Design Practicum 2019 IC201P

Self-Transformable Quadruped Robot

Group 14

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Abstract

As legged robots are suitable to be used in unstructured environments, it becomes a popular field of research nowadays. These robots have many abilities, of which the most unique one is mobility. Many challenging tasks have been performed by mobile robots of many different designs. The terrain over which, these robots must be able to move is often uneven, slippery or muddy, which gives rise to many challenges, particularly stability. In this project, we are going to design a self transformable quadruped which would be able to overcome the unstructured terrains in environments. This robot will transform itself into the best form according to the external environment around it. It can walk on four legs, crawl on rough surfaces, can climb at a particular height (less than 15 cm), can climb on slopes(less than 40 ◦)and undergo narrow passage(greater than 7cm). Such types of robots can be used at such places where human reach is not possibles planetary exploration or any other rescue operation. In this way, it would be helpful for society as well as the technological advancement of our country.

Chapter 1

Introduction

1.1 Problem Statement

Everyone has an interest in learning about planets and the universe. What if, there is a help in observing and collecting data about different planets?

In various fields such as military and scientific exploration, we face unknown conditions and terrain. Robots have been used for some time now, but we still face challenges which require human interference now and then. So, the main problem this project aims to tackle is the movement of a body in different types of terrain.

1.2 Aim

Our aim is to build a Self-Transformable Quadruped Robot which will be able to overcome the problems mentioned above. It will be able to change its shape and orient itself according to the terrain for superior locomotion. It will be able to switch its shape for better and fast movement.

There are many areas where it is difficult for humans to reach. Our robot is a solution for such situations. Our robot is by-default in walking mode but according to the obstacles in front it will convert into:

1.) Crawling Mode: If it founds a rough surface.
2.) Car Mode: If it has to move beneath that obstacle.

1.3 Scope

Our Self-Transformable Quadruped Robot can be used in places which need specialized access such as military needs, emergency services, etc. It has a great scope in modern military surveillance and as it can access areas which makes it suitable for emergency and rescue operations. There has been an increasing demand for sophisticated technological equipment to automate these areas for a long time and thus it will be a great help in the above-mentioned fields

We want technology to be available to everyone and be easily accessible. Thus, by making a simple yet powerful solution at a cost-effective price we want to make our product to be used by organisations (like ISRO or Indian army).

Chapter 2

Review of Literature

2.1 Previously built four legged robots

Legged robots are basically used for avoiding the problems of traversing on multiple terrains. Many quadruped (four legged) and hexapod(six legged) were built previously. But these robots does not completely solve the issue of travelling on multiple terrains. Their degree of freedom is limited to three or four only. Normal quadrupeds are inefficient when it comes about travelling on irregular surfaces. Though they can walk on such rough surfaces but their efficiency decreases. Quadruped are having fixed height so they can't even travel through the narrow passage. When it comes about travelling on slopes we need some car form of the robots so that it can travel smoothly on slopes. Link below shows the basic design of quadrupeds build previously.

https://journals.sagepub.com/doi/full/10.5772/57351

Thus, due to such problems in quadrupeds and hexapods we need some other efficient mechanisms which can avoid the problems of multiple terrains. Our project is about the advancement of features of such quadruped robots. We are adding the feature of transformation in quadrupeds. Thus, the quadruped will transform itself into best form which is favourable according to external terrain.

