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A Study on Four-Legged Field Robot's Leg Mechanism

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Abstract

The key challenges of a four-legged field robot are leg mechanism, leg and body motion control. As a result, this paper discusses the leg-making process and motion control of a four-legged robot. Many obstacles arise with the construction of a four-legged field robot. The problems in building the robot were also discussed in this paper. Many mathematical methods for smooth control of linear and nonlinear motion of dynamic systems were introduced in the twentieth century. Sensors, actuators, and control algorithms are frequently employed in the construction of field, aerial, and underwater robots. Wheeled robots are the most frequent type of field robot because, in comparison to aerial and underwater robots, they are easier to manage. Wheeled robots, on the other hand, have a number of drawbacks, including the inability to navigate stairwells and difficult terrain. As a result, a four-legged robot is constructed in this work to address these issues. Many challenges arise during the building of a four-legged robot, including suitable electric motor selection, leg mechanism and motion control, and synchronisation of movement of four legs for steady robot movements.

Keyword: *Four-legged robot, Leg Mechanism, Microcontroller board, Robot movements*

INTRODUCTION

A robot is a machine that can be programmed. It is built around the task at hand and is controlled by a microcontroller board. Many people have been studying and working on field robots in recent years. It covers both wheel-controlled and legged robots. Although it is easier to create a wheeled robot than a legged robot, it has a number of drawbacks, including the inability to walk on stairs and rugged terrain. A quadrupedal robot, sometimes known as a four-legged robot, is more complex to construct and manage, but it can navigate rough surfaces and stairs with ease. As a result, the goal of this research is to create a four-legged robot.

Khaled M Goher and Sulaiman O Fadlallah devised a two-legged portable apparatus that allows individuals with lower-limb limitations to undertake leg and foot rehabilitation activities in public without feeling self-conscious [1]. The system is modelled using the Lagrangian method. Jing Liu et al. investigated many types of legged robots, as well as their issues and potential trends [2]. Lee and Shih are working on the NCTU quadruped-1, a quadruped walking vehicle built at National Chiao Tung University. They employed nonlinear feedback first, then model reference adaptive control to regulate the motion and position of the legs. Its total weight and leg length are 50 kilogrammes and 0.6 metres, respectively [3]. Marc Raibert et al. created a rough-terrain robot that can move in both indoor and outdoor hilly, rocky, and muddy environments [4]. They discovered that certain areas, such as quieter operation, self-righting, increased autonomy, and mobility in harder terrain, require more attention.

The primary goal of this project is to improve the leg mechanism and control the robot's mobility. The three-dimensional model of the four-legged robot is shown in Figure 1; the completed model is shown in Figure 2. The robot's length, width, and height are 14 inches, 8.5 inches, and 8 inches, respectively. In contrast, the robot's total weight is 3 kg.

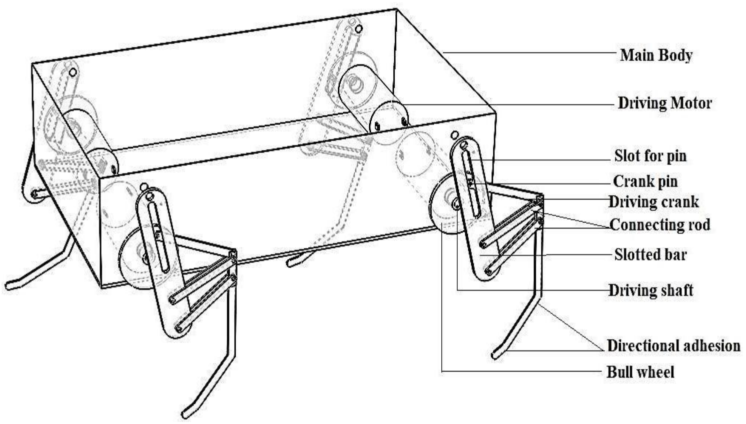

Figure 1: 3D model of the four legged robot

Figure 2: Four legged robot (constructed model)

MECHANISM OF THE LEGS

One of the key challenges with a four-legged robot is the design and development of the leg mechanism. First and foremost, one leg was planned and built. There were two motors for each of the legs in that configuration. One motor rotated the lower portion of the leg, while the other moved the entire leg. However, the weight of the entire leg was so great that the main motor could not lift it. In this scenario, eight motors were required for four legs, resulting in an excessively heavy construction. As a result, it may become

With movement, the pace slows down. Replacing it with a high torque motor was not an option because it would add weight to the system, defeating the goal of decreasing weight. On the other hand, it is a load-carrying robot; if the body is too heavy, transporting more loads will be difficult. As a result, the initial attempt (Fig. 3a) failed.

