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# Difficulties to Develop a Four Legged Robot

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**ABSTRACT**
Development process of a four legged robot is discussed in this paper. During making the robot many difficulties are faced. This paper is mainly focused on difficulties and their remedies. In 20th century many mathematical methods are introduced for smooth control of linear as well as nonlinear motion of dynamic system. Sensor, actuator and control algorithm are commonly used to build up field, aerial as well as under water robot. Among different types of field robots wheeled robots are commonly built because compare to aerial and under water robot these are easier to control. On the other hand, there are various limitations of wheeled robot such as move on stairs and rough topography. Therefore, to overcome these problems, in the present study, a four legged robot is developed. During development of a four legged robot many difficulties are arisen such as proper electric motor selection, leg mechanism and motion control as well as synchronization of movement of four legs for steady motion of the robot.

Keywords: Field robot, Gear motor, Leg mechanism.

## 1. Introduction

Robot is a programmable machine. It is designed on the basis of the task perform and controlled by the microcontroller board. In recent years many people are studying and working on field robot. It includes wheel controlled robot as well as legged robot. Even though it is easier to develop wheeled robot than legged robot but it has various disadvantages such as walk on stairs and rough terrain. On the other hand, quadrupedal robot also known as four legged robot is difficult to develop and motion control but it can move on rough surfaces and stairs without any trouble. Therefore, in the present study, it is planned to develop a four legged robot.

Khaled M. Goher and Sulaiman O. Fadlallah [1] developed a two legged portable system, which allows patients with lower-limb disabilities to perform leg and foot rehabilitation exercises anywhere without any embarrassment. The system is modeled by applying Lagrangian approach. Jing Liu et al. [2] studied different types of legged robot, their problems and future trend. Lee & Shih, work on a quadruped walking vehicle constructed at the National Chiao Tung University which is referred as NCTU quadruped-1. For controlling the motion and position of legs, first of all, they used non linear feedback and after that model reference adaptive control. Its total weight and length of each leg is 50 kg and 0.6 m respectively [3]. Marc Raibert et al. developed a rough-terrain robot that is able to move in outdoor steep, rocky and muddy as well as in house [4]. They found that further attention is necessary on several areas like quieter operation, self righting, more autonomy and travel in rougher terrain.
The main objective of this work is to develop the leg mechanism and control the movement of the robot. Fig. 1 shows the 3D model and Fig. 2 shows the constructed model of the four legged robot. Length, width and height of the robot are 14 in, 8.5 in and 8 in respectively. Conversely, total weight of the robot is 3 kg.

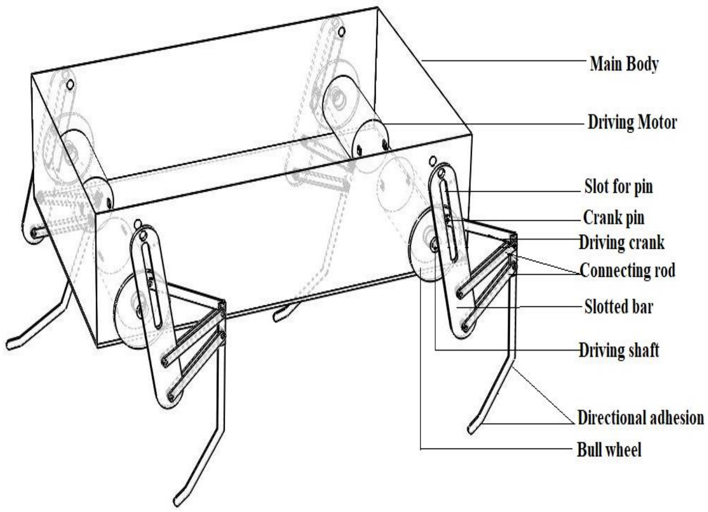


Fig. 1 3D model of the four legged robot

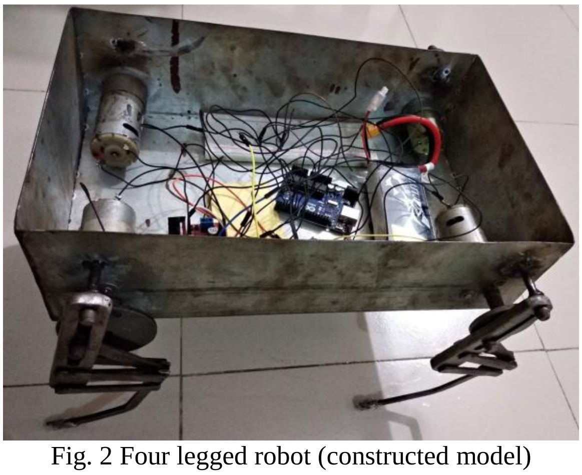

Fig. 2 Four legged robot (constructed model)

