The Sixteenth International Symposium on Artificial Life and Robotics 2011 (AROB 16th '11),
B-Con Plaza, Beppu,Oita, Japan, January 27-29, 2011

Jumping rhythm generator by CPG for a multi-legged robot

Masaaki Ikeda
Department of Advanced Systems Control Engineering,
Saga University,
1 Honjomachi, Saga 840-8502, Japan
Email : 09539002@edu.cc.saga-u.ac.jp,

Kiyotaka Izumi
Department of Mechanical Engineering,
Saga University,
1 Honjomachi, Saga 840-8502, Japan
FAX: +81-952-28-8587
Email: izumi@me.saga-u.ac.jp

Keigo Watanabe
Department of Intelligent Mechanical Systems,
Okayama University,
1-1-1 Tsushima-naka, Kita-ku,
Okayama-shi 700-8530, Japan
Email: watanabe@sys.okayama-u.ac.jp

Abstract: Three features of a legged robot are listed as the discrete disposition of supported legs, the flexible posture without changing disposition of supported legs, and the obstacle avoidance with a three dimensional behavior. The maximum height of an avoidable obstacle is defined by the leg mechanism of a robot. The capability of obstacle avoidance is improved by a jumping motion. In this paper, we discuss the rhythmic jumping of a multi-legged robot using the central pattern generator (CPG). Authors propose the construction method of CPG for six legged robot, in which each leg has a compressed spring. The effectiveness of the present method is illustrated by some simulations.

Keywords: Legged robot, Jumping robot, Central pattern generator, Robot simulator

I. Introduction

In recent years, working places of robots are expanding from factories to outdoors and homes, etc. Required tasks of mobile robots are rescue operations in dangerous places such as a disaster area and the scene of an accident, and assistance of human at a home. Mobilities on a rough terrain of a robot are demanded to be high. Mobile mechanisms which have high energy efficiency are a wheel type and a crawler type. Those mechanisms are able to travel on the terrain which is secured a continuous contacting surface, however, the mobility of those mechanisms is almost low on the rough terrain which has big bumps. The legged mechanism has a high capability of movement on a rough terrain because of some features which are a discrete disposition of supported legs, the flexible posture without changing the disposition of supported legs, high degree of freedom, etc. Many legged type robots have been developed with several concepts which are biomimetic machines, and improvements of mobile capability and adaptation capability against for any ground conditions.

Moreover, it is listed to one of the features of a legged robot ranging over an obstacle that three-dimensional obstacle avoidance behavior of getting over and moving is possible. However, the point that the obstacle of the height exceeding the excursion of a leg cannot be overcome as a subject of this feature can be considered. Movement by a jump or flight can be considered to this subject.

It is shown clearly that a living thing controls periodic movement which was autonomously adapted to environment by making feeling feed back to the central pattern generator (CPG) of the neural circuit which exists in a spine. CPG is applied to a legged robot and research which controls an autonomous periodic motion by feeding back the information acquired from the sensor attached to the robot to the mathematical model of CPG to environment like walk behavior is done[1], [2].

In this paper, a jump is adopted as a method of easing restriction of the avoidance operation by the mechanism in the obstacle avoidance of a legged robot, and it thinks of the mobile robot of six leg types which has a jump mechanism. Moreover, CPG generates the desired value for a jump mechanism, and a periodic jump is enabled. The effectiveness of the proposal approach is examined from the result of the simulation using OpenHRP3 which is the distributed component type robot simulator.

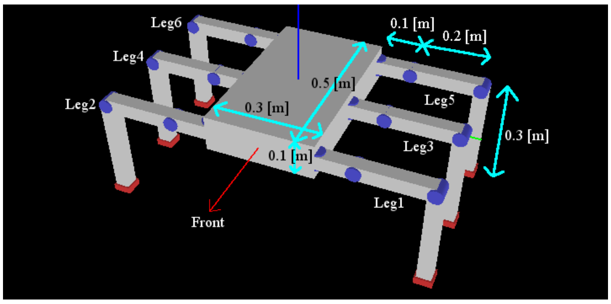

Fig. 1: Jumping six-legged robot

II. Jumping Six-Legged Robot

Although it is in the number of legs of a legged robot variously, in this paper, we adopt a six-legged robot, because this robot can always keep static stability. In order to perform posture maintenance and walk movement, there are three joints in each leg of a robot. It has a mechanism of the direct acting furthermore slid to each leg apical portion as a jump mechanism for leg them. Therefore, as for the jumping-of-flow-control-valve legged robot to examine, since it is an existing six-legged robot, 4 degree of freedom is a robot which has 24 degree of freedom in total at each leg. The target six jumping-of-flow-control-valve robot models, each link length, and the leg number which were used by the kinetics simulator are shown in Fig. 1. The line extended on a robot in Fig. 1 expresses perpendicular above, makes this a z axis, and makes an x-axis the line extended in the direction of this side of a robot. Further Axis, Direction which makes an axis and a right-hand system It is considered as an axis. Moreover, let the field which is in sight to the front with Fig. 1 be a front face of a robot. Saw from the robot, and become an odd number on left-hand side, it is made to turn into even numbers on right-hand side, and the leg number of each leg set the leg number of the front left-hand side leg to Leg1.

