Small Campaign, Outfield and Uneven Terrain Walking Robot

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***Abstract*— We have designed a Four Legged Robot with each leg having three degrees of freedom. Legged Robotics is inspired from nature for fast, efficient and versatile movement. We have achieved it through coordinated movement of joints, which enables adaptation to environment and improved mobility. Our Objective was to replicate the animal motion and increase mobility as compared to wheeled robotics.**

I. Introduction

Our objective was to design a four legged robot which is capable of moving on an uneven terrain. The mechanical design of the robot should resemble the Pronograde Posture (walking with the body parallel to ground) of an animal. The servo motors attached to the joints in all four legs will help in achieving Quadrupedal mode of locomotion.

The algorithm has been specifically designed to develop a gait pattern that could maintain the stability of the robot with each deliberated movement. A camera has been mounted at the top to display live video during locomotion.

The secondary objective comprises of condition monitoring i.e. displaying the outputs of accelerometer, temperature sensor and current sensor on GUI and Wireless Communication.

Legged Robots are capable of moving on irregular terrains because of their ability to vary their legs configuration. Therefore legs are inherently adequate systems for locomotion on uneven terrains. The area of contact between the foot and the surface on which the robot is moving can be made in such a way that the ground support pressure is significantly small as compared to wheeled robots. Multiple Degrees of Freedom in the leg joints legged makes legged robot capable of changing the direction of heading without any slippage. The height of robot body can be varied. Damping and decoupling effect between terrain irregularities and the body can be introduced. As a result of which legged robots exhibit superior mobility on naturally occurring terrains.

We have designed an algorithm in which with each leg movement, the weight is instantly shifted to other three legs of the robot to prevent it from losing its balance. This mechanism enables the robot to retain its stability with each deliberated movement.

II.. Block Diagram

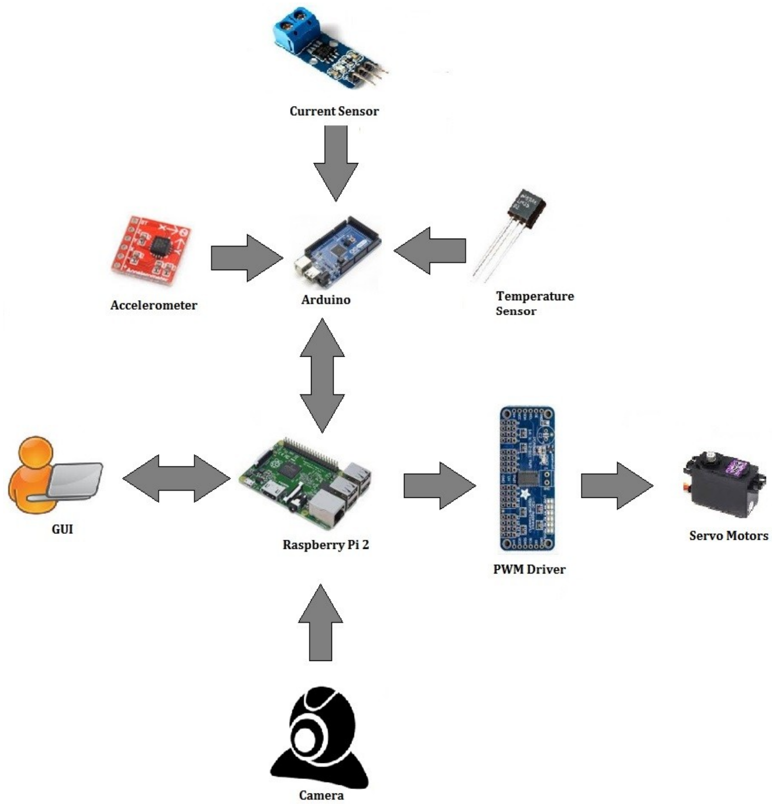

Fig.1. Block Diagram

III. Algorithm

The main problem in making the robot walk was the weight of the base. We had to shift the weight before each leg motion or else the robot would fall down. To overcome with this issue we applied weight shifting technique according to which, before pulling any leg off the ground the weight was distributed on the other three legs such that the robot is balance on just three legs. This solved our weight shifting problem and we could easily lift any leg of the robot without making it fall.

The next problem was to make a pattern of legs motion that can be run in a loop for continuous walk of the robot. Since we were going for sensor less control of the robot, this task was very difficult to achieve. After trying a number of gait patterns we came across one that could be used. The trick was to bring legs at same position as they were at the start of the motion. This resulted in reduced step size but we were able to run the code in loop.

IV. Mechanical Design

Throughout the project we tried to keep the mechanical portion of the project simple and used easily available materials. There were two options in consideration for the material of the body - Aluminum or Acrylic. Both of them have their own merits and demerits. Both of the materials are light weight. Aluminum is much stronger but according to our requirements we didn't need strength as much, as we needed less weight because of the limitations of the actuators. So we decided to go with acrylic because of its light weight and easy machinability.