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## 2. Leg Mechanism

Design and development of the leg mechanism is one of the major issues of four legged robot. First of all, one leg was designed and fabricated. In that design, there were two motors for each of the legs. One motor was used to rotate the lower part of the leg and another had the function of move the whole leg. But the whole leg was such heavy weight that the main motor was not able to lift the weight. In this case, eight motors were needed for four legs, which made the whole structure too much heavier. Thus, it might become slower with movement. Replacing this with a high torque motor was not possible as it would make the system weightier and consequently, target of minimizing the weight would be failed. On the other hand, it is a load carrying robot; if the body has too much weight then it would be difficult to carry additional loads. Therefore, the first attempt [Fig. 3 (a)] went wrong.

At the second case, a mechanism with linear tubular actuator was being considered. It was designed by using SolidWorks. The design was looked good and satisfactory. It was also checked if it would give proper motion to the leg. In this design, actuator was used for holding the heavy weight of the body. It was the simplest mechanism of motion of the leg. The leg was constructed according to the design. Fig. 3 (b) shows the fabricated model of a leg. However, after the construction, a new problem was found. The actuator itself had heavy weight. After attaching with the leg, the leg was too heavy to rotate with the driving motor. It was very difficult to rotate the leg with stepper motor (NEMA 17). Furthermore, the actuator was very slow during giving feed. Since there was lack of availability of actuator in Bangladesh it was not possible to replace and recheck the mechanism. Thus, second design was failed to fulfill requirement.

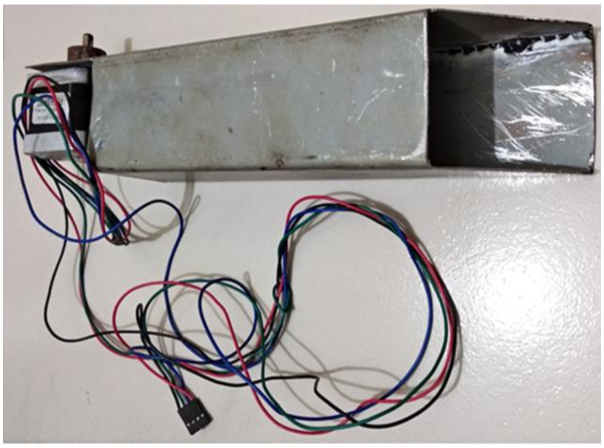


Fig. 3 (a): Fabrication of the leg (First attempt)

Fig. 3 (b): Fabrication of the leg (Second attempt)

Fig. 3 (c): Fabrication of the leg (Third attempt)

Since first two designs were too weighty, therefore, at the third attempt, main objective was to reduce the weight of the leg. It need to be less weight so that, the driving motor can easily move it. Hence, a new design with a new mechanism was made. It was a four bar linkage mechanism using one motor. Fig. 3 (c) shows the four bar linkage mechanism. Aluminum sheet was used to construct the leg. Therefore, weight was dramatically reduced. In addition, it does not need any secondary motor to rotate the lower portion of the leg. One motor was enough for the rotation the entire leg. But during the test run of the leg, it was being stuck at the linkages. Further more, the leg was just bending in one position, hence, it was not possible to give a forward feed to the robot. As few problems were being solved in this design, therefore, some hope was gained from this work. Thus, further design and development of the leg was encouraged using one motor for each leg.

Fig. 3(d): Fabrication of the leg (Selected for use)

At the third attempt, the weight problem was solved and found a way to design the leg with one motor and mechanical linkage. Therefore, during the fourth attempt the target was to make the linkages smooth and clear. Finally, crank-slider mechanism [Fig. 3(d)] was considered to give motion to the leg. For this a bull wheel was needed. The wheel was made of iron. The wheel is connected to the motor shaft and a crankshaft. Therefore, it was the main part after the motor shaft to maintain the proper motion. It needs to be strong so that, it would not bend or break down.

### 2.1 Walking Mechanism

The walking mechanism of the leg was not so much easy. Leg was manufactured in four different ways. However, in first three cases, there were problems, and hence fail to run the robot. At last, come out with an idea of bull wheel crankshaft, connecting rod and crank slider mechanism. The motion of the leg is controlled by a gear motor. Fig. 4 shows the flow chart of the leg motion.

Here, the motor shaft is connected with the bull wheel. The pin of the bull wheel is connected with the crankshaft. The crankshaft is connected with the lower leg. The connecting pin can slide through a slot in a slotted bar. The slotted bar is attached with the main body through a pin in such a way that pin is fixed and slotted bar can rotate. The slotted bar is connected with the lower leg by using connecting rods.