The total mass of a robot is 12 kg. The maximum height of the axial direction of the robot in the posture of Fig. 1 is set to 0.35 m. The sliding mechanism for a jump of the leg point is shown in Fig. 2. The sliding mechanism for a jump is slid in +0.05 m and -0.05 m on the basis of the leg point. In addition, the leg used each leg as the same mechanism.

III. Jumping Rhythm Generator

CPG is a kind of a neuron model and generates the periodic signal it is supposed that it is deeply related to the periodical activity of a living thing of the periodic signal.

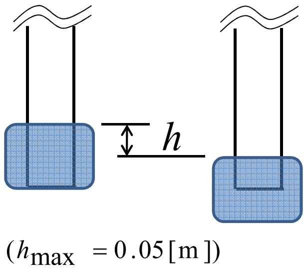

Fig. 2: Slide mechanisms for jump

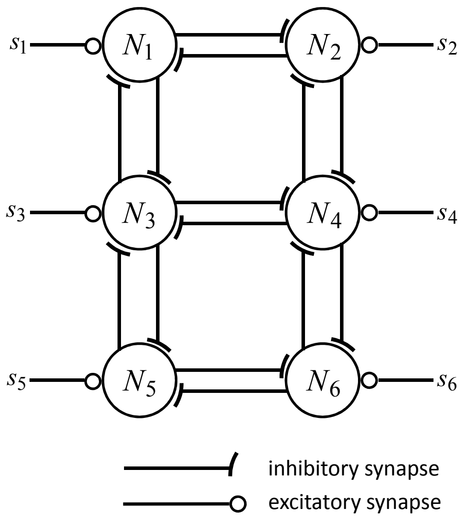

Fig. 3: Network for CPG

When two or more CPG neurons exist, it is known that the phenomenon called drawing in with the passage of time will generate the output cycle signal of each neuron by defining the coupling coefficient between neurons. Although there were some mathematical models proposed so far in CPG, in this paper, Matsuoka oscillator with a comparatively simple relation of a parameter was used[3]. Matsuoka model was following formula.

$$\begin{aligned} T_r \frac{\mathrm{d}u_i}{\mathrm{d}t} + u_i &= -\sum_{j=1}^{n} a_{ij} y_j + s_i - b f_i \\ y_i = g(u_i) &\quad (g(u_i) \triangleq \max(0, u_i)) \\ T_a \frac{\mathrm{d}f_i}{\mathrm{d}t} + f_i &= y_i \end{aligned} \tag{1}$$

Where, t is time variable, i, j is number of neuron. T_r is rise time constant, u_i is membrane potential of neuron body, a_{ij} ($\geqq 0$ for $i \neq j$ and $= 0$ for $i = j$) is a weight of inhibitory synaptic connection from j-th neuron to the i-th neuron. y_i is a firing rate or output of the neuron, s is an impulse rate of input. b is the parameter that deter-

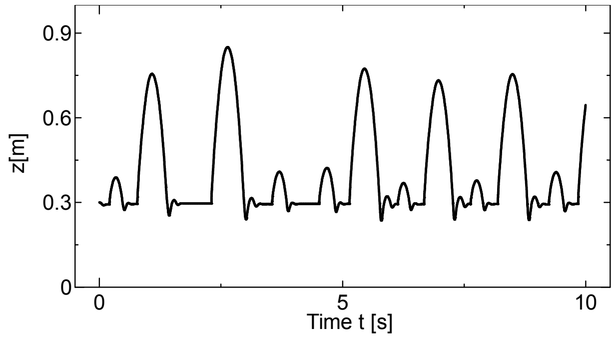

Fig. 4: The vertical posision of the robot

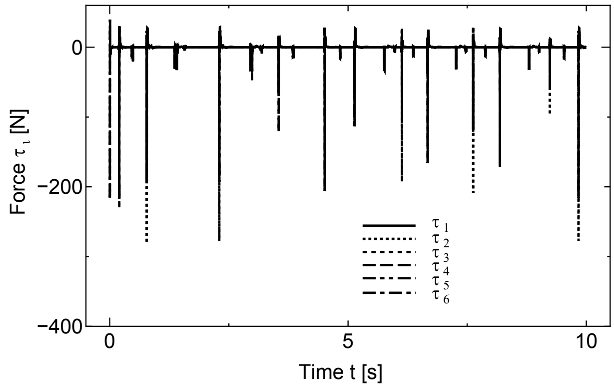

Fig. 5: Driving forces of soles

mines the steady-state firing rate for a constant input. f is adaptation variable, T_a is adaptation time constant.

