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Invited Paper

Development of Legged Robot Having a Double Joint Mechanism

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Abstract. In recent years, robots for service industry and home use, which have begun to spread, must act in the space where stairs and steps created on the premise that human beings use exist. Therefore, the robot needs a high-speed and dynamic operation like a human being. In this research, we propose a legged robot having a double joint mechanism. The legged robot is composed of a thigh, a knee, a calf, a lower thigh, a calf, an ankle, and a toe. The movable range of the thigh and the lower thigh is expanded by the double joint mechanism of the knee and the acceleration area of the thigh and the lower thigh is increased during the jumping motion.

1. Introduction

The range in which robots are used has expanded rapidly in recent years, and it is widely used not only for industrial use but also for service industry and home use [1]. Such a robot is required to move in a space where there are steps and stairs that are built on the premise that a bipedal walking person is active. Also, for the purpose of shortening the moving time, speed equal to or higher than that of human move is required. In response to these, we aim to realize high-speed dynamic movement similar to humans in robot jump.

In this research, focusing on the fact that the jumping robot [2] developed last year was not suitable for the jumping motion, we propose a legged robot having a double joint mechanism. The movable range of the thigh and crus is expanded by the double joint mechanism. This mechanism increases the acceleration section of the thigh and the crus at the time of the jumping motion. This aims for dynamic movement similar to humans. We developed a legged robot with such a double joint mechanism and confirmed the significance of the proposed legged robot by verifying the feasibility of a jumping motion which is a typical high speed operation as a legged robot. We also verify whether it is possible to step up stairs as an application example of such jumping motion. In this case, Article 23 Section 3 Chapter 2 of the Building Standard Act [3] stipulates that the maximum height of the stairs is the stairway of the housing and is less than 230 mm. Therefore, we carried out the ascending experiment using steps of similar height. In addition, by using a worm gear as the power transmission mechanism of the drive motor, it has a structure mechanically responsible for much of the stall torque generated at the time of rapid stop from high speed motion.

In this research, the spring type actuator using the permanent magnet which was developed in the past is not mounted, and improvement of the mechanism of the robot is mainly chiefly. However, we think that spring type actuator using permanent magnet is useful for jumping robot, and use crank mechanism for power transmission for future mounting.

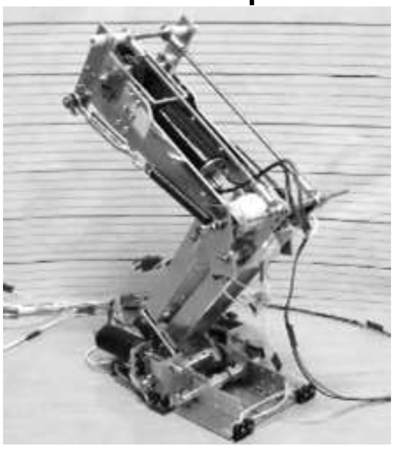

Fig. 1. Legged robot.

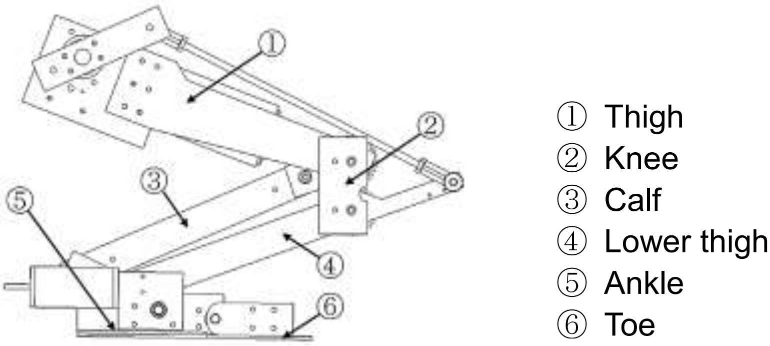

Fig. 2. Schematic of legged robot.

Table 1 Dimensions of legged robot.

Width	[mm]	110
Height	[mm]	420
Depth	[mm]	190
Total mass	[kg]	2.25

2. Experimental Equipment

2.1 Structure of Legged Robot

Fig. 1 is a picture of a legged robot with a double joint mechanism developed in this research.

Fig. 2 is a schematic diagram of a legged robot. Table 1 shows the dimensions when the legged robot is extended. This legged robot is composed of a thigh, a knee, a calf, a lower thigh, an ankle, and a toe. The knee part is a double joint mechanism, and the thigh part and the lower thigh part are interlocked by a spur gear. This legged robot also has a two-joint interlocking mechanism and a crank mechanism. The two-joint interlocking mechanism interlocks the joint of the knee portion and the ankle portion. By using a crank mechanism for power transmission, we obtain thrust by tension and extension. This reproduces the thrust due to tension and extension similar to the permanent magnet type spring actuator mounted on the jumping robot before. In addition, we incorporate a tension spring in the thigh for the purpose of compensating the weight of the robot and assisting the jump.

