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# Quadruped robot that uses central pattern generator to traverse terrains

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**ABSTRACT**

The main aim of this project is to design and fabricate a quadruped robot that can traverse through various terrains and exhibit different gaits. The different gaits of the robot are generated by a CPG (Central Pattern generator). Central pattern generator produces periodic motion for robots legs. In general, central pattern generator works even when the signals from sensors and brain are cut off. To stabilize the motion and detect obstacles a CPG has been proposed uses feedback from sensors to stabilize the robot's motion. CPG accepts inputs from a gyroscope and ultrasonic sensor and produces waveform for leg movements. The proposed model of the robot employs 'all-elbow' configuration for better pitch control in uneven terrains.

**Keywords:** Central pattern generator, Four legged robots, Legged robots, Quadruped robot, Quadrupeds.

## 1. INTRODUCTION

Legged robots or vehicles can traverse through various terrains which are inaccessible for robots with wheels. Wheels are designed to move only on prepared surfaces like smooth surfaces, roads, rails, etc. However, it's not the same condition with legged robots. Legged robots can fence or step over obstacles. Where as wheeled robots need to somehow move over it, or take a different path. A system on four legs is another walking scheme found readily in nature. Quadruped robots have the gain of maintaining static stability when not moving, but require control for dynamic walking. There are many diverse techniques for a quadruped robot to walk including alternating pairs and opposite pairs as in hexapod robots. The stability of four-legged animals depend on the position of the center of gravity. The center of gravity will be moved in to support polygon as soon as they lift one leg off the ground and enter in to swing phase. Quadrupeds transfer their body positions in a suitable manner to guarantee that the vertical projection of their COG on to the support surface falls within the support. Additionally, quadrupeds display a number of diverse periodic sequences of leg movements, such as canter , walk , crawl, and trot., which vary in the sequence in which the legs touch theground. The transition from one gait pattern to the next or another is related to speed and efficiency.

Four legged robots lies between two legged robot and six legged robots in terms of stability and control system. It is more stable than two legged robots but less stable when compared to six legged robots, especially when one or more legs is in swing phase. In terms of control system, four legged robots have control system which is less complex than six legged robots. Energy consumption is less when compares to six legged robots. The speed is also more when compared to six legged robots.

### 1.1. Literature survey

Estremera et al., [1] presented a method for generating free gaits for quadruped robots which are capable of carrying out omnidirectional locomotion on irregular terrain with static stability. The integration of terrain details has been given in addition to increase adaptability.

Shugen et al., [2] designed a successive gait-switching or transition method for a quadruped robot to exhibit omni directional static walking. The gait transition was achieved successively when compared to crawl gaits and the rotation gaits, while the feet hold in same or common positions after and before gait shift or transition. The gait-transition time duration is reduced by cautiously designing the foot pose of the crawl gait and the rotation gait, while limiting the feet in rectangular reachable motion ranges.

Pablo et al., [3] designed an artificial central pattern generator. The artificial central pattern generator is designed through a network of phase oscillators. Simulated robots areregulated or controlled by this central pattern generator using an interface that interpolates recorded or saved angular positions of their target poses.

Duc et al., [4] presented a unique Central Pattern Generator model for controlling four legged walking robots. A well-studied recurrent neural network is employed as oscillators to produce simple harmonic periodic signals that display limit cycle effects. Then, an approximate Fourier series is applied to convert those simple signals into random wanted outputs under the phase constraints of numerous primary quadruped gaits.

C.C. Brown et al., [5] designed and proposed a control system of a four-legged robot for operation on vertical landscape is explained. The necessity is that the trajectory of the robot should be varied continually on-line according to exteroceptivesensor data was addressed with the development of a temporal gait control strategy.

Cristina et al., [6] developed a locomotion controller, which is capable to producing omni directional locomotion and a controller for path planning to steer it to desired direction. The controller for heading direction is able to adapt to sensory-motor visual feedback, and adjust its trajectory according to the visual data that change the control parameters.

Liangwen et al., [7] described a stable workspace of a hand–foot-integrated quadruped walking robot, which is significant concern for stable operation of the robot. This robot was implemented with pooled structure of parallel and serial mechanisms, whose workspace was once the subspace of the workspace in which the system was treated as stable.

Lei et al., [8] proposed a technique for a quadruped robot control system based central pattern generator and fuzzy neural networks. A simple central pattern generator is adopted for a timing oscillator; which generates the periodic motion pattern of legs. Fuzzy neural networks are used here to control the motion of the joint to get a desired stable trajectory motion.