2.1 Mathematics Involved

Mathematical calculations involved in walking mechanism is basically derived from inverse and forward kinematic equations. Each joint in the leg of quadruped act as separate coordinate system. Inverse kinematics equations are applied at these coordinates to find the positions or coordinates of leg for balanced movement of robot. The link below shows the inverse kinematics equations involved:
https://www.ijstr.org/final-print/sep2017/Inverse-Kinematic-Analysis-Of-A-Quadruped-Robot.pdf

2.3 Algorithms and walking methodology

There are different type of walking styles of quadruped robots. These walking styles are known as gait. The gait design are basically taken from the walking styles of four legged animals. The walking style of four legged animals is observed and the same style is implemented in these quadrupeds. Following are different types of gaits used in quadrupeds:

1.Creep Gait
2. Trot Gait
3. Crawl Gait

Details of the gaits is given in link below:
https://oscarliang.com/quadruped-robot-gait-study/

2.4 Other Inspirations

Inspirations of building a transformable robots came from the hollywood movie "**Transformers**", where the robots can transform themselves into various forms. Thus, in this project our inspiration is to make real world transformer robots.

Chapter 3

Report on the present investigation

3.1 Product Design

As our project's name describes, it has four legs each of which will contain 1 wheel, 4 180◦ servo motors and 1 360◦ servo motor connected by servo motors aluminium connectors. Apart from the legs, the robot has a base which is connected to all the legs and have Arduino Mega, Breadboard, Temperature and Humidity Sensor, Ultrasonic Sensor, LCD Display, Gyro Sensor, Bluetooth Module, power source on it.

The following images are the SolidWorks design for three different views:

