Quadruped Robot with Speed and Direction control

Rohit Ranjane[1], Rutuja Chavan[2], Radhika Mahajan[3]

[1,2,3]*Students, Dept. of Electronics and Telecommunication Engineering, Pimpri Chinchwad College of Engineering, Pune, Maharashtra, India*

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Abstract - *Quadruped Robots are currently still in their early stages of development, they present many advantages due to their high mobility and ability to traverse rugged terrain as opposed to conventional wheeled robots. The objective of this project is to design and manufacture an autonomous quadruped robot which should be capable of walking in different terrains and avoid obstacles. At the same time, it should be able to change its direction and speed in order to follow the given path. While doing so we have to consider various aspects of robot such as walking mechanism, stability, motors/actuators selection, efficient power distribution, circuit protection, efficient algorithm, avoiding any unwanted condition like stalling of motors.*

***Key Words*: Quadruped, Robot, Autonomous, Micro-controller.**

1. INTRODUCTION

Robotics is essentially the concept of creating machines that lessen human effort and can operate autonomously. The idea dates back to classical times, but research into its potential uses and applicability was not fully realized till the 20th century. The role of robotics has often been to mimic human behavior and manage tasks in a similar fashion. Today, this field is so rapidly growing that the research, design, and building of new robots serve various practical purposes, whether domestic, commercial or military. Another aspect that has been gaining momentum in recent years is that of walking machines and their extraordinary benefits and advantages over wheeled robots. However, the major obstacle that needs to be tackled in all these different applications is that of energy efficiency, stability and motion planning. The plan is to incorporate all these aspects into one model and find optimal configurations for walk-gait of a quadruped.

1.1 Objectives

- To design and manufacture an autonomous quadruped robot which is capable of walking in different terrains
- To develop the quadruped robot in such a way that it should be able to change its direction and gait cycle as per the conditions
- To develop the image processing capabilities of the Quadruped to recognize its surroundings

1.2 Problem Statement

To develop and manufacture an Autonomous Quadruped Robot which shall be able to walk over various terrains and recognize its surroundings

2. METHODOLOGY

2.1 Block Diagram

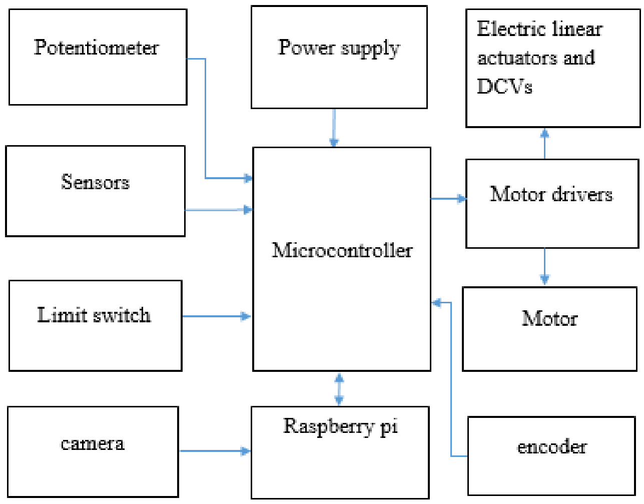


Fig-1: Block diagram

STM32 F4 Discovery micro-controller board and Arduino Nano were used for handling the processing capabilities in this project. Both can be easily interfaced with computers, motor-drivers and various sensors

The STM32 F4 discovery board was the main micro-controller board and it acted as the master, while the 5 other Arduino nano boards acted as slaves. The Raspberry Pi 3 Model B was used for handling the image-processing capabilities of the robot. The sensors were interfaced to the STM32F4 board. All of the above components were powered with the help of 4s LiPo battery.

The Hardware components used :

1. Microcontroller boards (STM32F4 Discovery board and Arduino Nano)
2. Raspberry Pi
3. Electric linear actuators
4. Motors

5. Motor drivers
6. Batteries
7. Buck Converter
8. Direction control valve
9. Logic Level converter

The sensors used were :

1. Proximity Sensor
2. MPU6050
3. Rotary Encoder
4. Potentiometers
5. Camera

2.2 Working

The STM32F4 Discovery board was used as the Master Micro-controller, and the other 5 Arduino Nano boards were used as slave micro-controllers. The responsibility of the Arduino Nano boards was driving the Linear actuators and managing the stability of the robot by the data received from MPU6050 gyroscope. All of which in turn helped the Robot to move, as they were used for driving the legs.
The proximity sensor was used for Detecting the objects in front of the Robot. The potentiometers were used for measuring the angular travel of the legs between the joints. The MPU6050 was used for determining the position of the robot by determining its Axial co-ordinates. The camera was used for detecting the surrounding objects, it was interfaced with the Raspberry Pi.

