International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 05 | May-2018 www.irjet.net p-ISSN: 2395-0072

A Real Time Design and Implementation of Walking Quadruped Robot for Environmental Monitoring

Ritesh G. Waghe[1], Deepak Bhoyar[2], Sagar Ghormade[3]

[1] Research Scholar, Department of ECE, Abha Gaikwad-Patil College of Engineering, Nagpur, India
[2] Asst. Professor, Department of ECE, Abha Gaikwad-Patil College of Engineering, Nagpur, India
[3] H.O.D, Department of ECE, Abha Gaikwad-Patil College of Engineering, Nagpur, India

***

Abstract - *Four-legged robots also referred to as quadruped or a quadrapod, can have very complex locomotion patterns and it provide the means of moving on surface where wheeled robots might fail. This conceptual shows usage of different creeping walks to accomplish synchronized development of the robot The objective of this project is to develop a reliable platform that enables the implementation of stable and fast static/dynamic walking on even or uneven terrain. This also consisting of a different types of sensors embedded on it for detecting a real time status of the environmental condition and transmit it to the base station using wireless module.*

***Key Words*: Quadruped, Terrain, Kinematic algorithms, Sensor**

1. INTRODUCTION

In many cases, there is a requirement for mobile platforms that can move in areas with difficult landscape conditions where wheeled vehicles can't travel. Samples of such situations can be found in search and salvage task, and in addition in conveying payloads. Not at all like wheeled robots, walking robot are described by great portability in unpleasant territory. The primary objective of this paper is to show an inventive, modular and reasonable design of a four-legged robot for environmental research purposes

The objective is to create a cheap legged platform, which allows research and testing of walking chassis and monitoring environmental conditions. The robot should either be driven from the base station or remote location that should send all available data from sensors, which will be displayed on the computer in the user interface program. It is also important to create and program a system into the microcontroller unit (MCU) of the robot, which would have the capacity to control the servomotors and sensors

1.1 Why Legged Robot?

Today's era is of robotics. One of the most important part of a robot is its chassis. There are several basic robot types: wheeled, tracked and legged robot. Wheeled robots are fast, but not suitable for rough area. Tracked robots are slower, but more suitable to rugged area. Legged robots are slow, much difficult to control but extremely powerful in rough area. Legged robots are capable to cross large holes and can operate even after losing a leg. Many researches were performed in this field in past few years, because of its large potential. Legged chassis are especially ideal for space missions. There are also several projects in military research.

Legs have unmistakable points of interest over wheels. The biggest advantage is in transvers ability and proficiency. Legged robot has a unique ability to

- Isolate their body from territory abnormalities
- Avoid undesirable foothold
- Regulate their stability
- Achieve energy efficiency

These advantages are very desirable in modern robotics, and therefore a lot of research is being put into creating robots that can walk.

1.2 Background and Related Work

Examination of walking machines started in the nineteenth century. One of the first models showed up around the year 1870. For 80-90 years, endeavors were made to build walking machines based on different kinematic chains that were supposed to generate a desired motion profile during operation. During those years, numerous models were proposed, yet the execution of a large portion of these machines was constrained by general cyclic s walking forms and the inability to adjust a walking pattern to the landscape. In the late 1950s, it turned out to be clear that machines ought to not simply be based on kinematic mechanisms that provide cyclic movements, and that there was a need to integrate planning and control systems. The first robot to move independently with computerized control and electric propulsion was built in 1966 by McGhee and Frank. The main task of the robot's computer was to unravel the kinematic equations involved and to control the electric motors that drove the legs, such that the robot could go forward while maintaining equilibrium constraints. Since then, and following the advance of control technique technologies, computing resources and motion actuators, many different robots with varied abilities have been built. Examples of these abilities include running, walking over rough terrain, jumping over obstacles, climbing and more

Robots have wide history of being used following the time when industrialization. There has been and steadily developing improvement in the field which noted in the few records.

When in 1954 George C. Devol field a U.S. patent for a programmable system for exchanging the article between distinctive parts of a manufacturing plant, he composed: "The present invention makes available for the first time a more or less general purpose machine that has universal application to a vast diversity of application where cyclic control is desired."

In 1967-68 the initially wheeled walking machine utilizing vision and different sensors, were accounted for. In 1974, the first servomotor impelled and microcomputer controlled robot were monetarily dispatched and they were utilized by NASA to gather tests from the surface of mars In 1981, a microprocessor based pneumatically worked pick and place Robot was indigenously created by the creator S.R.DEB in the Production Engineering Department at Jadavpur University. In 1984, Bhabha Atomic Research Central has built up a 6-axes multipurpose Robot, having weight around 300kg and can move an end-of-arm, heap of 10kg, including that of end effecter.