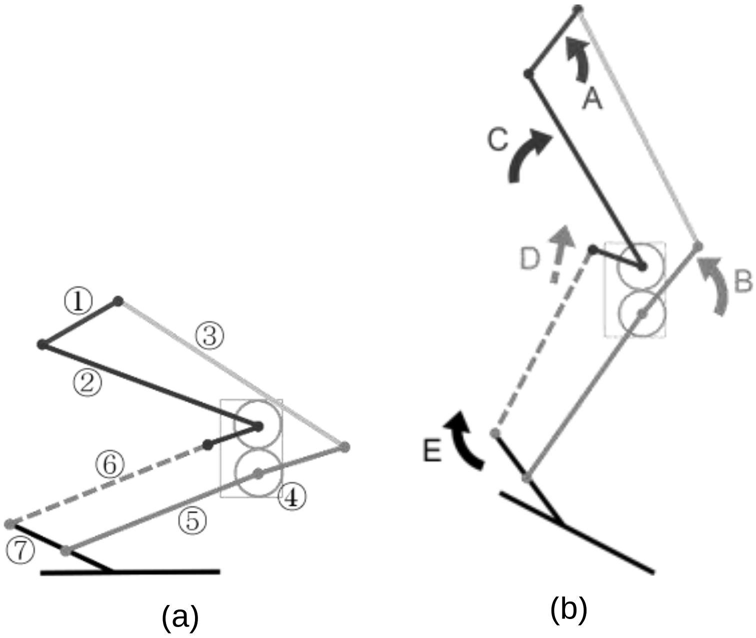

Fig. 3. Principle of jumping motion.

2.2 Principle of Jumping Motion

Fig. 3 (a), (b) shows a schematic diagram of the operating principle of the legged robot.

In Fig. 3 (a), the solid line 1 is the crank. Solid line 2 is the thigh. Solid line 3 is a connecting rod connecting the crank and the lower thigh. The circle 4 is a spur gear fixed to the thigh and the thigh. Solid line 5 is the lower thigh. Dashed line 6 is the calf. Solid line 7 is the ankle and toe. The square frame is the knee part.

In Fig. 3 (b), the rotational torque of the thigh DC motor is the crank rotational torque (A). As a result, the connecting portion of the lower thigh portion connected to the crank is pulled upward, and the lower thigh portion rotates at the axis center on the lower side of the knee portion (B). In the double joint mechanism, since the thigh and the lower thigh are structured to move in conjunction with the spur gear, the thigh also rotates with the rotation of the lower thigh (C). In addition, the thigh and the calf are connected, and the calf is pulled upward by the rotation of the thigh (D). At the same time, the lower thigh rotates, and the ankle rotates (E). Those thigh, the calf, the lower thigh, and the ankle move the robot and extend it. The legged robot makes a posture inclined forward before extension operation and attaches a DC motor to the ankle to determine the jumping direction.

3. Experimental Equipment

The legged robot judges the posture from the ON / OFF of the microswitch. The output voltage determined by this is amplified by the amplifier to supply power to the DC motor of the thigh and ankle. By shooting the jumping motion from the horizontal direction, we read the scale on the back and measure the jumping height. Also, the jumping time is measured by a signal from ON / OFF of the microswitch attached to the ground contact part. The ground contact part is toe and heel. For the ankle motor, apply applied voltage determined by trial and error, 10 V when determining the jumping direction, -6 V at the bending operation. Measurement of jumping height and jumping time is carried out with respect to jumping motion accompanying no pulling operation of the ground contact portion and jumping motion accompanied with pulling up of the ground contact portion. In addition, a step ascent experiment of the steps considered as the staircase is performed by the jumping motion accompanying the pulling operation of the ground contact portion. Here, the height from the lower end of the ground contact portion to the floor is defined as the jump height.

4. Experimental Results and Discussion

4.1 Jumping Experiment 1

In this experiment, 17.0 V was applied to the thigh motor during extension operation and -10.0 V was applied 0.10 s after the extension operation was completed.