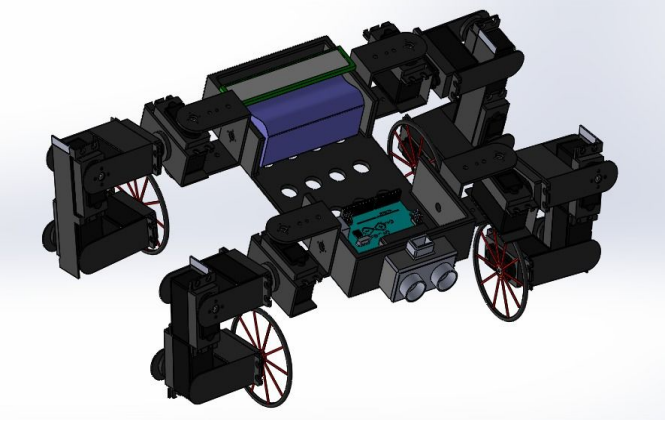


Fig3.1 Isometric View

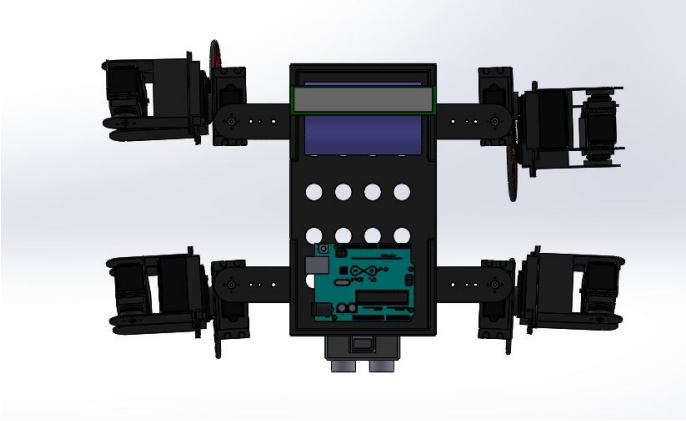


Fig3.2 Top View

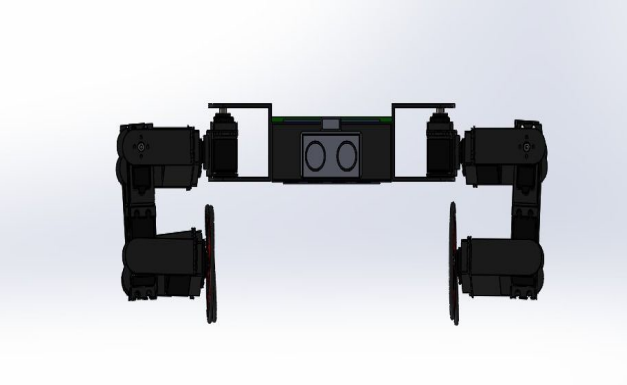


Fig3.3 Front View

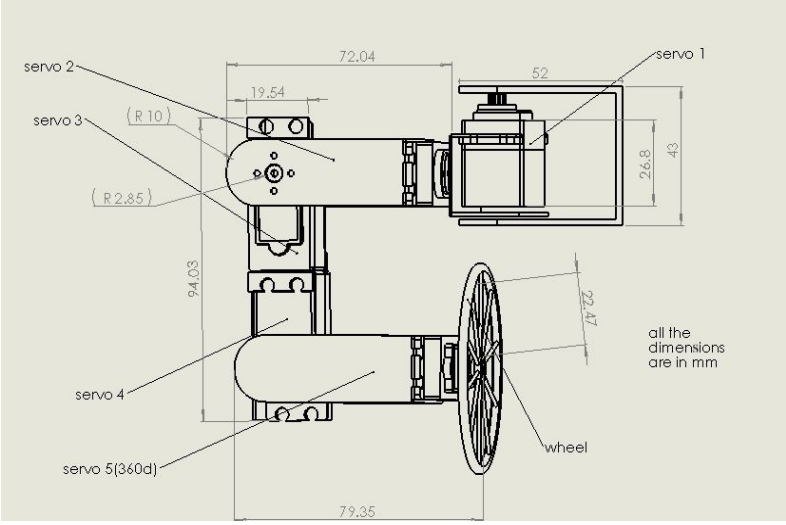


Fig 3.4 2-D representation our model for one leg

3.2 Components Required

3.2.1 Servo motors

High torque digital servo motors are used to control the movement of each leg. The servo motors used are ordered from the given link:
https://robokits.co.in/motors/high-torque-metal-gear-standard-digital-servo?gclid=Cj0KCQjwrJ7nBRD5ARIsAATMxsv5xjjrrStMTx3xZJXir7hqGon8OrekvUUp7wcSKlg2_27SveZmC8EaApvCEALw_wcB

For rotating the wheels of the robot 360 degree continuous rotation servo motors are used.

3.2.2 Servo brackets

Aluminium Brackets are used to interconnect the servo motors and to give support to them. Following different types of aluminium brackets are used:

1). Multipurpose aluminium servo bracket

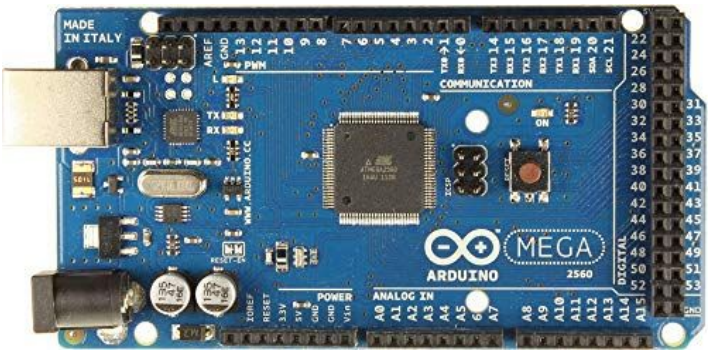
2). Short U shaped servo brackets

3). Interconnect aluminium brackets

All the above aluminium brackets are ordered from https://robokits.co.in/

3.2.3 Microcontroller

The microcontroller used in to control all the servos and sensors is Arduino mega. The **Arduino Mega** is a microcontroller board based on the ATmega2560.



Arduino Mega is the main control unit of the robot.

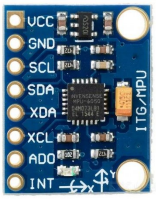
3.2.4 Sensors controls

Different types of sensors are used to sense the surroundings of the robot. Following are the sensors used:

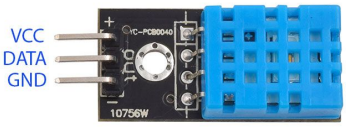
1). Ultrasonic sensor - Used to calculate the distance of obstacles in front of robot.