Today, there are a substantial number of active research programs in the field of legged locomotion. Apart from designing and building the robot itself, the main challenges are the planning and implementation of the legs' motions in generate a walking sequence, namely, how to plan the steps of the robot so that it moves in a desirable way while maintaining equilibrium constraints (quasi-static walking) or else maintaining the stability of the robot (dynamic walking)

At present, there are number of lab-scale quadruped robots being utilized as a part of exploration, for example, LittleDog from Boston Dynamics, StarlETH and ALoF from ETH, TITAN-IX, MRWALLSPECT III, the "bug like robot" created at Technion, AiDIN-III from Sungkyunkwan University (SKKU), and others. These models have complex mechanical designs, such as custom-made joints and structures, non-uniform motors and custom electronics. These models are specifically designed with powerful processing units or built-in sensors. The main advantage of the design presented in this paper is that it can be built from off-the-shelf products. Therefore, it can be used immediately in a simple and cost-effective manner. In addition, the proposed robot is based on open-source code and hardware, thus enabling future improvements. Such improvements might include sensor capabilities, control circles and the mechanical structure. The combination of the mentioned design features makes the robot unique and innovative and leaves it optimized for research and monitoring purposes.

1.3 Drawbacks of Existing Work

There are several companies, which are producing quadrapod models and platforms. These companies offer a variety of hobby and research level robot kits and parts. They come in several types of quadrapod that differ in the body shape and leg construction. Numerous robots accompany programming, which gives control of servomotors utilizing inverse kinematics and making custom gaits.

Although several solutions already exist and have great potential, each one of them has some disadvantage. The first one is price, which is quite high. Another disadvantage is equipment of the robots. Many of the robots have limited expansion options, like missing foot sensors, which are difficult to install later, or servomotor type with insufficient power or features. Also the batteries are often built in the body and it is difficult or even impossible to remove them.

2. CHARACTERISTICS OF LEGGED ROBOT

This part is focuses on several characteristics of walking robots. Some classifications of walking robots and most common walking gaits are described.

2.1 Classification of Walking Robot

There are many ways to define walking robots

- By a body shape
- Number of legs
- Number of degrees of freedom per leg
- Locomotion technique.

To achieve many different configurations various options can be combined. By body shape it can be classified into two category Mammal and Spider which is shown in Fig.1

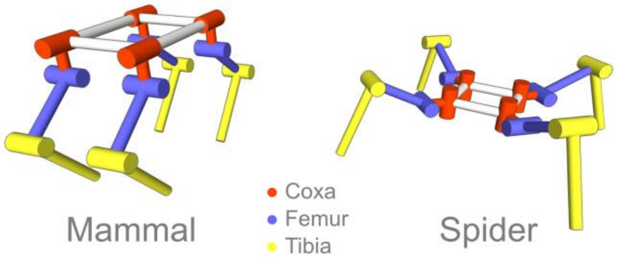


Fig -1: Mammal and Spider robot body shape

At least two degrees of freedom are needed to construct a walking robot – first for lifting the leg, second for rotating it. Nevertheless, for a good functioning robot there should be three degrees of freedom, because the legs move along a circle and the forward movement of the body causes slipping between the foot and the surface, which can be compensated by third joint.

2.2 Walking Theory

In order for the quadrapod to walk, several algorithms need to work together to form a complete controller. The end product at every time interval is the position set-point for each servo. Walking patterns need to be chosen, swing trajectories calculated and leg position constraints updated.

Depending on velocity, different gaits are selected by a controller. To execute these gaits each leg will have a stand phase and a swing phase. Whereas the stand phase is when the leg has ground contact at all time. During the swing phase a trajectory between two stand positions must be properly calculated by the controller. Due to size of hardware such as leg length, servo positions and body width, certain constraints will restrict the possible leg positions. The positions of each leg will also affect remaining legs possible position space. Due to resemblance between a quadrapod robot and legged insects a lot of inspiration can be taken from insect locomotion and biometrics.

2.2.1 Walking Gaits

To move a quadrapod in any direction the legs has to push it in that way, resulting in legs getting further away from the quadrapod body. In order for this to continue the legs have to be lifted and moved back into the vicinity of the body. This can be done in several different ways and possibilities increases with the amount of degrees of freedom. The most common way of creating gaits is by manual programming. More sophisticated methods exist and some of them include mimicking stick insects, evolving patterns using genetic algorithms or using artificial neural networks. Some of the most common gaits used are creep and trot gait. They are used for slow and medium movement respectively. The basic difference between these gaits are the usage of one or two legs simultaneously in swing phase, Figure 2.