Jiaqi et al., [9] presented a central pattern generator Method and Trot Gait Design for a Quadruped Robot. The walking period and step length are set as constants to maintain a fast speed while changing different foot trajectories to examine walking quality. Experiments show that kicking the leg towards back improves stability of body. Then, a steady and smooth trot gait is designed. Furthermore, inspired by Central Pattern Generators, a central pattern generator model of series type is proposed to achieve dynamic and robust trot gait. It is generally believed that central pattern generator produces rhythmic movements, such as swimming, walking, and flying, even when separated from brain and sensory inputs. The central pattern generator model proposed is inspired by the series concept, and it can learn automatically the previous designed trot gait and reproduce it and the ability to change its walking frequency online as well.

Daniel et al., [10] described a simplified gait for a quadruped walking robot of forward type. The presented gait is a straight line, periodic, monotonically forward gait and can be used easily for adaptive gait control, requiring only little alterations. He demonstrated that support polygon generated by connecting the feet positions that are touching the ground, only certain order of leg movements will generate the SLPMF gait.

## 12. System portrayal

*Design*

Parts of the quadruped robot are body, link 1, link 2 and servomotors of the robot. The link 1 and link 2 are made with revolute joints. The link 1 will be connected to the body and link 2 will be connected to link 1.

*Main body*

The robot's main body is made of aluminum. Aluminium is used due to its properties like low weight, high strength, easy machining and excellent resistance to corrosion. The leg distance from each other is increased so that the movement of the each step will be increased and the limitation posed by the leg movement is addressed. The construction of the robot frame as per its dimensions finalized using Solid works.

*Control unit*

The Arduino UNO is a microcontroller board based on the ATmega328. AT mega is a single chip micro-controller created by Atmel. It has all components required to support the microcontroller. To control the servo motors and other sensors Arduino is used. Arduino is used to control the position of the servo motor.

*Motor Selection*

A servo motor is a rotary actuator it permits for precise control of the angular position. It consists of a motor and sensor for position feedback. And also, it requires a relatively complicated controller, to module designed specifically for the use of servomotors. The shaft of the motor is paired with encoder for providing position feedback. In the simple, the position is measured and considered output. Then, it is compared with required angle or position. If the output position differs from the required position, error signal formed which causes the motor to rotate in each direction. Then, as the position approaches, the error signal slowly reduces and turns to zero. The servo motors mounted on the robot is used to bring the robot leg to the required position

*Power source*

The Lithium polymer battery is used in this project. They are also called as LIPO batteries. Relatively low self-discharge. Self-discharging is less than other batteries. Low maintenance is sufficient for LIPO batteries. No periodic discharge is needed there is no memory. It provides 5.5 amps current and a voltage of 12.5 volts, which is sufficient for DC motor and servo motor use further. It requires protection circuit to maintain voltage and current within safe limits and moreover its cost is high when compared with other batteries. It is used in the project as it is comparatively small and has less weight, which is the main requirement of the project.

*Sensors*

To measure orientation of the body, GY-521 MPU-6050 module is used. It is a 3 Axis Gyroscope and Accelerometer. MPU-6050 contains a MEMS gyro and a MEMS accelerometer in a single chip. Using this sensor the orientation of the body is maintained.

To detect walls and obstacles, ultrasonic sensors are used. It contains a transmitter and receiver. Transmitter emits a beam of ultrasonic waves for a very short duration. Receiver picks up the deflected waves. The time duration between transmitted and received waves is used to find the distance between them.

## 2. METHODOLOGY

An apt methodology is followed to select suitable mechanism, kinematic concept and design for the quadruped robot. First initialize the drawing robot design, select suitable link lengths and calculate the joint angle according to the workspace limitations.

### 2.1. Design consideration

The quadruped robot is designed with proper dimensions using SOLIDWORKS software. Body, motor and legs are designed and assembled. Fig. depicts the entire assembly of the robot. The body is designed in such a way that the robot can maintain stability even one or more leg is in the swinging phase. The frame is constructed in such a way it provides proper support to other links in an efficient manner. Frame is built in the form of H shape to provide a light weight robot.