3. Specifications

3.1 Hardware Specifications

3.1.1 STM32F4 Discovery

The STM32F4DISCOVERY kit leverages the capabilities of the STM32F407 high performance microcontroller.

Table-1: Specifications of STM32F4 Discovery board

Micro-controller specifications	32-bit ARM Cortex-M4 with FPU core,1-Mbyte Flash memory, 192-Kbyte RAM in an LQFP100 package
Power Supply	Through USB Bus or from 3V to 5V external power supply
On Board sensors	LIS302DL or LIS3DSH ST MEMS 3-axis accelerometer. MP45DT02 ST-MEMS audio sensor Omni-directional digital micro-phone.

3.1.2 Arduino Nano

The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328P. It has 30 pins. The 8 pin of them (19-26 pin) are Analog pins. While the other 14 pins are Digital pins. Arduino Nano has 8 channel ADC (Analog to Digital Converter) Through the RX and TX pins you can communicate serially with other devices. It has 2 pin interrupt, namely int0 and int1.

Table-2: Specifications of Arduino Nano

Micro-controller	Atmel ATmega328
Operating Voltage	5V
Input Voltage	7V to 12V
Digital and Analog I/O Pins	14 Digital Pins (Of which 6 provide PWM output) and 8 Analog Pins
Clock Speed	16 MHz

3.1.3 Raspberry Pi 3 Model B

Raspberry Pi is an ARM based credit card sized SBC (Single Board Computer) created by Raspberry Pi Foundation. Its specifications are as follow:

Table-3: Specifications of Raspberry Pi 3 Model B

Micro-processor	1.3 GHz ARM Cortex-v8 Quad Core
RAM	1GB SDRAM
Power Supply	Up to 5V, 2.5A
USB	14 Digital Pins (Of which 6 provide PWM output) and 8 Analog Pins
Ports	4 USB Ports (USB 2.0), Micro SD slot
GPIO	40 Pins
Graphics	VideoCore IV 3D graphics core
Camera interface	CSI port for connecting the Raspberry Pi camera

3.1.4 Electric Linear Actuator:

Electric linear actuators provide linear movement of piston/rod with the speed proportional to applied voltage. It consists of motor, gear box, lead screw and rod. When motor rotates, its rotary motion gets converted to linear motion with help of gear box-lead screw assembly. There are two limit switches on both sides of stroke so that minimum and maximum position is limited.

Table-4: Specifications of Arduino Nano

Voltage rating	12 V
Load Carrying Capacity	200 N
Stroke Length	50mm
Speed	45mm/sec

3.1.5 Battery

Lithium polymer batteries are used for meeting the power requirements of the Robot. LiPo batteries (short for Lithium Polymer) are a type of rechargeable battery that has taken the electric RC world by storm, especially for planes, helicopters, and multi-rotor/drone. They are the main reason electric flight is now a very viable option over fuel powered models. RC LiPo batteries have four main things going for them that make them the perfect battery choice for RC planes and even more so for RC helicopters over conventional rechargeable battery types such as NiCad, or NiMH.

- RC LiPo batteries are light weight and can be made in almost any shape and size.
- RC LiPo batteries have large capacities, meaning they hold lots of energy in a small package.
- RC LiPo batteries have high discharge rates to power the most demanding electric motors.
- Unlike NiCad or NiMh; LiPo's have no "memory-effect".
- These batteries provide high energy storage to weight ratios, are capable of safe fast discharges, and can be configured in an endless variety of voltages, capacities, shapes, and sizes.