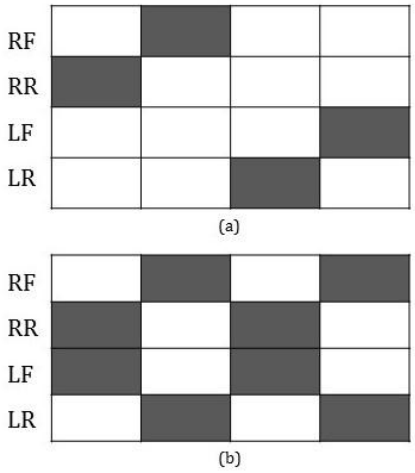


Fig -2: Gait diagram for two common gaits that can be implemented. Black symbolizes swing phase. (a) Creep, (b) Trot.

2.2.2 Creep Gait

The basic alternating diagonal walk called the creep, sometimes known as the crawl, it also known as static stable gait. The alternating diagonal walk has dynamic stability (Trot gait), the creep has static stability. Only one leg is ever lifted from the ground at a time, while other three maintain a stable tripod stance. The ground legs are maintained in a geometry that keeps the center of mass of a body inside the triangle formed by the three points of tripod at all times. As the suspended leg moves forward, the tripod leg shit the body forward in synchrony, so that a new stable tripod can be formed when the suspended leg comes down.

The tripod can shift the body forward simultaneously with the suspended leg, giving a nice smooth forward movement.

This method should provide good speed on level ground.

The tripod can shift the body forward d after the suspended leg has touch down, giving a more tentative and secure forward movement this method should be useful when engaging obstacles or moving over broken ground.

The diagram below shows the basic timing for the leg positions when doing a creep gait.

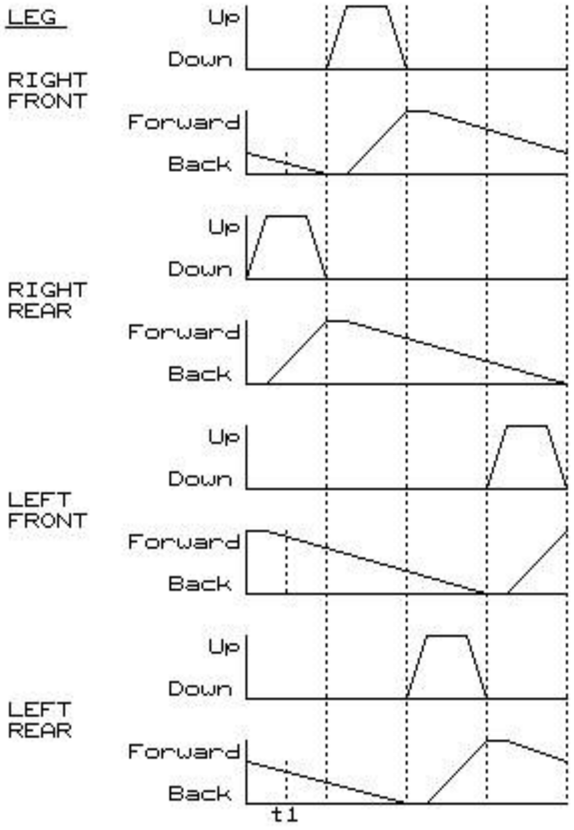


Fig -3: Timing diagram for leg positions when doing creep gait

The creep gait works with 4-beat timing. One leg at a time, starting with the right rear, picks up and moves forward and down during one beat and then slowly moves backward during the next 3 beats. During the second beat, the front leg on the same side goes through the same motion. During the third beat, the rear leg on the opposite side does the same. Finally, the front leg on the opposite side does similar, during the fourth time beat. The cycle repeats, and forward motion continues. Each leg picks up and moves forward during its own quarter phase, and then moves backward during the other three quarter phases. The overall action results in very smooth and even forward movement, since all legs are constant motion here. The body remains nice and level.

2.2.3 Trot Gait

The alternating diagonal walk has dynamic stability, its sometimes called amble gait. Two diagonal legs swing forward while the others two support the body and moves backward. It's one of the quickest gait because two of its legs are lifted at one time, although it's not very energy efficient.