Fig. 4 shows the time away from the ground of the toe and heel. From Fig. 4 it was confirmed that the jumping time was 0.26 s. In addition, Fig. 5 is a continuous photograph of the jumping motion without pulling up the ground contact part. In this experiment, it was confirmed that the jumping height was about 70 mm. In the jumping robot developed last year, it was not possible to confirm the jumping height by visual observation. In comparison with this, the legged robot developed by this research was confirmed to be about 70 mm at the jump height of the total center of gravity. From this, from the last year we think that the leg type robot developed in this research was suitable for jumping.

4.2 Jumping Experiment 2

In order to improve the jumping height, a jumping experiment was performed by a jumping motion accompanied with a pulling operation of the ground contact portion. A jumping experiment was conducted in the jumping motion accompanied with the pulling operation of the ground part by applying 17.0 V at the time of extension operation and -17.0 V at the end of the extension operation to the thigh motor. As a result, it was confirmed that the jumping height was about 240 mm and the jumping time was 0.31 s. From this, it was confirmed that the jumping height of about 170 mm was improved compared with the jumping motion without the pulling operation of the ground contact portion.

4.3 Step Ascent Experiment

Since the jumping height of about 240 mm was confirmed from the jumping motion accompanying the pulling operation of the ground contact part, we prepared a step with a height of