Table-5: Specifications of Battery

Capacity	8000mAh
Constant Discharge	40C
Max Discharge	50C (10 sec)
Balance Plug	JST-XH
Discharge Plug	4mm HXT
Charge Rate	1-3C recommended, 5C Max

3.2 Mechanical Design Specifications:

Overall Dimensions	(938 x 418 x 754) mm (L x W x H)
Material	Stainless steel, Aluminum, Nylon-66
Estimated weight	17kg
Link length 1(upper)	274 mm
Link length 2(lower)	248 mm
Maximum source voltage	24V
Maximum allowed pressure	600KPa

Table-6: Mechanical Design Specifications

4. TECHNOLOGIES USED

4.1 Image Processing

For image processing, OpenCV and NumPy libraries with python programming language were used.

OpenCV: OpenCV was designed for computational efficiency and with a strong focus on real-time applications. Written in optimized C/C++, the library can take advantage of multi-core processing.

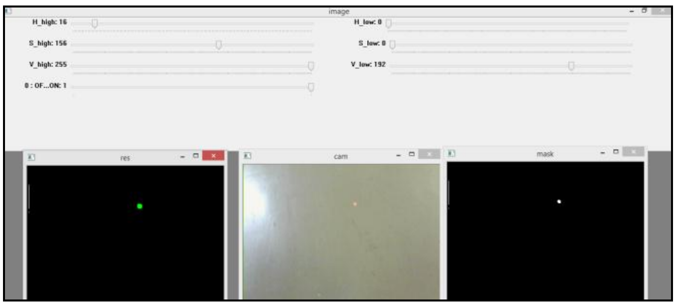
NumPy: NumPy is a library for the Python programming language, adding support for large, multi-dimensional arrays and matrices, along with a large collection of high-level mathematical functions to operate on these arrays.

PYTHON IDLE was used for programming. IDLE is an integrated development environment for Python, which has been bundled with the default implementation of the language.

Implementation for Laser detection using Image Processing:

- At first, the ranges for H (hue), S (saturation) and V (value) of laser light need to be set manually in order to apply mask to captured image and then get the co-ordinates of the contour at the output
- The second step is to verify the coordinates for their similarity.

With the help of this the robot can be controlled.



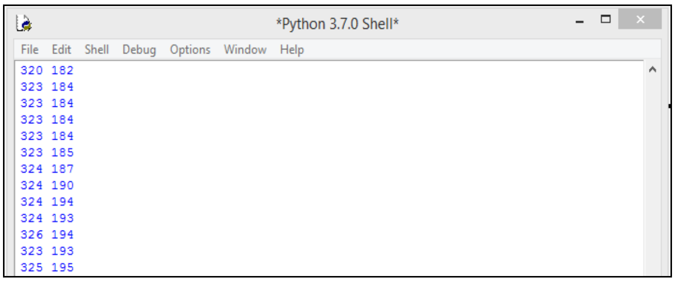


Fig-2: Simulation results for Laser detection

Implementation for detection of Horizontal and vertical lines for following a specific path:

- For detecting any line in the image, we have used 'Hough transform' providing certain parameters such as size of line it can detect.
- Once lines are detected, next step is to filter out only horizontal line. This is done by examining angle of the line from origin of coordinate system.
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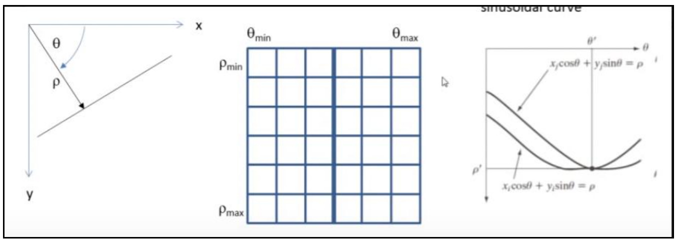

Fig 3: Parametric description of a straight line

- If θ is 90°, then detected line is horizontal. The following fig shows the detection of horizontal line.
- Once line detected, we can also examine color of that line by determining HSV/BGR values of coordinates of line