The stability of the body is related to the frequency of the legs being lifted and placed, the quicker, the less shaky you will find it is. Of course it's has something to do with the design of the feet as well, if the feet has a large contact are with the ground you will find it stay better while the other two legs are lifted

2.3 Inverse Kinematics

Each leg constitutes of three links (Coxa, Femur, Tibia) and three actuators (Body-Coxa, Coxa-Femur, Femur-Tibia). The first actuator connects the leg to the body. It is a shoulder pivot and is referred as γ. This angle controls the rotation of the whole leg in the plane parallel to the [x, y] place of the robot's body. The first link is called Coxa, is usually rather short and connects shoulder pivot with the elbow. Another actuator is placed between Coxa and Femur. The angle is called α and allows vertical movement of the leg. The Femur is connected to the Tibia with another actuator. It allows the set the angle between them. The angle is called β and operates in vertical plane as well. This angle allows to place the foot near or far to the center of gravity (CoG). Both angles α, β operate in the same plane, which is perpendicular to the robot's base plane. All the links in the leg has a fixed length. The actuators connecting the links are standard servos. The output horn of a servo can be set for angle 0−180◦. Therefore a coordinate conversion between [x, y ,z] and angles α,β,γ must be provided The conversion can be based on standard trigonometric functions and law of cosines.

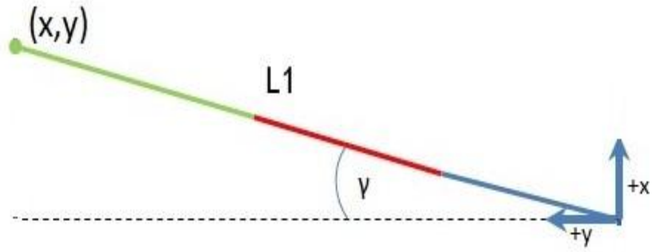


Fig -4: Inverse kinematics top view

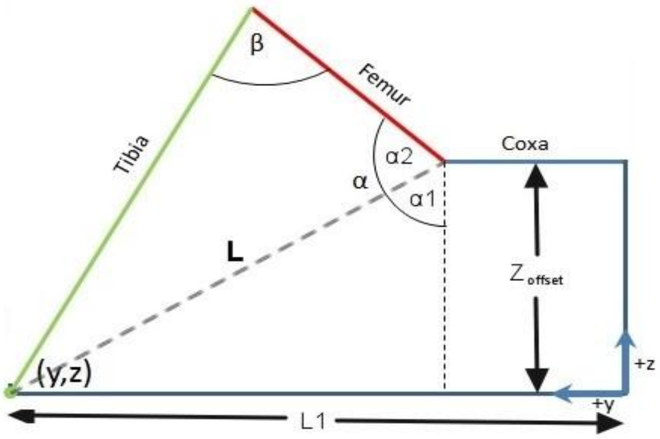


Fig -5: Inverse kinematics side view

$$\frac{x}{y} = \tan(\gamma)$$

$$\rightarrow \gamma = \tan^{-1}\left(\frac{x}{y}\right)$$

$$L = \sqrt[2]{Z_{offset}^2 + (L1\text{-}coxa)^2}$$

$$\alpha_1 = \cos^{-1}\left(\frac{Z_{offset}}{L}\right)$$

$$Tibia^2 = Femur^2 + L^2 - 2(Femur)(L)\cos(\alpha_2)$$

$$\rightarrow \alpha_2 = \cos^{-1}\frac{Tibia^2 - Femur^2 - L^2}{-2(Femur)(L)}$$

$$\alpha = \alpha_1 + \alpha_2$$

$$\alpha = \cos^{-1}\left(\frac{Z_{offset}}{L}\right) + \cos^{-1}\frac{Tibia^2 - Femur^2 - L^2}{-2(Femur)(L)}$$

$$L^2 = Tibia^2 + Femur^2 - 2(Tibia)(Femur)\cos(\beta)$$

$$\rightarrow \beta = \cos^{-1}\frac{L^2 - Tibia^2 - Femur^2}{-2(Tibia)(Femur)}$$

3. MECHANICAL DESIGN

A 6 mm thick hardboard was used in this project. The mechanical properties are adequate for the size of the construction. Hardboard is rather light material compared to aluminium or plastic, which positively contributes to the overall weight of the construction. The pillars connecting top and bottom plate of the robot are from polyamide rod, having the diameter of 8 mm. This material is strong enough to allow thread cutting. I used M2 screws to connect the top and bottom plates to the supporting polyamide pillars. The size of the robot was kept as minimal as possible in order to reduce the weight. The limiting factors are the size of the main board and the size of the servos used in legs. The tool AUTOCAD. This tool provides semi-professional level for technical drawings. The drawings were printed out and transferred to the hardboard. The small mechanical jigsaw was used to cut the parts. The joins were made from a graphic rod revolving in a plywood dry bearing. No classic bearing were necessary, the carbon properties combined with smooth surface of used 2 mm trick rods were meeting the requirements for this application. The complete construction part in shown in the drawing depicted in the figure 6.