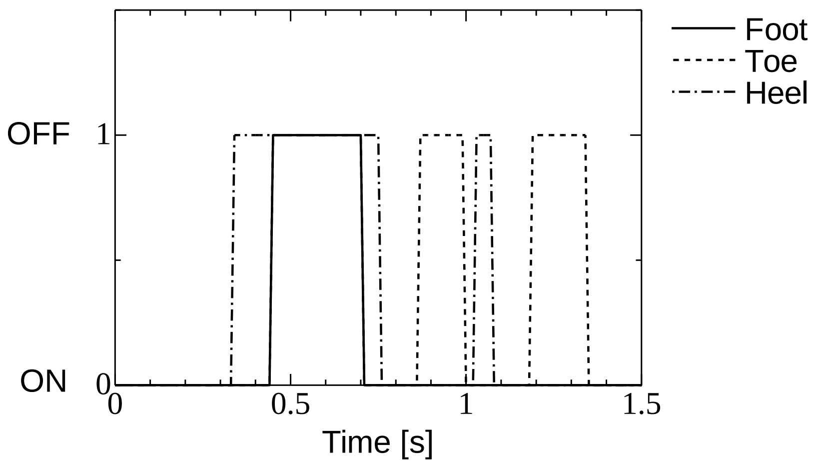

Fig. 4. Jumping time

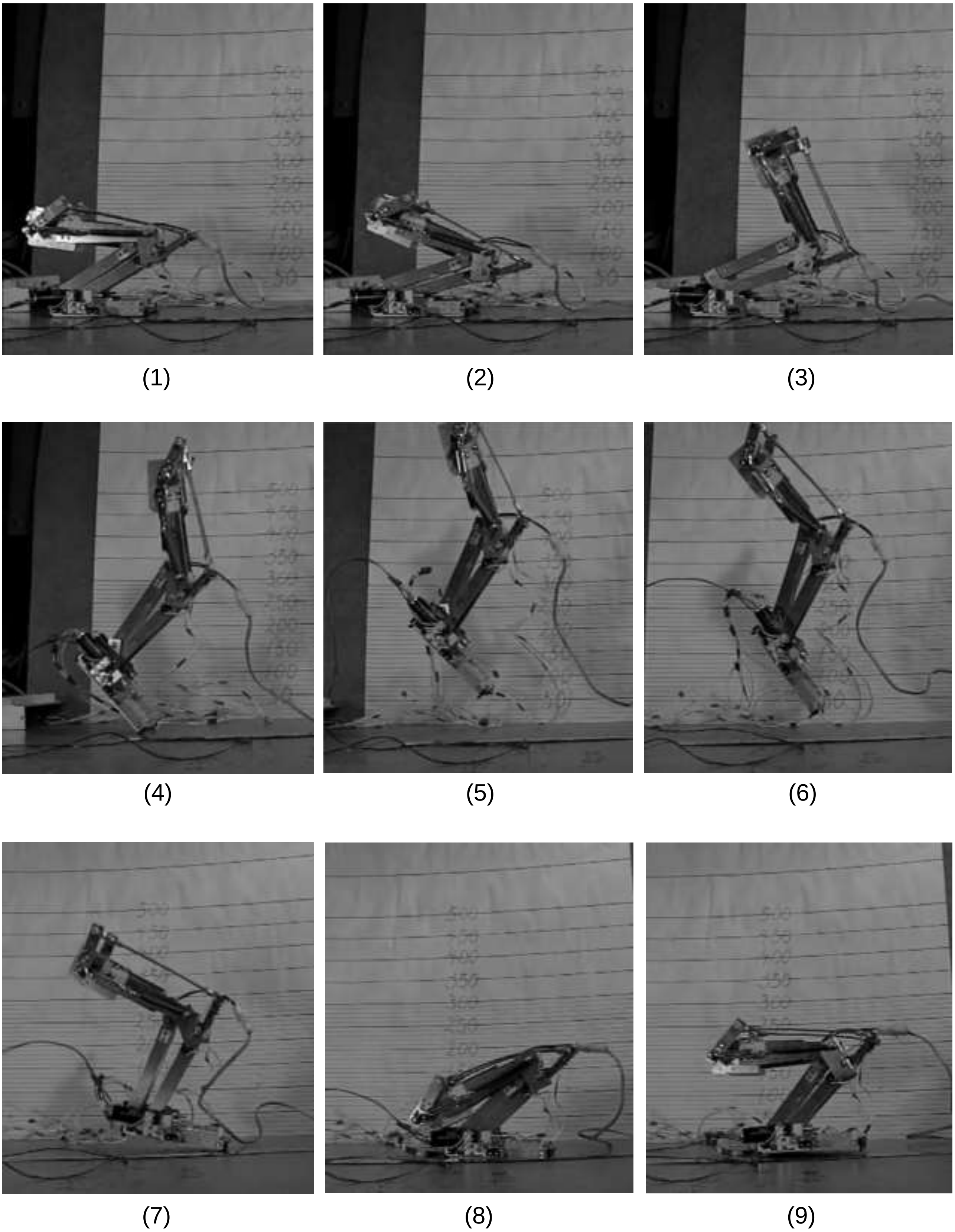

Fig. 5. Motion of jumping.

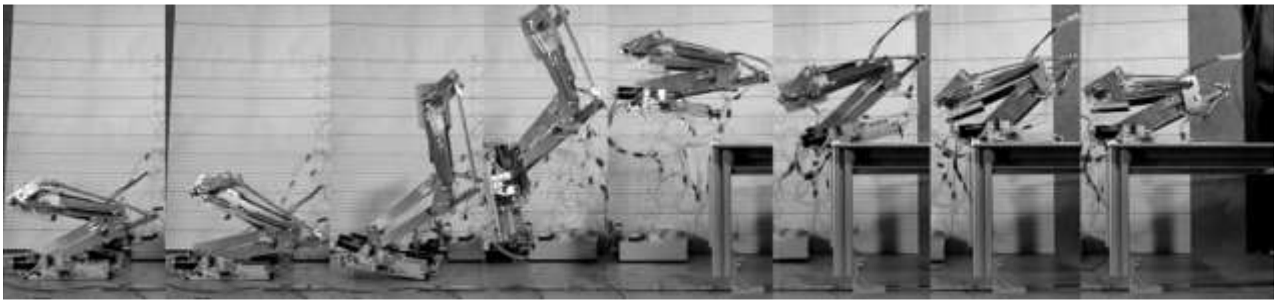

Fig. 6. Motion of step ascent.

accompanying the pulling operation of the ground contact part, we prepared a step with a height of 230 mm and carried out a step ascent experiment by the same jumping motion.

Fig. 6 is a continuous photograph at the time of the ascending experiment applying the thigh motor to 24.0 V at the extension operation and -24.0 V after the extension operation. From Fig. 6, we confirmed the ascent of the step with a height of 230 mm.

Based on the above, since we did not fall over after landing, we believe that continuous jumping and step ascending are possible by performing jumping action again after landing.

Continuous photographs have the shooting interval time and height aligned, and do not consider forward travel distance.

5. Future Challenge

Based on the mechanism of the legged robot developed in this research, we aim to develop a robot equipped with a spring type actuator using a permanent magnet. By making it a two-legged robot, it makes traveling possible. Since we succeeded in jumping by simple control with only the microswitch, we attach a potentiometer to each joint and improve the jumping motion by feedback control. Establishment of continuous jump and step ascent.

6. Conclusion

We developed a legged robot with double joint mechanism. By incorporating the mechanism in the knee part, we increased the acceleration section of the thigh and crus, and realized the jumping motion by the legged robot. We were able to perform a jumping motion by sequence control using a microswitch. We confirmed the jumping height of about 70 mm at the jump height of the total center of gravity and the jumping height of about 240 mm by the jumping motion accompanied with the pulling operation of the ground contact portion. As the jump robot succeeded in stepping up the step of 230 mm, we confirmed that it is possible to step up the stairs according to the Building Standards Act.

References

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