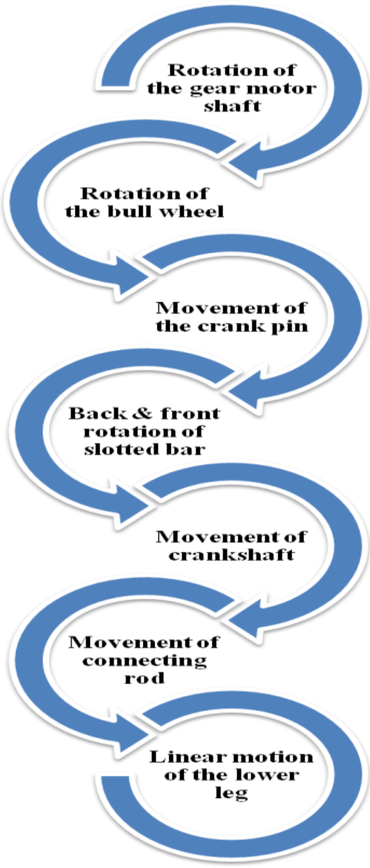
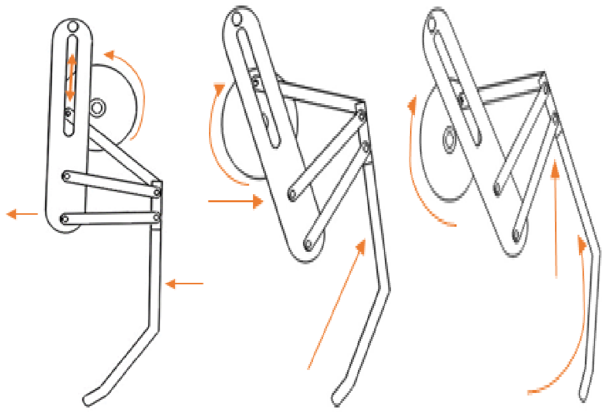



Fig. 4 Flowchart of the leg motion



(a) (b) (c)

Fig. 5 Walking positions: (a) position 1, (b) position 2, (c) position 3

Fig. 6 position of legs during moving of the robot

The wheel rotates with the motor shaft, thus the crankshaft moves backward & forward. The crank pin moves through the slot in the slotted bar.

The movement of the wheel gives feed to the crankshaft then pin slides into the slotted bar and convert the rotational motion into linear motion to move the lower part of the leg. With the forward movement of the slotted bar, the lower leg moves forward and the backward movement of the slotted bar moves the lower leg backward. The more the slider can move forward the more the lower leg can pass the distance. Fig. 5 shows the motion of different components as well as walking positions of the leg. On the other hand, Fig. 6 shows the movement of four legged robot during experiment.

## 3. Selection of electrical devices

Electric motor is a device that is used to convert electric energy to mechanical energy. A gear motor is an explicit type of motor that is designed to produce high torque and low speed to the output shaft at low input power. In the present study, initially stepper motor was selected. However, the stepper motor was not able to produce needed torque and its very weighty. As a result, stepper motor was replaced by gear motor. The RPM of the gear motor is 200.

Four brushed gear motor is used for the four legs of the robot. Each motor is connected with the bull wheel of the leg and the motor is attached to the main body of the


Fig. 7 Gear motor


Fig. 8 Arduino uno board

robot. A gear motor is shown in Fig. 7. Rated torque of the motor is 0.1765 N-m.

A 6000 mAh, 11.1V battery is used as power source. Weight of the battery is 442 gram. From this battery power is supplied to the microcontroller board and four gear motors.

An Arduino UNO (AU) is used for this robot as the main control board. It has a physical programmable circuit board called micro controller and several input and output pins in it. It has Special software called integrated development environment (IDE) is used to write code and upload to the Arduino. An Arduino uno board is presented in Fig. 8.

Two L298N motor shields are used to connect four motors with the micro controller board. L298 IC is utilized in the motor shield which is a dual H-bridge driver designed to drive inductive loads such as DC and stepper motors. A L298N motor shield is presented in Fig. 9.

