
- This bot will also have better stability and improved dynamic abilities improving its multi-terrain capabilities.
- Solar panels and electric batteries may also be added to make the bot eco-friendly.





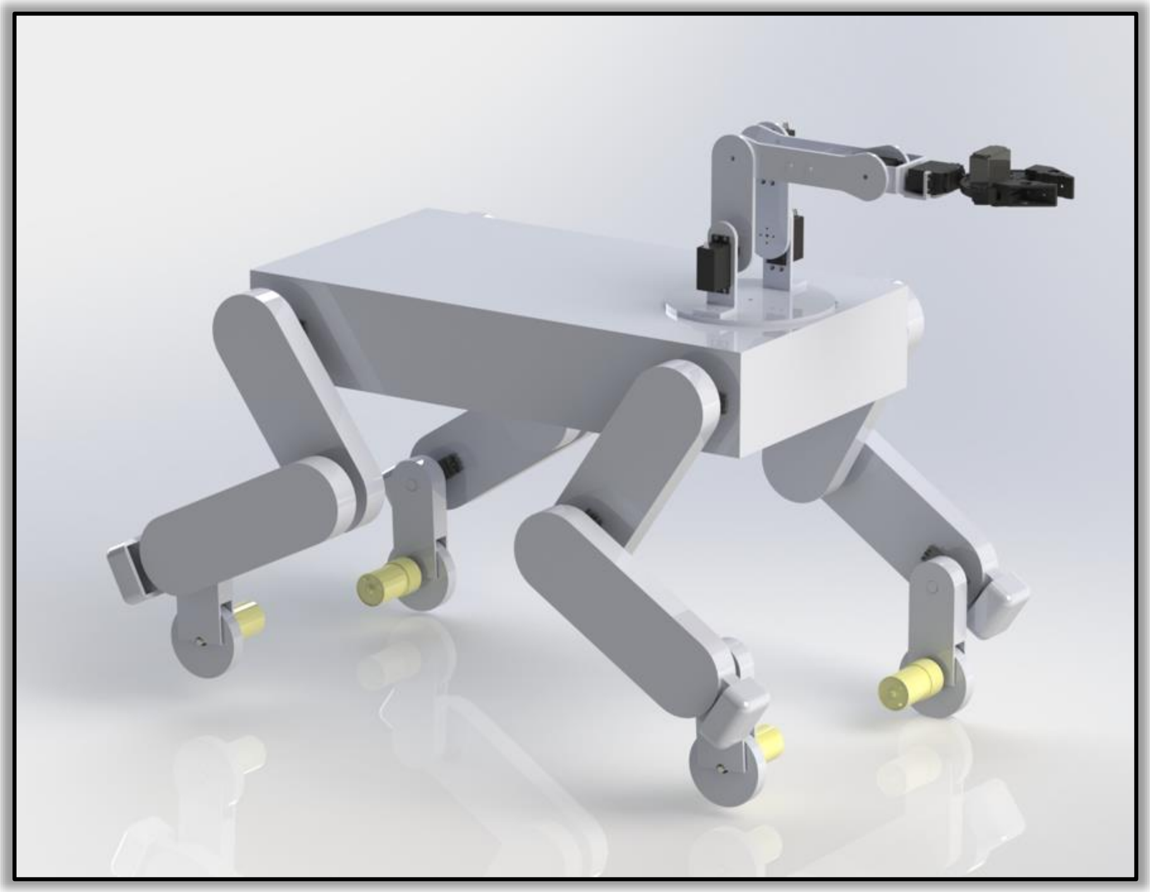


Figure 22. Free Wheeling Mode

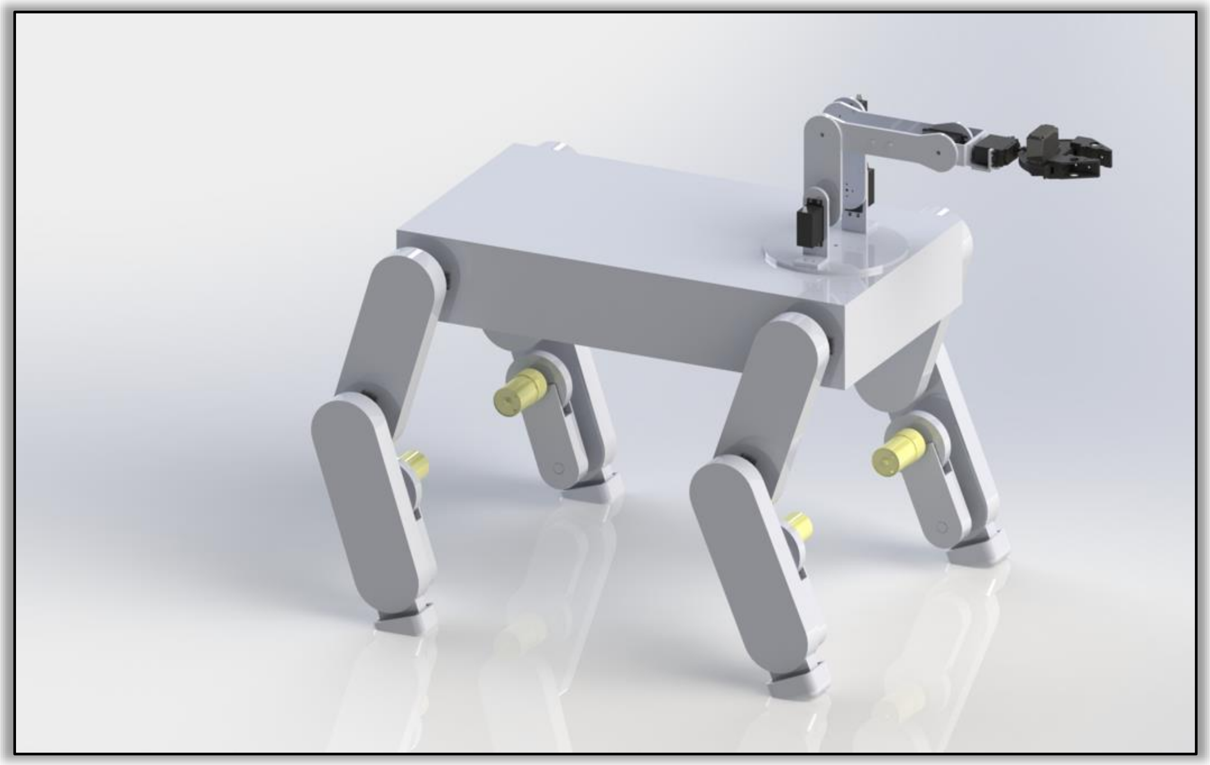


Figure 23. Walking Mode

CHAPTER 5
COMPARISON

COMPARISON WITH OTHER QUADRUPEDAL ROBOTS

Four-legged robots are also called Quadruped robots. An example is “Big Dog”. The comparison between our robot and theirs is the following:

- They are developed to traverse difficult terrain.
- They can exhibit quadrupedal motion.
- They can benefit from increased stability over two-legged robots, especially during movement.
- They can benefit from a lower centre of gravity than two-legged systems.
- In contrast to tripedal robots, four-legged robots are more popular.
- They use the alternating technique (in pairs) to walk.

Quadrupedal robots (Tetrapod robots) are statically stable, especially when no motion occurs. Stability features:

- They have 4-legs and their walking pattern is similar to that of animals.
- They are well balanced in posture.
- At slow speeds, they can move either by moving one leg at a time, ensuring a stable tripod or moving the alternate pair of legs to walk.
- Four-legged robots include The TITAN series, WildCat, Cheetah and the dynamically stable BigDog.

In contrast to other large-scale projects, our robot lacks the dynamic stability factor. But the concept behind both ideas remains the same. Other robots use a biologically inspired walking algorithm by lifting their legs to walk, while our project uses wheels to translate more like a conventional rover. On one hand, the gait system is more advanced and harder to implement. It provides stability but can also cause the vehicle to be slow. On the other hand, the wheel translation method used in our bot is generic and achieves a similar speed, if not faster. However, this comes with the drawback that the bot is not dynamically stable.

COMPLETE SCENARIO