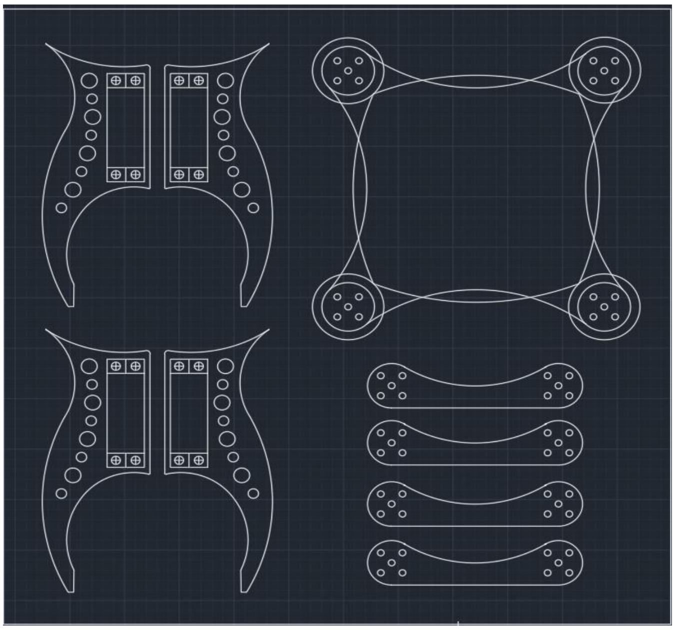


Fig -6: The complete parts of the robot, base body, legs, femur links

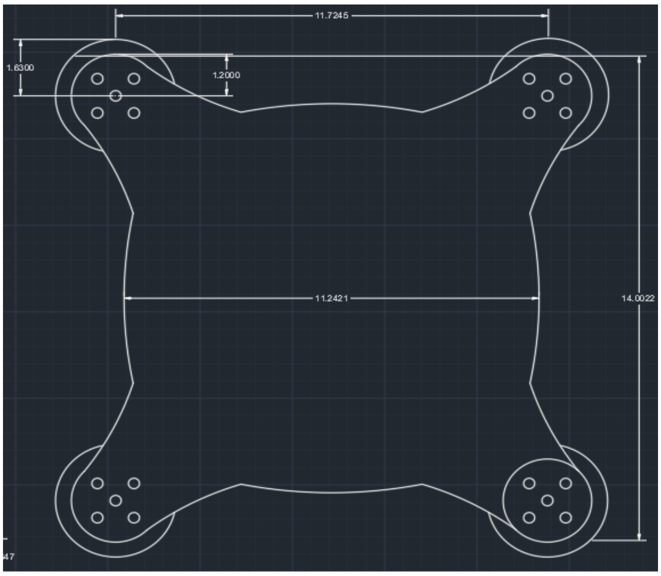


Fig -7: Base body

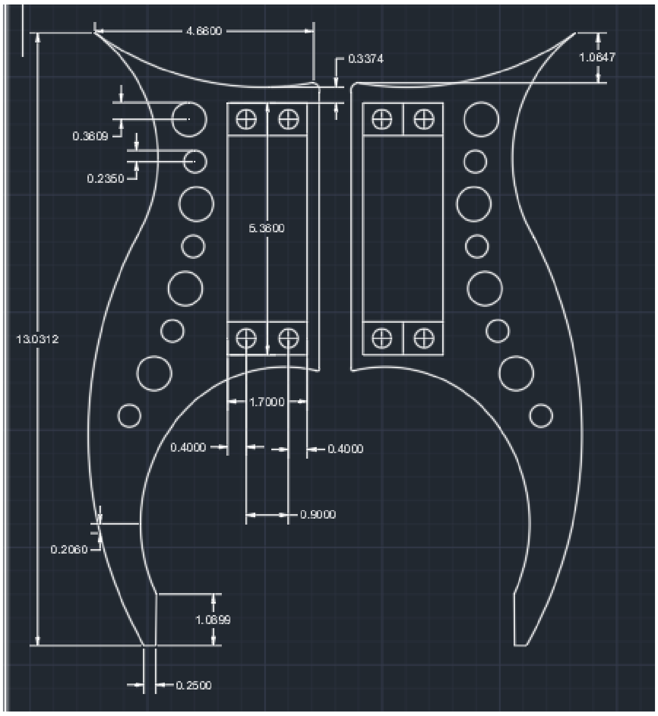


Fig -8: Legs

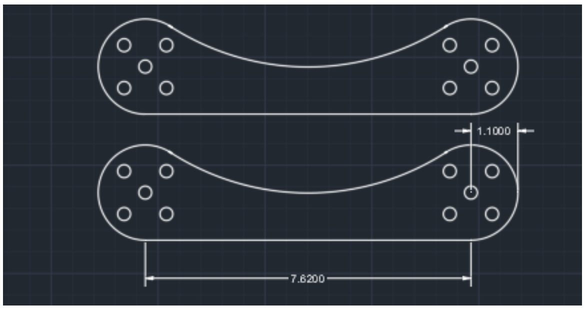


Fig -9: Femur link

4. ELECTRONIC SYSTEM

In order to control the robot there must be some control unit. MCU Atmega328p was chosen to drive the servomotors and sensors on this robot. All sensors like sonars, LCD display, accelerometer sensor, temperature sensor are connected to it. LCD display is connected by digital pins using integrated Hitachi HD44780 driver, which allows 4-bit or 8-bit mode. The 4-bit mode requires seven I/O pins from the Arduino, while the 8-bit mode requires 11 pins. There are also 12 servomotors connected to servomotor driver and driven by MCU using I2C protocol. The MCU is integrated on open-source electronic platform Arduino UNO R3. Arduino board is connected to the Raspberry Pi via USB cable. The whole scheme is in Figure 10.

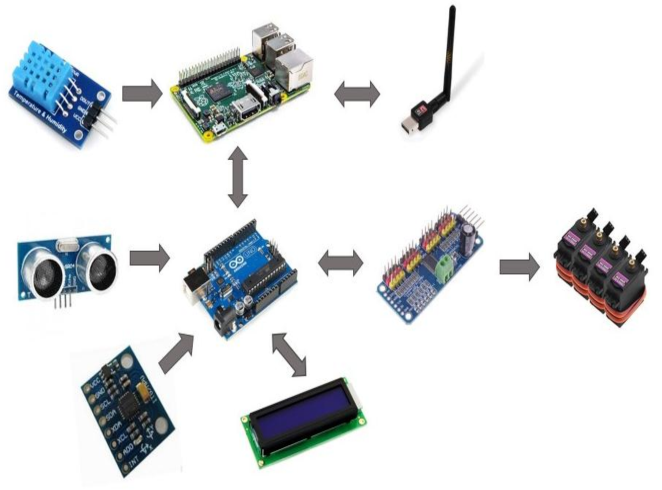


Fig -10: The electronic system of the robot.

In the center is a MCU Atmega328p integrated on a Arduino UNO R3. Most of the sensors like sonars, LCD display, triple axis accelerometer and gyro are connected to it. There are also 12 servomotors connected to servo driver and driven by MCU's I2C protocol. Arduino board is connected to the Raspberry Pi via USB cable. Raspberry Pi is connected to the computer via wi-fi module, temperature sensor is connected to raspberry pi GPIO pin.