In the second scenario, a linear tubular actuator mechanism was examined. Solid works was used to create it. The design appeared to be attractive and functional. It was also examined to see if it would allow the leg to move freely. The actuator was employed to support the body's considerable weight in this design. It had been the simplest mechanism of leg motion. The leg was built according to the blueprints. The constructed model of a limb is shown in (Fig. 3 b).

However, after the construction was completed, a new issue arose. The actuator itself was somewhat heavy. The leg was too hefty to revolve with the driving motor after it was attached to it. With a stepper motor, rotating the leg was extremely tough (NEMA 17). Furthermore, the actuator was quite slow when it came to delivering feed. It was unable to replace and test the mechanism due to a lack of actuator availability in Bangladesh. As a result, the second design failed to meet the criterion.

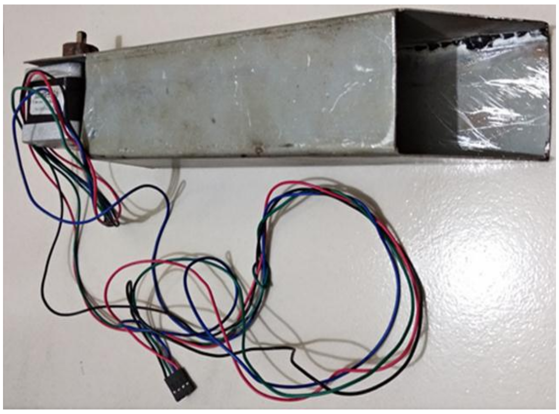

Figure 3 (a): Fabrication of the leg (first attempt)

Figure 3 (b): Fabrication of the leg (second attempt)

Figure 3 (c): Fabrication of the leg (third attempt)

Because the prior two designs were too heavy, the main goal for the third attempt was to lower the leg's weight. It must be light in weight in order for the driving motor to readily move it. As a result, a new design with a new mechanism was created.

One motor powered a four-bar linkage mechanism. The four-bar linking method is shown in Figure 3 (c). The leg was made out of aluminium sheet. As a result, the weight was drastically lowered. It also doesn't require an additional motor to spin the lower half of the leg. A single motor was sufficient to rotate the entire leg. However, during the leg's test run, it became caught at the connections. Furthermore, because the leg was only bending in one direction, the robot could not receive a forward feed. As a result of the limited number of difficulties tackled in this design, some hope was gained from it. As a result, utilising one motor for each leg, further design and development of the leg was encouraged.

The weight problem was solved on the third attempt, and a solution to create the leg with only one motor and mechanical connection was discovered. As a result, the goal for the fourth try was to make the connections smooth and clear. Finally, to move the leg, a crank-slider mechanism (Fig. 3d) was considered. A bull wheel was required for this. Iron was used to make the wheel. The motor shaft and a crankshaft are attached to the wheel. As a result, after the motor shaft, it was the most important component for maintaining appropriate motion. It must be sturdy in order to avoid bending or breaking.

Figure 3 (d): Fabrication of the leg (selected for use)

MECHANISM FOR WALKING

The leg's walking mechanism was not easy to master. Legs could be made in four distinct ways. However, in the first three situations, there were issues, and the robot was unable to run. Finally, devise a mechanism for the bull wheel crankshaft, connecting rod, and crank slider. The leg's motion is controlled by a gear motor. The leg action is depicted in Fig. 4 as a flow chart.

The bull wheel is attached to the motor shaft here. The bull wheel pin is attached to the crankshaft by a pin. The lower leg is attached to the crankshaft. A slotted bar allows the connecting pin to glide through. The main bar is linked to the slotted bar body through a pin in such a way that the pin remains stationary while the slotted bar rotates Connecting rods are used to link the slotted bar to the lower leg.

The crankshaft slides back and forth as the wheel spins with the motor shaft. The crank pin is inserted into the slot in the slotted bar and rotates.