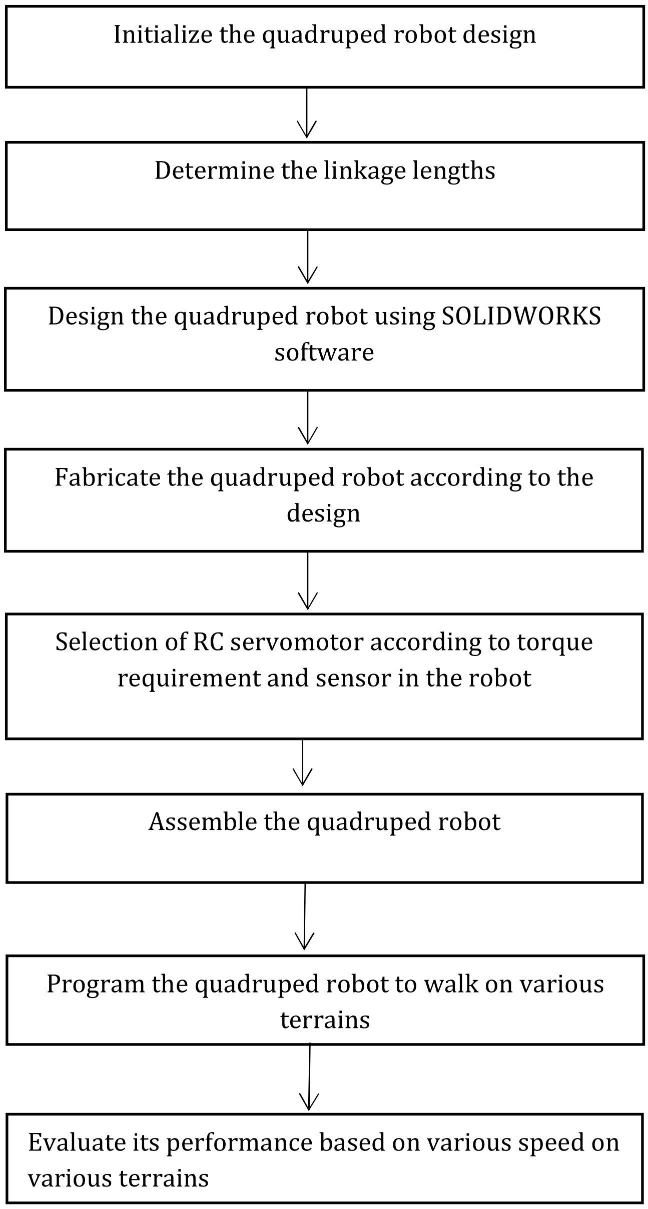


**Figure - 1: Methodology flow chart**

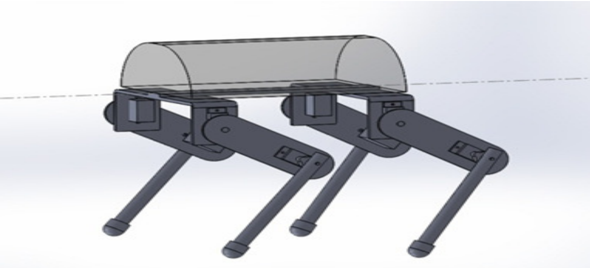

**Figure - 2: CAD model of the prototype**

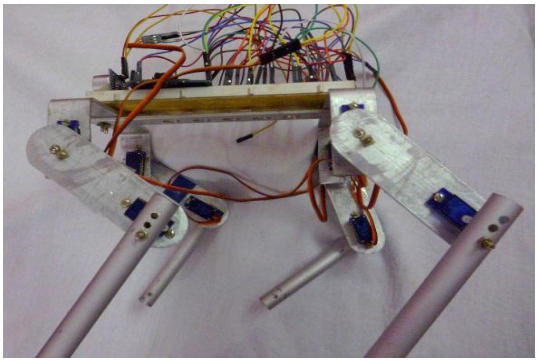

**Figure - 3: Physical model of the prototype.**

**Table - 6: D-H parameters**

| | a | α | d | θ |
|---|---|---|---|---|
| D-H Parameters | L1 | 0 | d1 | θ1 |
| | L2 | 0 | d2 | θ2 |