Fig. 9 L298N motor shield

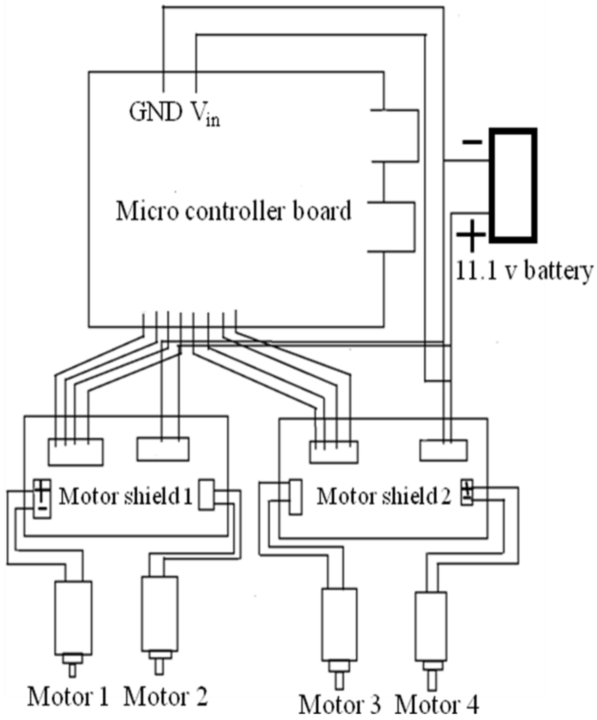



Fig. 10 Circuit Diagram of the electrical setup

Fig 10 shows the circuit diagram of the electrical setup. Power is supplied from the battery to the AU board as well as to the motor shields. Signal from the AU goes through the motor shield to the motor.

**4. Result and Discussion**

At the beginning of the experiment motors are disconnected from power supply and bull wheel is rotated manually. During experiment, for a given angular displacement of the bull wheel, leg's forward and backward displacement as well as slotted bar's angular displacement is measured. Fig. 11 shows the movement of different components of the leg and Experimental data is presented in Table 1.

Table 1: Linear and angular displacement of the leg and slotted bar respectively for different angular displacement of the bull wheel

| Rotation of Bull wheel (Degree) | Rotation of slotted bar (Degree) | Linear movement of the leg (Inches) |
|---|---|---|
| 30 | 5.294 | 1.147 |
| 60 | 10.588 | 2.294 |
| 90 | 15.882 | 3.441 |
| 120 | 21.76 | 4.588 |
| 150 | 26.471 | 5.735 |

Longest, shortest and cross distances between front and rear legs are also examined. Longest and shortest distances are 16 in and 6 in respectively (Fig. 12). On the other hand, Fig. 13 shows the rotational path and motion of the leg.

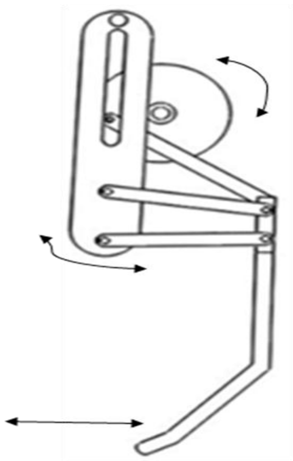
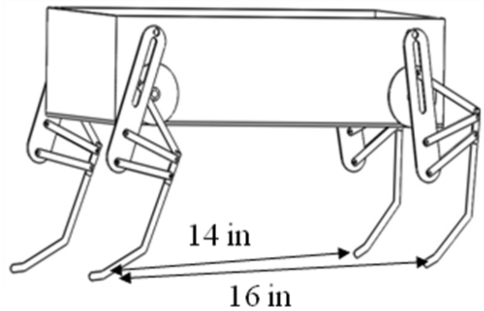
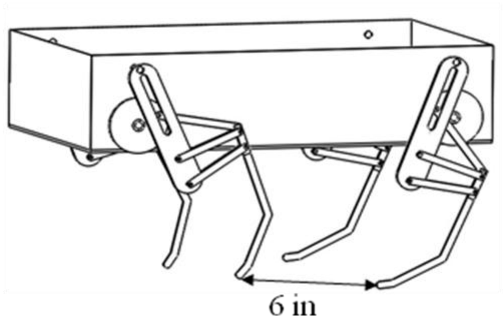


Fig. 11 Movement of different components of the leg




(a)




(b)

Fig. 12 Distance between front and rear leg: (a) longest, (b) shortest

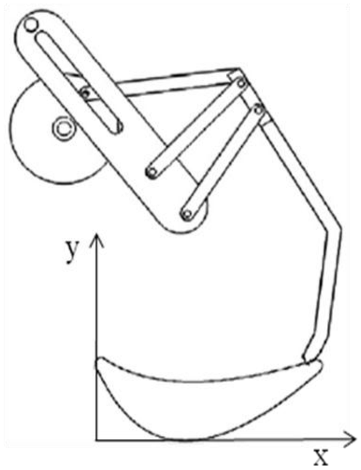



Fig. 13 Movement path of the leg.

## 5. Conclusion

Objective of this research was to develop a four legged robot. Finally a robot was built. During movement of the robot it was found that there was a lot of friction at different components of leg. Furthermore, after walking few steps two motors stopped working. This was happened because of weight of the robot and frictional loss in legs. Therefore, it is necessary to reduce the friction and weight of the robot. Addition of more powerful motor can be another option to solve the problem.

## Acknowledgement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