Raspberry Pi is a miniature computer the size of a credit card, to which a standard monitor, a keyboard and a mouse can be connected. It has extremely low power consumption (max. 3.5 W) and can run linux based operating system Raspbian. There are several models, which differ in RAM, the number of USB ports or GPIO pins. Raspberry Pi is equipped with a USB Wi-Fi dongle, which is connected to a wireless network, and runs client program, which is able to find the IP address of the server and gets connected to it. Sensor data are sent to a computer and also send to pubnub IoT platform after successful connection. Client is also capable of reconnect after disconnection. All sensors and servomotors are connected and driven by Arduino board. Robot is also equipped with ultrasonic distance sensors HC-SR04 – sonars. These sensors can measure distance from 2 cm to 400 cm. It has 4 pins – Vcc, ground, trigger and echo. Robot is equipped with four sonars, one for each side. Sonars are connected to raspberry pi using GPIO pins.

Energy to the entire system is supplied by one 11.1 V Li-Po battery with ultimate battery eliminator circuit. This power is sufficient for all servomotors and electronics.

5. Results

Fig 11: The robot body base (Top View)

Fig 12: The robot leg (Top View)

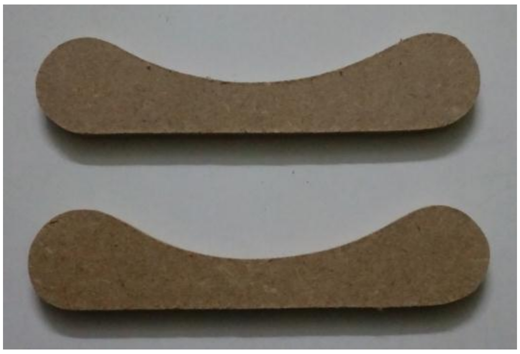


Fig 13: The robot femur link (Top View)