The current scenario in the research and development of this field shows a good level of improvement every year. The prime example of this is Boston dynamics are the leaders in this field, and we have taken inspiration from them.

Overall, our robot can increase or decrease its height, detect and overcome an obstacle, along with the simple translatory motion.

CHPATER 6

CONCLUSION

Through this project, we have addressed a largely untapped issue using a very different approach. Most conventional collision avoidance systems either go around an obstacle or reverse their path. By thinking out of the box, we came up with the idea of going over and under the obstacles. Since this concept was relatively new for us, it gave us a unique opportunity to learn new notions and software which would aid the project. Not only were we able to create the robot from scratch and perform various engineering tests on the bot, but we also learned how to create a virtual environment and deploy a method or algorithm to detect an object. We made the robot act accordingly without physically making the robot. Like every other project, this too has areas for improvement, which are shown in the prospects CAD file. Overall, we believe that our robot has a good level of industrial applications and can at least satisfy the basic requirements of manufacturing and maintenance engineering.

CHAPTER 7
SUMMARY

In this project report, a brief synopsis of the approach and process of creating our folding robot was depicted.

First, the motivation behind selecting such a topic was discussed along with the concept of folding robots.

Next the main features of the system were discussed and bifurcated into mechanical and electronics. The applications of those features followed.

In the end, the life cycle of this project was illustrated and an overall scenario was shown depicting where our robot stands in comparison to other similar products.

A list of softwares used for the complete project is as follows:

1. Dassault Systems Solidworks 2019
2. Coppelia Simulator (V-REP)
3. Proteus Design Suite 8.0
4. Autodesk TinkerCAD
5. Mathworks MATLAB & Simulink

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