The overall transformation matrix for forward kinematics can be represented as,

$$T = {}^{0}T_2 = {}^{0}T_1 * {}^{1}T_2$$

$${}^{0}T_1 = \begin{bmatrix} C1 & -S1 & 0 & L1C1 \\ S1 & C1 & 0 & L1S1 \\ S2 & 0 & 1 & d1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^{1}T_2 = \begin{bmatrix} C2 & -S2 & 0 & L1C1 \\ s2 & C2 & 0 & L2S2 \\ 0 & 0 & 1 & d2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$T = \begin{bmatrix} C12 & -S12 & 0 & LIC1+L2C12 \\ S12 & C12 & 0 & L1S1+L2S12 \\ 0 & 0 & 1 & d1+d2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Where,

L1 =Length of link 1

L2 =Length of link 1

C1 = cos θ1

S1 = sin θ1

C12 = cos (θ1 + θ2)

S12 = sin (θ1 + θ2)

d1 = joint distance from link1 to frame origin

d2=joint distance from link2 to frame origin

Fig.3 depicts the kinematics analysis of the robot leg with RR configuration obtained via MATLAB

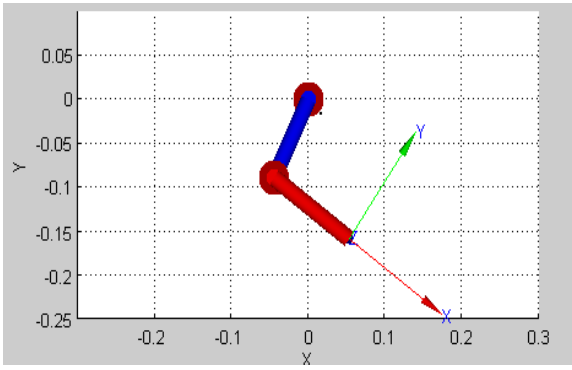


**Figure - 4: kinematic model.**

## 3. CONCLUSION

The quadruped robot is capable of traversing through various solid surfaces. The quadruped robot is also capable of climbing stairs. Design trails were made and corrected using SOLIDWORKS software. This robot can detect obstacle on its pathway and change its path accordingly. Fabrication of the design was done and experiments were carried out on the quadruped robot to analyze its efficiency. Further a camera can be fitted to the robotin addition to detecting the obstacle it can identify itby employing image processing algorithms. It can alsobe used to do terrain evaluation and path planning.

## 4. REFERENCES

1. Estremera, J and Santos DE. Generating continuous free crab gaits for quadruped robots on irregular terrain. **IEEE Transactions on robotics.** 2005; 21: 1067 – 1076.
2. Shugen MA, Tomiyama and Wada. Omni directional static walking of a quadruped robot, **IEEE Transactions on Robotics.** 2005; 21: 152 – 161.
3. Pablo, Kaluza, Teodor and Cioaca. Phase oscillator neural network as artificial central pattern generator for robots. **Neurocomputing,** 2012; 97: 115-124.

4. Duc, Trong, Tran, Ig, Mo, Koo, Yoon, Haeng, Lee, Hyungpil, Moon, Sangdeok, Park, Ja, Choon, Koo, Hyouk, Ryeol and Choi. Central pattern generator based reflexive controlof quadruped walking robots using a recurrent neural network Robotics and Autonomous Systems, **Robotics and Autonomus systems,** 2014; 62: 1497-1516.
5. Brown CC and Huissoon JP. Temporal gait control of a quadruped robot. **Robotics and Autonomus systems,** 2000; 30: 305-314.
6. Cristina P, Santos and Víto R Matos. CPG modulation for navigation and omni directional quadruped locomotion. **Robotics and Autonomus systems,** 2012; 112: 102-106.
7. Liangwen Wang, Wenliao Du, Xiaoqi Mu, Xinjie Wang, GuizhongXie and Caidong Wang. A geometric approach to solving the stable workspace of quadruped bionic robot with hand–foot-integrated function. **Robotics and Autonomus systems,** 2016; 37: 68-78.
8. Lei, Sun, Chinese, Acad, Hefei, Meng M. Wanming, Chen, Huawei and Liang. Design of Quadruped Robot Based CPG and Fuzzy. **Neural Network.** 2007; 23: 18-21.
9. Jiaqi, Zhang, Feng, Gao, Xiaolei, Han, Xianbao, Chen, Xueying and Han. **Trot Gait Design and CPG Method for a Quadruped Robot.** 2014; 11: 18-25.
10. Daniel J Pack and Kakc AC. An Efficient Forward Gait Control fora Quadruped Walking Robot Intelligent Robots and Systems. **Transactions of gait control,** 1995; 1: 533-548.