Moving and Breaking Motion Control of Quadruped Hopping Robot Using Adaptive CPG Networks

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1 Introduction

Physiological experiments suggest that basic locomotors patterns of most living bodies such as walking, flapping, flying and swimming are generated by central pattern generators (CPGs) which generates rhythmic activities[1]. CPG are neural networks that can endogenously (i.e. without rhythmic sensory or central input) produce rhythmic patterned outputs; these networks underlie the production of most rhythmic motor patterns. The first modern evidence that rhythmic motor patterns are centrally generated was the demonstration that the locust nervous system, when isolated from the animal, could produce rhythmic output resembling that observed during flight[2]. Then, the application of CPGs on quadruped hopping robot, Kondo proposed the CPG network to generate continuous jumping motion patterns[3].

In this paper, we study on the generation of moving and breaking motion control for our developed quadruped hopping robot while jumping continuously on two-dimensional space. Here, we used the reference height feedback control system to control the reference height for each leg independently. Therefore, we could create the differences height of front legs and back legs to generate the moving performance and correcting the body posture which has inclined to make the quadruped hopping robot jump vertically. On the other hand, we evaluated the effectiveness of Central Pattern Generator(CPG) network to keep the stability of quadruped hopping robot and avoiding it from tumble ahead.

2 Quadruped Hopping Robot

Figure 1 shows the developed quadruped hopping robot construction (overall length is 49cm, overall width is 49cm, overall height is 37cm and the total weight is 9.1kg). The quadruped hopping robot consists of four legs. Each leg is composed with a DC geared motor (12V, 200min^{-1}, 0.0098 Nm), a crank and a spring attached to the crankshaft. Then, each leg is connected to the shared platform.

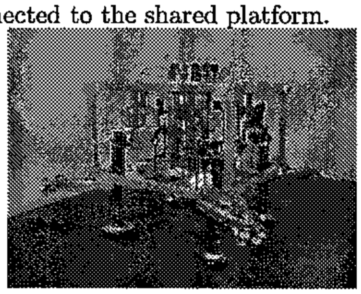

Fig. 1: Quadruped Hopping Robot

The developed quadruped hopping robot is developed by a DC geared motor which is driven by using DC amplifier and connect to the crank which used to push the platform. The continuous hopping of quadruped hopping robot could be generated by using floor repulsive force when the suitable force was applied to the spring at the suitable time.

3 Control System Configuration

3.1 CPG model

Figure 2 shows the block diagram of the CPG model with reference height control system which we used. Here, the inhibitory unit of the CPG includes the mechanical dynamics of the leg. Parameters u_e and u_i denote the internal states of the excitatory unit and the inhibitory unit, b and c denote the intrinsic excitatory and inhibitory coupling parameters, a denotes the excitatory coupling factor while B_0 denotes the constant bias input, $f(*)$ is the mechanical dynamics of the hopping robot's leg, K_a is the gain constant of the DC amplifier and d is the external disturbance which is the floor repulsive force in this case.

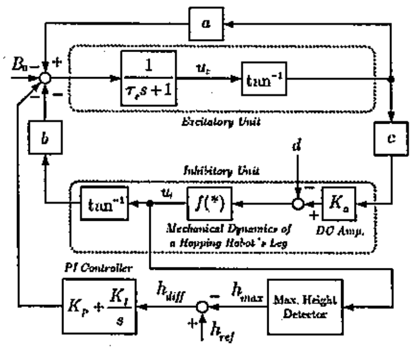

Fig. 2: Block diagram of CPG model and reference height control system for one leg

This control system also composed with the maximum height detector and the PI controller. By adding a feedback loop through a fixed gain PI controller, quadruped hopping robot keep the hopping motion and control the hopping height to achieve the reference hopping height. The PI feedback controller receives the command signal of the target hopping position as a reference h_{ref} and receives sensory feedback signals h_{max} from the ultrasonic sensors on each legs. The differences is given to the PI controller as a command signal.

3.2 CPG Networks

The quadruped hopping robot can jump continuously by applying the same periodic force to each spring of robot's leg and the cooperative oscillation among the CPGs is required. Figure 3 shows the configuration of typical CPG networks. By using this ring-and-cross type CPG networks, we could obtained the stable, continuous and rhythmical hopping performances[3]. In addition, we included the reference height control system with CPG model into each of robot's leg. Therefore, the hopping height of each legs can be controlled independently according to the reference height which have been set. The structure of CPG networks are illustrated in Fig.3.