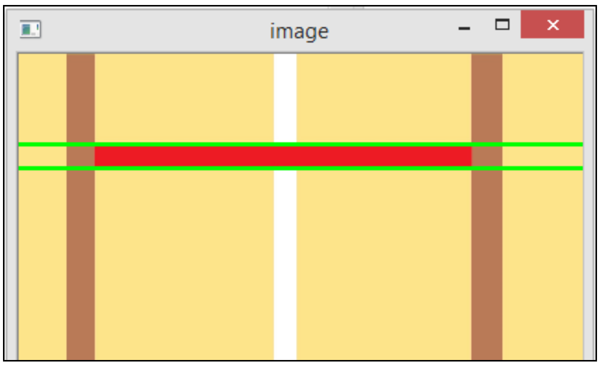

Fig 4: Detection of horizontal line

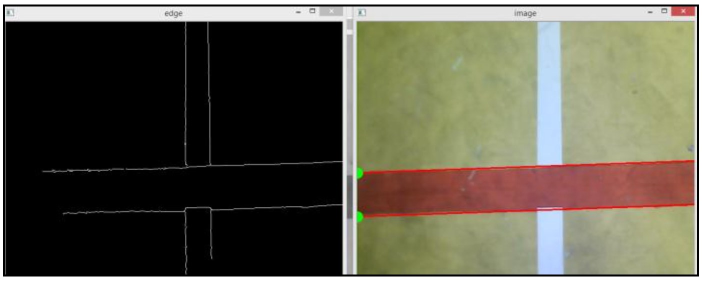

Fig 5: Testing results of detection of horizontal line

4.2 Use of Gyroscope:

In order to have straight walking, MPU6050 is used. It is interfaced with Arduino nano and respective data is serially communicated to STM32F4 board. Arduino nano monitors continuous reading of MPU6050. At the start of every cycle of walking, reading from nano is checked. This reading gives angle by which robot is deviated. If robot is deviated to right, push of right legs is increased and push of left legs is decreased. Similarly, if robot is deviated to left, push of left legs is increased and push of right legs is decreased. This helps the robot to achieve a straight walk over a guided path.

5. Actual Setup

5.1 Mechanical Setup

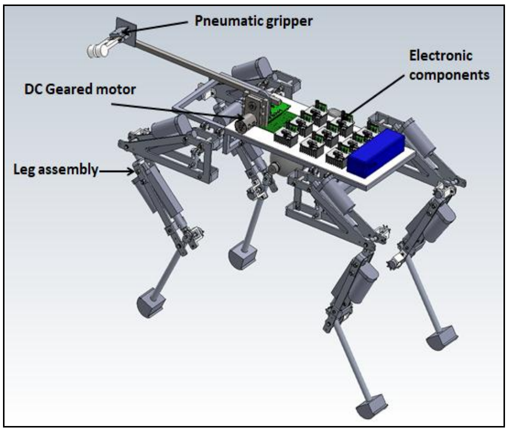

Fig-6: Mechanical design of the Robot

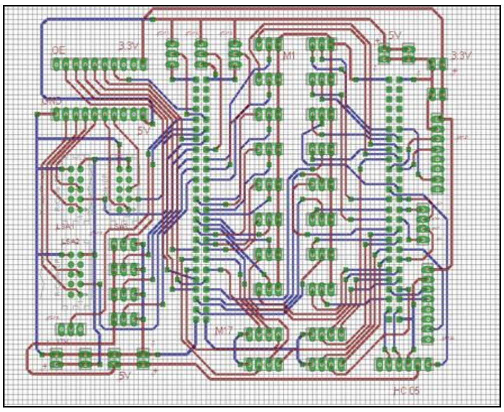

Fig-7: PCB Design

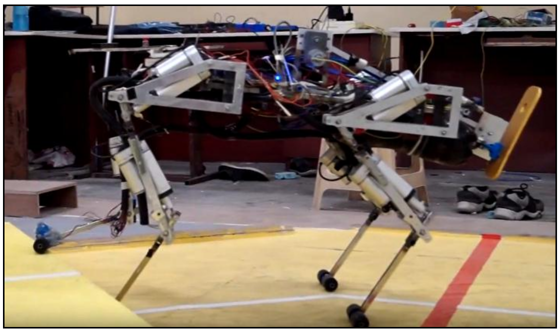

Fig-8 : Actual walking of Robot

6. CONCLUSION

We designed an Autonomous Quadruped robot which is able to sense its environment such as the obstacles present in its path. With the help of this detection, the walking mechanism of the robot can be changed accordingly while maintaining the stability of the robot. The motion planning is done through active sensor feedback and terrain detection with the use of a suitable control unit, various sensors, actuators, electronic components and applying the suitable algorithm to achieve the desired output. The legged robots are more advantageous than the wheeled robots because of their ability to walk in different terrains.

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