The crankshaft receives feed from the wheel, and the pin slides into the slotted bar to convert rotational action into linear motion, allowing the lower leg to move. The lower leg goes forward as the slotted bar moves forward, and the lower leg moves backward as the slotted bar moves backward. The more the ability of the slider to move forward, the greater the distance that the lower leg can cover. Figure 5 depicts the movements of several components as well as the leg's walking positions. Figure 6 depicts the movement of a four-legged robot during the experiment.

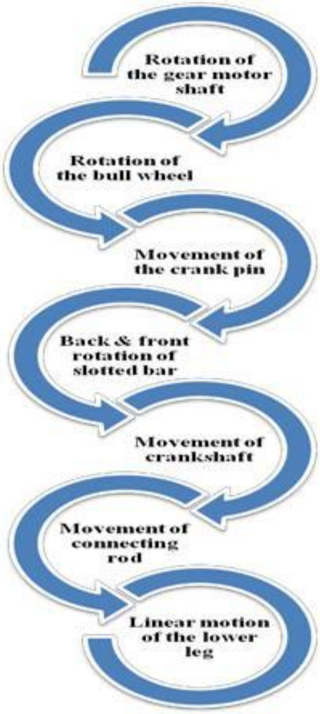

Figure 4: Flow chart of the leg motion

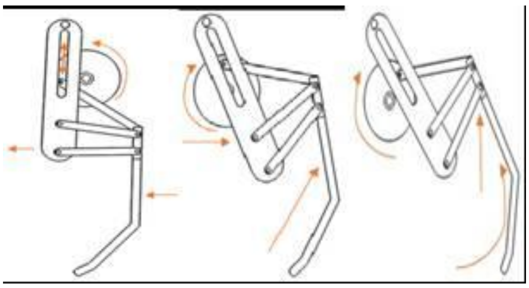

Figure 5: Walking positions: (a) position 1, (b) position 2, (c) position 3

Figure 6: Position of legs during moving of the robot

ELECTRICAL DEVICE SELECTION

A device that converts electric energy to mechanical energy is known as an electric motor. A gear motor is a specific type of motor designed to deliver high torque and low speed at low input power to the output shaft. Initially, a stepper motor was chosen for this inquiry. The stepper motor, on the other hand, proved unable to deliver the required torque and is somewhat heavy. As a result, stepper motors were phased out in favour of gear motors. The gear motor spins at 200 RPM. The robot's four legs are powered by four brushed gear motors. Each motor is connected to the leg's bull wheel, and the motor is hooked to the robot's main body. Figure 7 depicts a gear motor. The motor's rated torque is 0.1765 N-m.

Figure 7: Gear motor

The power source is a 6000 mAh, 11.1V battery. The battery weighs 442 grammes. The microcontroller board and four gear motors are powered by this battery.

The main control board for this robot is an Arduino UNO (AU). It contains a physical programmable circuit board known as a micro controller, as well as multiple input and output pins. It has integrated development environment (IDE) software that is used to write code and upload to the Arduino. Figure 8 depicts an Arduino UNO board.

Figure 8: Arduino UNO board

Four motors are connected to the microcontroller board using two L298N motor shields. The motor shield uses the L298 IC, which is a dual H-bridge driver for driving inductive loads like DC and stepper motors. Figure 9 shows a shield for an L298N motor.