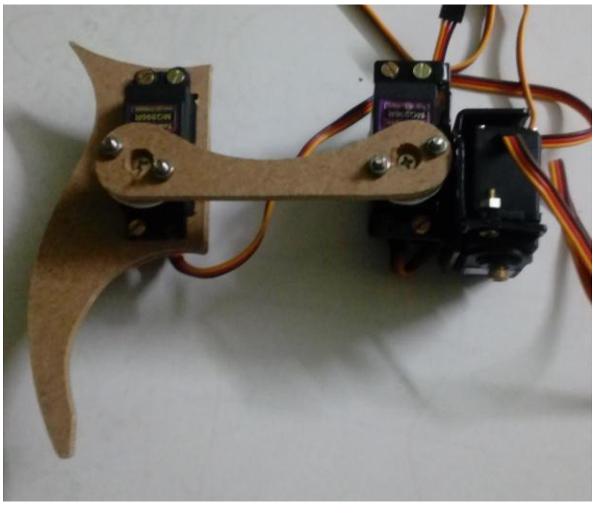


Fig 14: The robot front left leg

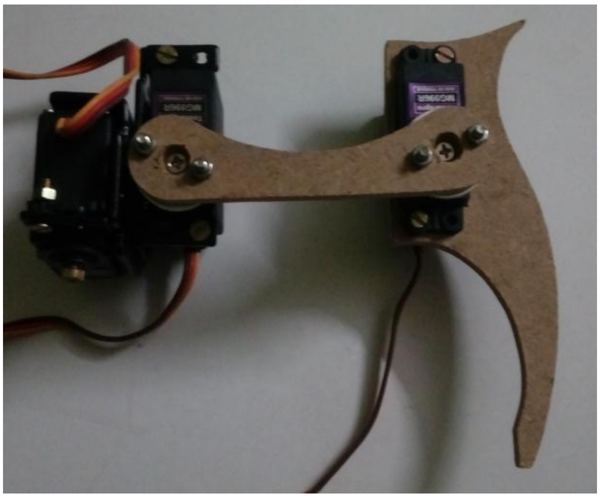


Fig 15: The robot front right leg

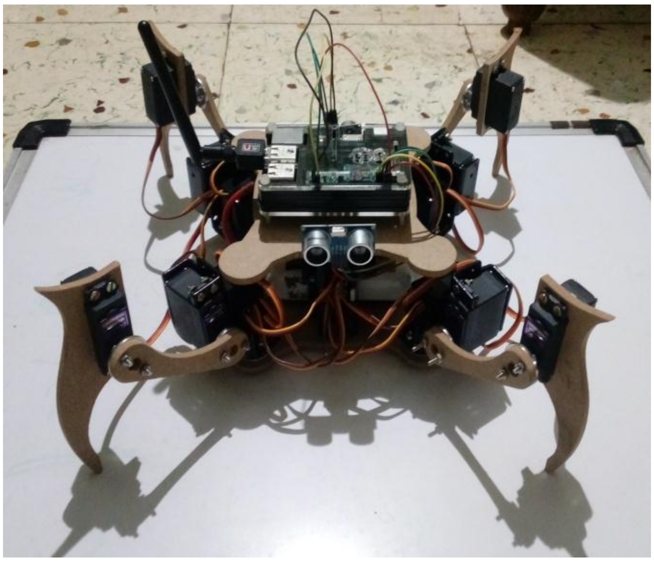


Fig 16: The complete robot

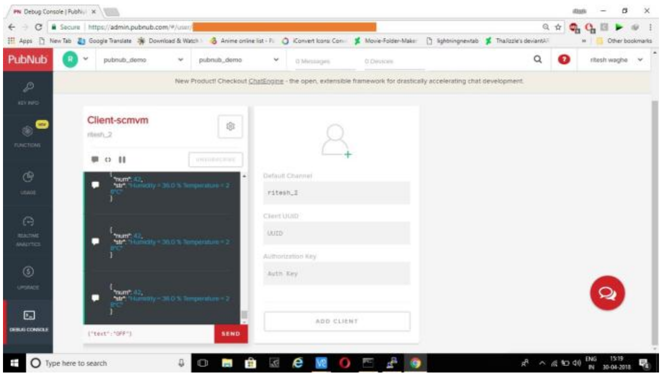
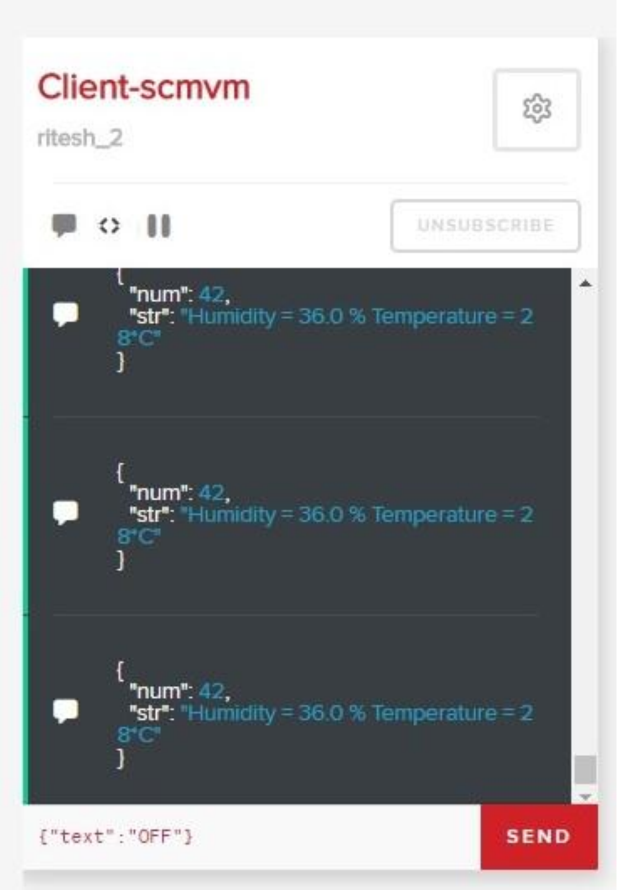