A. Leg Design

Legs of the robot were designed by keeping in mind the core requirement that they must have three degrees of freedom and the limitation of time. Each Leg consists of three parts. Lower Leg, Upper Leg and link. Upper leg and lower leg are very similar in shape. They vary in length and thickness. Four bearings are installed in Upper Leg (two at each end) so that lower leg, upper leg and link can freely rotate with respect to each other.

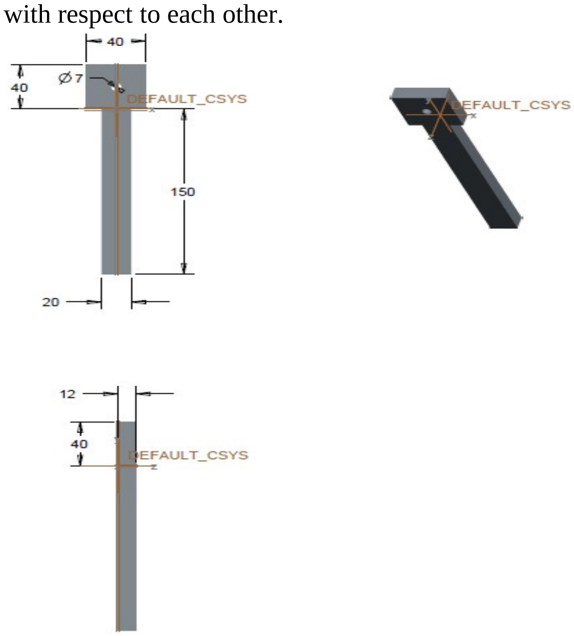

Fig.2. Lower Leg

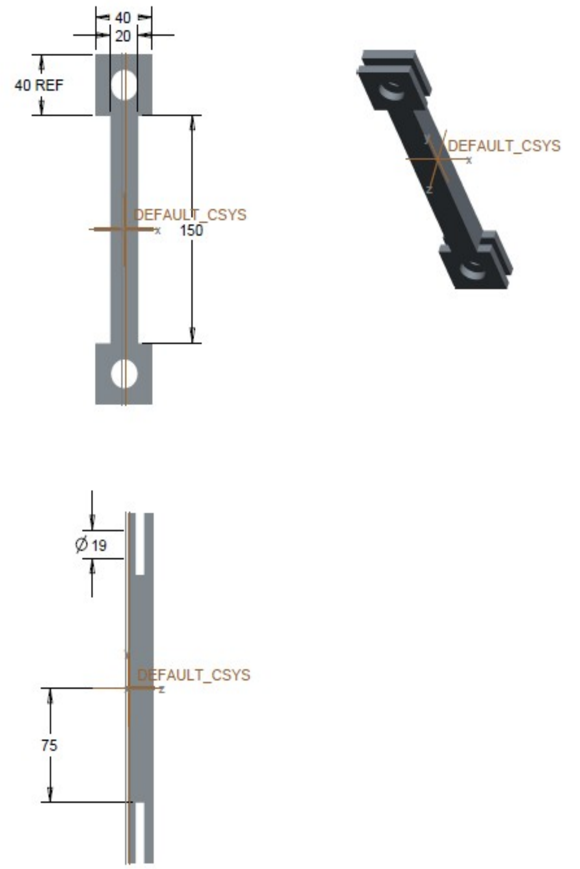

Fig.3. Upper Leg

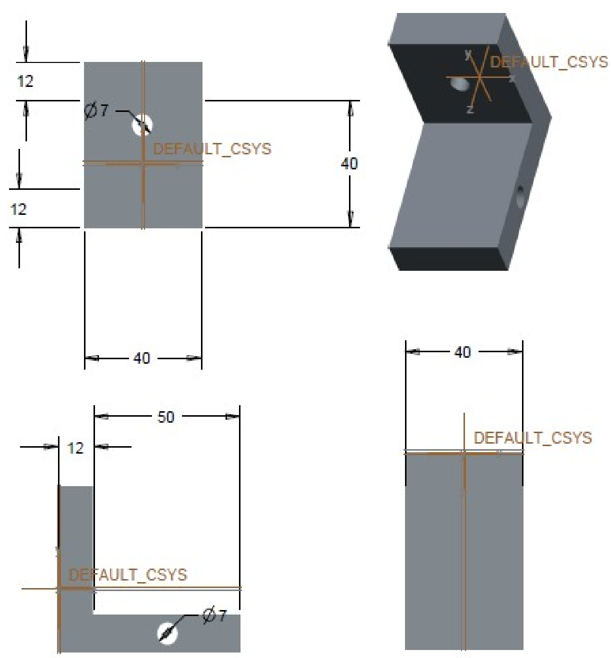

Fig.4. Leg-Base Link

B. Base Design

Base of the robot is a rectangular sheet of 8mm thick acrylic sheet. Its dimensions are 300x200mm. Aluminum angle irons are used for inter-connections between legs and base. Legs are connected to base via another bearing to allow rotation in plane perpendicular to the plane of motion of other two joints.