Figure 9: L298N motor shield

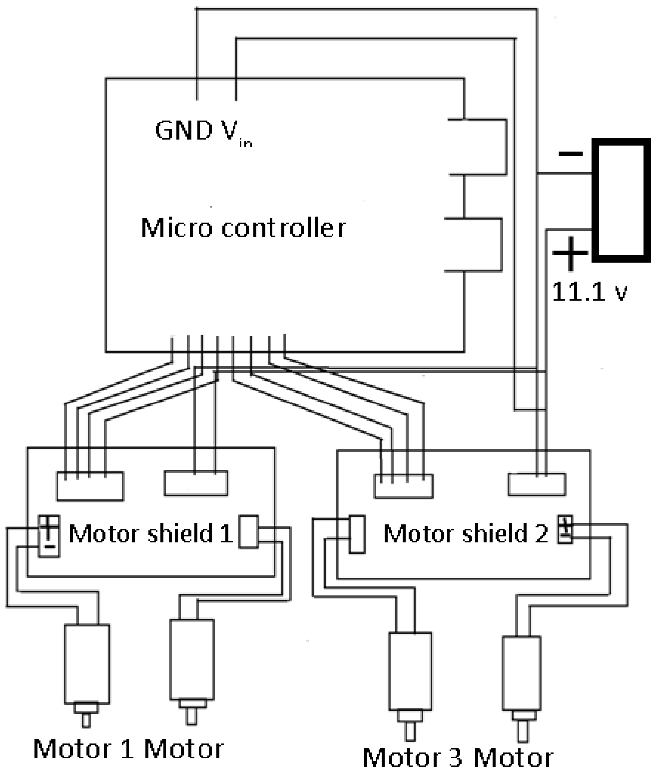

Figure 10: Circuit diagram of the electrical setup

Table 1: Linear and angular displacement of the leg at 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

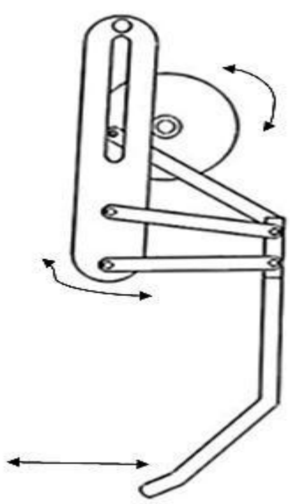

Figure 11: Movement of different components of the leg

The circuit design for the electrical setup is shown in Fig. 10. The AU board and the motor shields both receive power from the battery.

RESULT AND DISCUSSION

Motors are disconnected from the power source at the start of the experiment, and the bull wheel is manually rotated. Leg forward and backward displacement, as well as slotted bar angular displacement, are measured during the experiment for a given angular displacement of the bull wheel. Figure 11 depicts the movement of several leg components. Table 1 shows the results of the experiments.

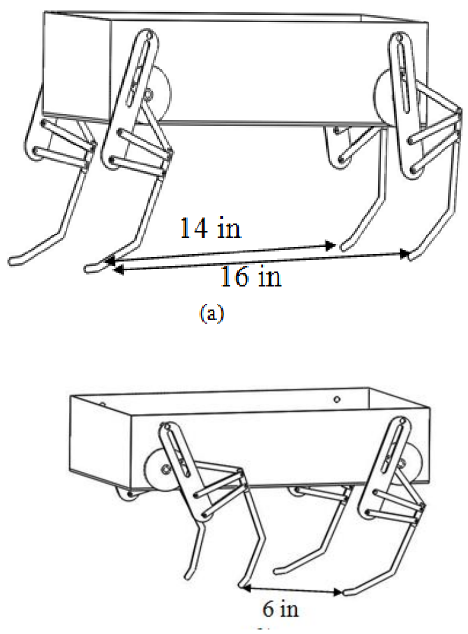

Figure 12: Distance between front and rear leg: (a) longest, (b) shortest

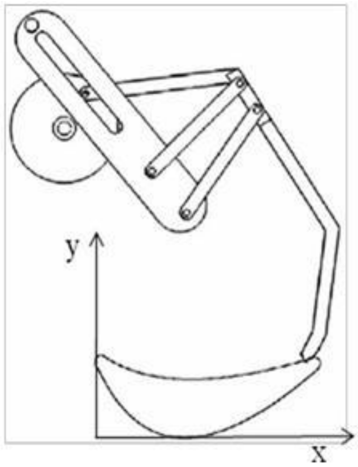

Figure 13: Movement path of the leg

The shortest, longest, and cross distances between the front and back legs are also measured. 16 in and 6 in are the longest and shortest distances, respectively (Fig. 12). On the other hand, Fig. 13 depicts the leg's rotational route and motion.

CONCLUSION

The goal of this study was to create a four-legged robot and investigate the leg mechanism. Finally, a robot was constructed. It was discovered that there was a lot of friction at several components of the robot's leg during movement. Furthermore, two motors quit working after a few steps. This was caused by the robot's weight and frictional loss in the legs. As a result, it is vital to lower the robot's friction and weight. Furthermore, a higher powerful motor may be another option for resolving the issue.

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