2). MPU6050 - It is the gyro sensor basically used for balancing the robot.

https://drive.google.com/open?id=19AO5x2D0czuYVMCEU0Zdnt5FkUdwpQg2



3). DHT11 Module - It is a temperature and humidity sensor which sense the temperature of its surroundings.



3.2.5 Bluetooth module

HC-05 a bluetooth module which is a transceiver is used to control the robot remotely from smartphone.

3.2.6 Jumper wires - They are the connecting wires used to connect the circuit.

3.2.7 Power source - A 4400 (2C) MAH 11.1V Li-ion battery is used to power the bot. Batter is ordered from https://robokits.co.in

3.2.8 16x2 LCD - It is used to display the distance of the obstacle, temperature and relative humidity.

3.3 Working Principle

3.3.1 Principle behind walking on four leg

Basic working principle behind the walking of self transformable quadruped is gait analysis and inverse kinematics. With the analysis of these equations and gait the help the bot to walk in balanced way. We are using trot gait for walking of our quadruped on four leg. In trot gait mechanism the diagonally opposite legs are lifted from floor and other two diagonally opposite legs moves backward which give the bot forward thrust and thus the bot moves forward from trot gait design.

The basic principle for balancing of the robot is that when one of the leg of the robot gets lifted in air, the other three leg must align themselves in such a way that the centre of mass of the bot remains inside the triangle formed by these legs.

3.3.2 Principle behind ultrasonic sensor

Ultrasonic sensor is used measuring the distance of objects from robot. Basic principle behind its working the emission ultrasonic sound wave (high frequency sound waves) in fixed interval. The speed of sound is taken as 334 m/sec.

The echo pin of sensor send ultrasonic wave which reflects back from the obstacle and received at the trig pin of sensor. The time of travelling of wave is calculated from sensor and the speed of sound is known, thus from distance of obstacle is calculated from formula:

Distance = Time * Speed

Distance = Time * 334

3.3.3 Principle behind MPU6050

The gyro sensor takes the input from its movement in x,y,z direction and gives the output between +17000 to -17000.

These values can be further mapped between 0 to 180 to control the servo motors.

3.3.4 Arduino Code

Following google drive link includes the arduino code which is running the robots-

https://drive.google.com/open?id=19AO5x2D0czuYVMCEU0Zdnt5FkUdwpQg2

3.4 Functionalities

As the name suggests, our robot will transform into different modes and the different functionalities we have implemented to achieve our project objective are:

- Walking
- On wheels
- Crawling
- Climbing a Height
- Move Up/Down on a Slope

3.4.1 Walking

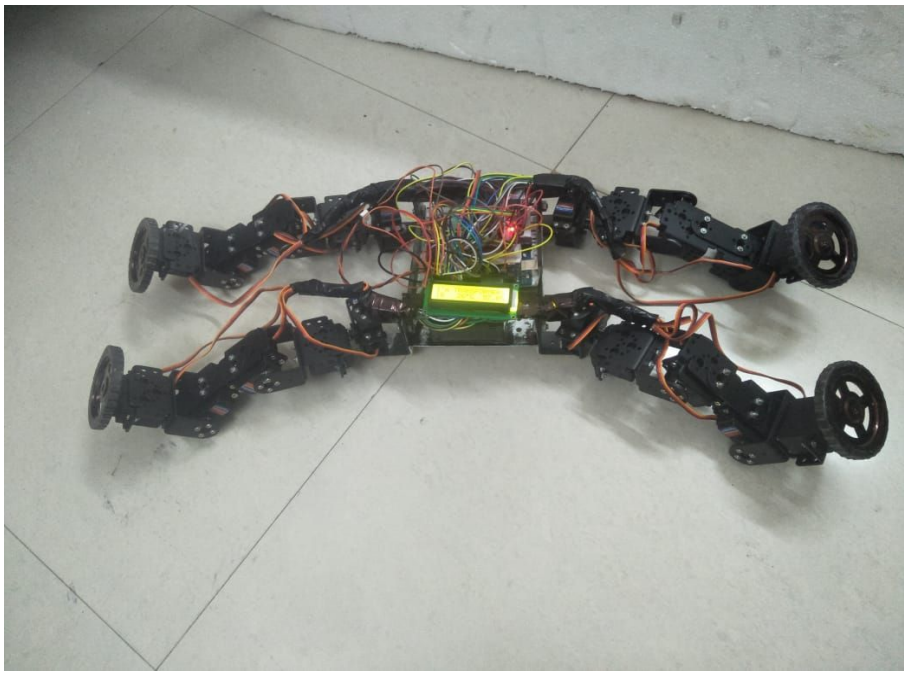
In this mode, the robot will be standing on 4 legs and will move on its four legs balancing its Center of Mass. Basically, this mode is for smooth surfaces.