V. Electronic Design

A. Power Circuit

In view of our power requirements we had the option to connect our battery directly to the PWM multiplexing boards which would further drive the servo motors. The voltage rating of the multiplexing board was around 5-6V whereas our battery supplied 12.6V when charged. Hence we had to step down our voltage to supply the board in the safe operating range. For that we used 7806 regulators which gave a normal output of 6V and around 0.8 to 1A.

According to our calculations even if all 13 motors were somehow in stall condition, they would draw maximum 39A current. This assumption was taken up for the sake of safety, overheat conditions and smooth operation of the motors. Given one regulator provides up to 1A, current rating was not enough to drive 13 servo motors, where one servo motor draws around 1.5A on normal operating conditions and 2.5-3A on stall condition. The best option to implement was to cascade the regulators in parallel to enhance the current output and keep the voltage output constant. For that we had to cascade forty 7806 regulators to meet the above mentioned conditions.

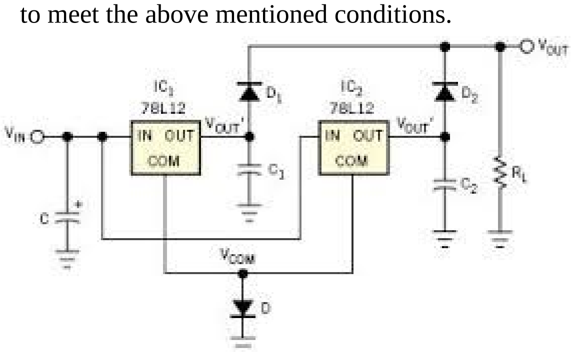

Fig.5. Paralleling of Regulators

The picture above shows two regulators cascaded in parallel.

The problem encountered when cascading the regulators was due to inherent variations in the manufacturing of the regulators. Not all regulators give the exact rating voltage but instead there is a tolerance level and each regulator gives output above or below the mentioned value which we call as mean value. This gives rise to a condition where one regulator with the output value above mean becomes a generator and the other one which is below the mean value becomes a load. To avoid this diode must be connected to the output of each regulator to avoid current flowing back if its voltage output is below mean value. The problem encountered due to this phenomena is that regulators start to overheat when current flows inside them and after a certain period of time becomes dysfunctional causing the circuit to break and hence all regulators fail.

Capacitors of 1000uF are connected at each output of the regulator to control the surges as well as smoothing of the output to avoid damage to the motors and multiplexing boards. A large rating capacitor of 2500uF was connected to the input for the same purposes and to avoid damage to the regulators in case of glitches in transient phase. Therefore, we made 2 separate boards and in each PCB board we cascaded 20 regulators to supply one side of the robot i.e. left side motors or the right sided motors. Each board had the supply capacity of 20A and 6V.

B. Graphic User Interface (GUI)

GUI of the robot is made using Tkinter library of Python. Tkinter is a powerful tool for making GUIs in Python. We have made the GUI on Raspberry Pi’s operating system. We access the desktop of raspberry Pi via SSH client. Robot GUI consists of three buttons which are responsible for different functionalities of robot. It also consists of a Label which contains different sensor reading as received from Arduino. In addition to that controls for camera motion are also included in the GUI.

C. Serial Communication of Arduino & Raspberry Pi

Arduino and Pi communicate serially via a USB cable. Python library for Raspberry Pi, PySerial is used for this purpose. All the sensors are connected to Arduino which Processes their readings and transmits them serially to Raspberry pi which then shows the readings in GUI. The Serial communication between the two is taking place at 9600bps.

VI. CONCLUSION

We have successfully designed the robot. We have developed a walking algorithm and have made the robot walk on different terrains like Grass, Road, Concrete and Rocky.

There is an almost infinite list of possible applications where such high-mobile robots can be deployed:
- Remote Surveillance
- Construction and mining companies for construction site transporter
- Inspection of large scale industrial environments Police etc. for bomb disposal and for exploration Fire brigades
- Exploration in dangerous environment Search and rescue teams
- Operators of polluted facilities
- Security agencies as mobile security guard
- Luggage transporter
- As walking aid for persons with mobility limitations
- Researchers advertising agencies for interactive advertisement
- Entertainment industry e.g. for amusement park attraction

VII. FUTURE ENHANCEMENTS

The Robot we have designed can be improved in many ways for it to have a more versatile motion.

- Firstly, the robot motion can be made sensors based by designing specialized feet and by using force sensors at their bottom.
- Mechanical Design can be improved by using linear actuators which have a very quick response and have a greater load capacity.
- Weight of the robot can be greatly reduced by using a rectangular aluminum frame as a base instead of a solid sheet.
- Image processing can be used for an efficient gait pattern and more stable foothold selection.

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