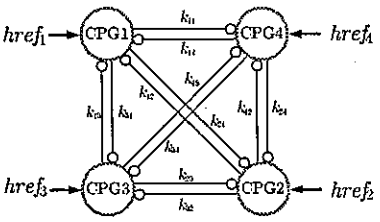

Fig. 3: Ring-and-cross type CPG networks

4 Moving and Breaking Method

Here, the method which we approached is used the reference height feedback control system to create the differences height of front legs and back legs to make body posture incline ahead for moving performance. Then, the correction of body posture which has inclined by setting the reference height for all legs to 20cm could make the quadruped hopping robot jump in one dimension called breaking motion. We have conducted the whole experiment in 60sec which in the first 10sec period, we set the reference hopping height for all legs to 20cm to maintain the oscillation of hopping performances, in advance. Then, after 10sec until 40sec, the moving performance are been set. Therefore, started from 40sec to 50sec, our proposed breaking motion performance are set following with the moving performance from 50sec to 60sec.

5 Experimental Setup

The proposed CPG network is expressed using a MATLAB/Simulink model on a host computer. Then the model, built by a realtime workshop, is downloaded to a xPC target computer. The xPC target computer is run by using a realtime OS. The position of the center and each leg are measured using ultrasonic sensors which are used as sensory feedback signals of the CPG. We also included the current sensors into the system which are used to monitor the current value which have given to each leg on each jumping motion. In this experiment, the sampling time for the control is set to 0.01 sec.

6 Experimental Results

Here, the internal parameters of CPGs are set to the typical value as $a = 0.1$, $b = 2$, $c = 1$, $B_0 = 0.01$, $\tau_e = 0.1$, $f = 0.1$ and the PI controller's gains are set as $K_P = 5.5$ and $K_I = 0.4$ in advance, in order to generate the efficient hopping performances. As the results, we could see the changing of control signals, current values and hopping height values in Fig. 4 in order to generate the successful moving and breaking motion. For the breaking performance, the control signals for leg 1 and leg 3 are increasing to -10V to achieve the reference height which have set to 20cm. However, the control signals for leg 2 and leg 4 are unchanged according to reference height which unchanged. At the same time, the maximum height for leg 1 and leg 3 are increasing from 18cm to 20cm while maximum height for leg 2 and leg 4 are still remain at 20cm to make the vertical hopping motion.

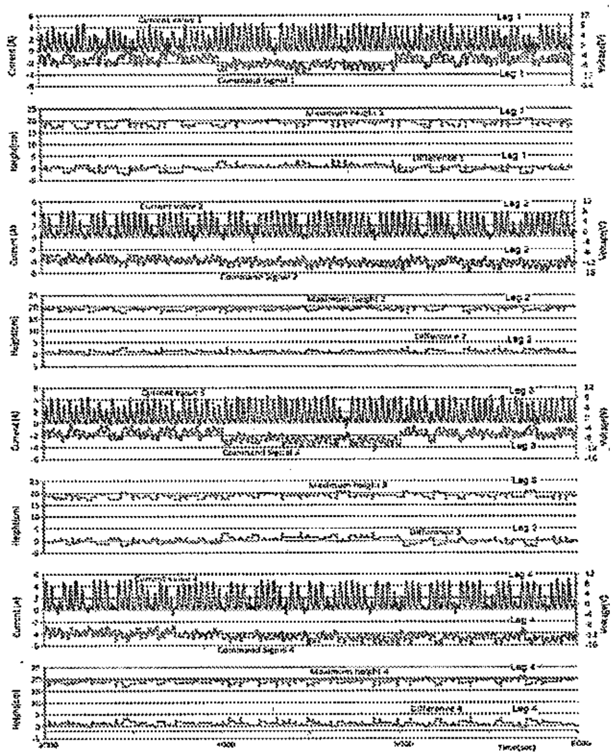

Fig. 4: Experimental results for moving and breaking performances

7 Conclusions

In this paper, we have proposed the moving and breaking motion method in action to give stabilization to our quadruped hopping robot. Here, we confirmed the effectiveness of approach method to generate moving and breaking motion control of quadruped hopping robot while making continuous jumping vertically. On the other hand, we also obtained the effectiveness of CPG networks which act as a command center for the musculoskeletal system to generate the continuous hopping performances and to keep the stability of quadruped hopping robot and avoiding it from tumble ahead.

References

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