3.4.2 On Wheels (Car Mode)

In this mode, the robot will be on wheels and will move like a car. This is for smooth and rough surfaces both. This mode is used when the robot has to cross a narrow passage(Greater than 15 cm). It is faster than the walking mode.

3.4.3 Crawling

In this mode, the robot will open its legs and start crawling. The mode is suitable for rough surface.



3.4.4 Climbing a Height

When height(less than 15 cm) is encountered, it will start climbing on that height.

3.4.5 Move Up/Down on a Slope

When it has to move on a slope it will convert in the car mode and can move down/up on a slope of less than 45◦.

3.4 How it is beneficial for society?

3.4.1 Military missions - Such transformable robots are useful in military missions. The bot can act as a spy robot. The camera attached can give the necessary informations.

3.4.2 Interplanetary Exploration - Such robots can be sent to different planets to know the living conditions on them. The temperature sensor and camera in it can be used to know useful information. Such a multi-terrain robot can avoid many difficulties in its path.

3.4.3 Rescue Operation - There are many places where human reach is not possible. I case of any emergency where human can't reach such robots can be used.

3.5 Cost Estimation

S.n	Name of component	Quantity	Cost (in Rs)
1	Arduino Mega	1	879
2	Jumper wires	130	260
3	Bread board	1	59
4	Ultrasonic sensor	1	99
5	Camera	1	419
6	Bluetooth module	1	329
7	Aluminum brackets for servo connection	36	4908
8	360 Servo Motor	4	2596
9	Servo Motor high Torque	16	17936
10	Nut and bolt (4mm)	30	140
11	Li battery	1	1338
12	Wheel	4	Dp lab
13	Gyroscope sensor	1	299
14	Servo driver	1	399
15	Temperature sensor	1	219

Total	29898

Chapter 4

Results and Discussions

We were successfully able to design, build, test, and innovate our Self-Transforming Quadruped Robot. From the initial concept of how the end product should look like, to the actual end product we were able to transform our imagination into reality.

Our product was able to crawl on rough surfaces, pass narrow passages having a height of greater than 7 cm, to climb stairs(less than 15 cm) and move on a slope(slope angle less than 40 ◦).

We explored and studied various topics, like inverse kinematics and got to know more about Arduino, different kind of sensors in detail to finally come up with a finished prototype. We are particularly happy by the transforming capabilities of our robot to adapt to the terrain, this is a very essential part as the whole idea of a quadruped robot revolves around the successful transformation when needed.

In the end, it was the dedication of our team and constant mentoring and guidance we were able to complete the task in the given schedule, money and timeline.

Chapter 5

Summary and Conclusions

5.1 Brief Report

Legged robots are the future of the technology but only legged robots are not much efficient. Thus,the their efficiency can be increased by making them transformable. Our project is based on the same. It can avoid the difficulties in walking on multiple terrains. This robot can climb on a particular heights, can crawl on rough surfaces, can walk on four legs, can go through narrow passage and is capable of run on slope.