Fig 17: Temperature monitoring on pubnub



Client-scmvm
ritesh_2

```
{
  "num": 42,
  "str": "Humidity = 36.0 % Temperature = 28°C"
}

{
  "num": 42,
  "str": "Humidity = 36.0 % Temperature = 28°C"
}

{
  "num": 42,
  "str": "Humidity = 36.0 % Temperature = 28°C"
}
```

`{"text":"OFF"}`

Fig 18: Temperature monitoring window

6. CONCLUSION

I designed, constructed and tested a quadruped robot during this project. The robot can walk using creep gaits, can rotate and it is equipped with sonars, temperature sensor, triple axis accelerometer - gyro and LCD display. I also designed an user interface program in C, which allows to control and monitor the robot.

ACKNOWLEDGEMENT

I am profoundly grateful to Prof. Sagar Ghormade, H.O.D., AGPCOE, for his expert guidance and continuous encouragement throughout to see that this project rights its target since its commencement to its completion. I am also grateful to Prof. Deepak Bhoyar (Co-ordinator) for his support and guidance that have helped me to expand my horizons of thought and expression. I would like to express my deepest appreciation towards Dr.S.M.Chandekar, Principal and Prof. Pragati Patil, VicePrincipal, ECE Department, AGPCOE, whose invaluable guidance supported me in completion of the of this project. At last I must express my sincere heartfelt gratitude to all friends and staff members of ECE Department who helped me directly or indirectly during this course of work.

REFERENCES

[1] M. Hutter, C. D. Remy, M. A. Hoepflinger, and R. Siegwart, “Efficient and Versatile Locomotion with Highly Compliant Legs”, IEEE/ASME Transactions on Mechatronics, Vol. 18, No. 2, April 2013, 449-458

[2] M. Hutter, H. Sommer, C. Gehring, M. Hoepflinger, M. Bloesch, and R. Siegwart, “Quadrupedal locomotion using hierarchical operational space control,” The International Journal of Robotics Research (IJRR), vol. 33, no. 8, pp. 1062–1077, May 2014

[3] G. C. Haynes, Alex Khripin, Goran Lynch, Jon Amory, Aaron Saunders, Alfred A. Rizzi, and D. E. Koditschek ,"Rapid Pole Climbing with a Quadrupedal Robot," IEEE International Conference on Robotics and Automation. May 2009

[4] C. Remy, O. Baur, M. Latta, A. Lauber, M. Hutter, M. Hoepflinger, C. Pradalier, R. Siegwart, “Walking and crawling with ALoF: a robot for autonomous locomotion on four legs”, Industrial Robot: An International Journal, Vol. 38, No. 3, 2011, 264-268.

[5] Yam Geva, Amir Shapiro“A Novel Design of a Quadruped Robot for Research Purposes Robot for Research Purposes”, International Journal of Advanced Robotic Systems

[6] Sakagami, Y., Watanabe, R., Aoyama, C., Matsunaga, S., Higaki, N. and Fujimura, K. The intelligent ASIMO: system overview and integration. In Proc. of IROS, 2002, 2478- 2483.

[7] Hirose, S., Fukuda, Y., Yoneda, K., Nagakubo, A., Tsukagoshi, H., Arikawa, K., Endo, G., Doi T. and Hodoshima, R. Quadruped walking robots at tokyo institute of technology. IEEE Robotics & Automation Magazine, 2009, 16(2), 104-114.

[8] Fujita, M. and Kitano, H. Development of an autonomous quadruped robot for robot entertainment. Autonomous Robots, 1998, 5.

[9] Pratt, J. Exploiting inherent robustness and natural dynamics in the control of bipedal walking robots. Dissertation, Massachusetts Institute of Technology, 2000.