5.2 Conclusions

We designed a prototype according to our concept. We tried to complete the project in the given budget and tried to get the maximum possible efficiency with the materials available and with the increase in the budget can lead to a far better product.

In present days, these technologies are less used in military purposes but it will be very useful and helpful for the army in the future and will also be helpful in the exploration of the planets.

5.3 Future Scope

Our project is just a prototype built in the given time duration and budget. But many improvements can be done and the efficiency of the product can be improved.

5.3.1 Automation of the robot

Right now, in our project due to poor quality of camera automatic change of mode is not possible but Automation can be done with the use of ultrasonic sensors and good quality of cameras, which will do the image processing and detect the obstacle by its own and change the mode according to the obstacle.

5.3.2 2-legged Robot

It is possible to move the robot on two legs also by balancing the Centre of Mass of the robot.

5.3.3 High Range and Fast Data Transfer

In our project, we have a range of 10m for data transfer using Bluetooth HC-05 module, but definitely, it can be increased using Wi-Fi and High Range Transmitter and Reciever. Also, the data transfer rate through the Bluetooth is slow, it can be increased.

5.3.4 Moving on Rough Surface

Right now we are limited with servo motors having only 15 kg-cm torque, as they are expensive(around Rs 1300 each and using 20 same servo motors), but there are many powerful servo motors available in the market which help our robot to move easily on a rough surface. As energy is dissipated due to friction and a part of the power supplied by the motors is required to overcome the friction, so sufficient energy does not reach the required material.

Chapter 6

Appendix

All the robots and robotic analysis is done on the basis of inverse and forward kinematics. The movement of robots is based on the inverse and forward kinematic equations. Inverse kinematics is the mathematical process of recovering the movements of an object in the world from some other data, such as a movement of robotics arms.
Following link show the study of inverse kinematics :
https://en.wikipedia.org/wiki/Inverse_kinematics
Following link pdf show the inverse kinematics equations and their proofs:
http://cdn.intechweb.org/pdfs/379.pdf

Chapter 7

Literature Cited

7.1 References

We were able to able to complete our quadpod robot with the help of the following references :

- A Novel Design of a Quadruped Robot for Research Purposes :
  By Yam Geva, Amir Shapiro
  https://journals.sagepub.com/doi/full/10.5772/57351

- Inverse Kinematics Analysis of a Quadruped Robot :
  By Muhammed Arif Sen, Veli Backircioglu, Mete Kalyoncu
  https://www.ijstr.org/final-print/sep2017/Inverse-Kinematic-Analysis-Of-A-Quadruped-Robot.pdf

- Quadruped robot GAIT study :
  By Oscar Liang
  https://oscarliang.com/quadruped-robot-gait-study/

- Robotics - Inverse Kinematics :
  By Connor
  https://www.youtube.com/watch?v=f9kxhj5bR6w

Chapter 8

Acknowledgements

We have taken effort to complete the project, however it wouldn't have been possible without the kind support and mentoring of our Advisors, and institute. We would like to extend our sincere thanks to all of them.

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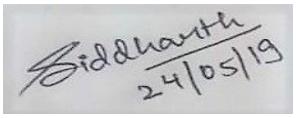
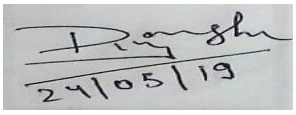
Our thanks to our TA and colleagues who have willingly helped us in the development of our project.

Siddharth Gupta



Divyanshu Kumawat



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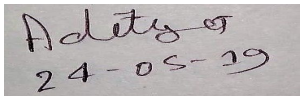
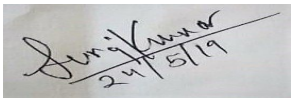
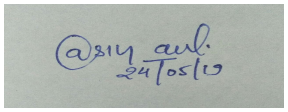


Suraj Kumar



Vikas Verma



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