The composition of the CPG network by inhibition binding of six neurons used in this paper is shown in Fig. 3. The output value y from each neuron of the constituted CPG network is carried out as a next desired value of the sliding mechanism for a jump of the leg number i as shown in following equation.

$$h_{oi} = -y_i \tag{2}$$

However, it is less than a value with x of the robot center of gravity, and the acceleration of y axial direction, When the acceleration of an axial direction approaches gravitational acceleration enough, it thinks that the shake of a robot was fully settled, and it limits to when the shake of a robot is fully settled, and a CPG output is used as a desired value. The output of the sliding mechanism for a jump is calculated by the following formula using the desired value acquired from CPG.

$$\tau_i = P(h_{oi} - h_i) + D(v_{oi} - \dot{h}_i) \tag{3}$$

Where, i is number of the leg, h_i is the displacement of the slide joint, v_{oi} is objective velocity (Now, $v_{oi} = 0$). P is the proportional gain, D is the differential gain. Thus, the force for a jump is generated with the generated period.

IV. Simulation

1. Setting up of parameters

It is referred to as $T_r = 0.3, s_i = 0.25, b = 10.5, T_a = 0.2$ and each parameter given to the Matsuoka oscillator of CPG used for the simulation is an initial value of the membrane potential u of each neuron. It carried out and the initial value of $u_1 = u_4 = u_5 = 0$, $u_2 = u_3 = u_6 = 0.05$ and a fatigue state f was set to $f_1 = f_4 = f_5 = 0$, $f_2 = f_3 = f_6 = 0.05$. Coupling load of the CPG network was set to $a_{12} = a_{13} = 2.5$,$a_{21} = a_{24} = 2.5$, $a_{31} = a_{34} = a_{35} = 2.5$, $a_{42} = a_{43} = a_{46} = 2.5$, $a_{53} = a_{56} = 2.5$ and $a_{64} = a_{65} = 2.5$. The control gain used for the force calculation in the case of a jump was set to $P = 4500$ and $D = 1$.

2. Results

The force outputted to each sliding mechanism is shown in Fig. 5. The orbit of the body of a robot is shown in Fig. 4.

The output of each CPG neuron is shown in Fig. 6. Fig. 6 is put in order by neuron numerical order from the top. By the constituted CPG network, Phases of the first, the fourth and the fifth neurons is same each other. Similarly, outputs of the second, the third and sixth neurons have same phase. Moreover, a phase shift from which the phase angle of such combination obtains the maximum by turns is seen.

The number of times of a jump is because the shake of a robot was not fully settled, so few things are not outputting force compared with the number of times of an output of CPG. Conversely, the force currently outputted calculates the output of CPG when conditions are fulfilled. When the output of Fig. 5 and the orbit of Fig. 4 are measured, it turns out that it has jumped immediately after outputting force. However, it turns out that the height proportional to the output of force has not necessarily come out.

This is because slope of the force outputted since force is outputted when slope of the CPG output of the phase angle of another side is negative when one of the two is 0 among the outputs by two kinds of phase angles also becomes negative. On the contrary, the height to which one output is proportional to force since slope of the force outputted when slope of the CPG output of the phase angle of another side is positive also just becomes by 0 is obtained. When a CPG output is larger, it turns out that the jump to which it is higher to output force is carried out. Moreover, in order that the direction whose slope of the output of CPG the CPG output of two kinds of phase angles is both positive at the time or more of zero at the time of the output of force may work strongly, it turns out that the height proportional to force is obtained.

V. Conclusions

It is checked that a robot jumps periodically by using the network composed of CPG neurons which are modeling with Matsuoka osillator. The robot has six legs which are equipped jump mechanism. In the CPG network of this paper, the height of the jump at each time changed unintentionally. This feeds back the force sensor of a robot, and the information on a gyro sensor to CPG, and is expected that a suitable CPG output to which the height of a jump becomes fixed is obtained by presuming time until a posture is stabilized from the flight duration and landing of a robot.

References

[1] Ijspreet AJ (2008), Central pattern generators for locomotion control in animals and robots: A review. Neural Networks 21:642-653

[2] Liu GL, Habib MK, Watanabe K, Izumi K (2008), Central pattern generators based on Matsuoka oscillators for the locomotion of biped robots. Artificial Life and Robotics 12(1-2):264-269

[3] Matsuoka K (1987), Mechanisms of Frequency and pattern control in the neural rhythm generators. Biological Cybernetics 56(5-6):345-353

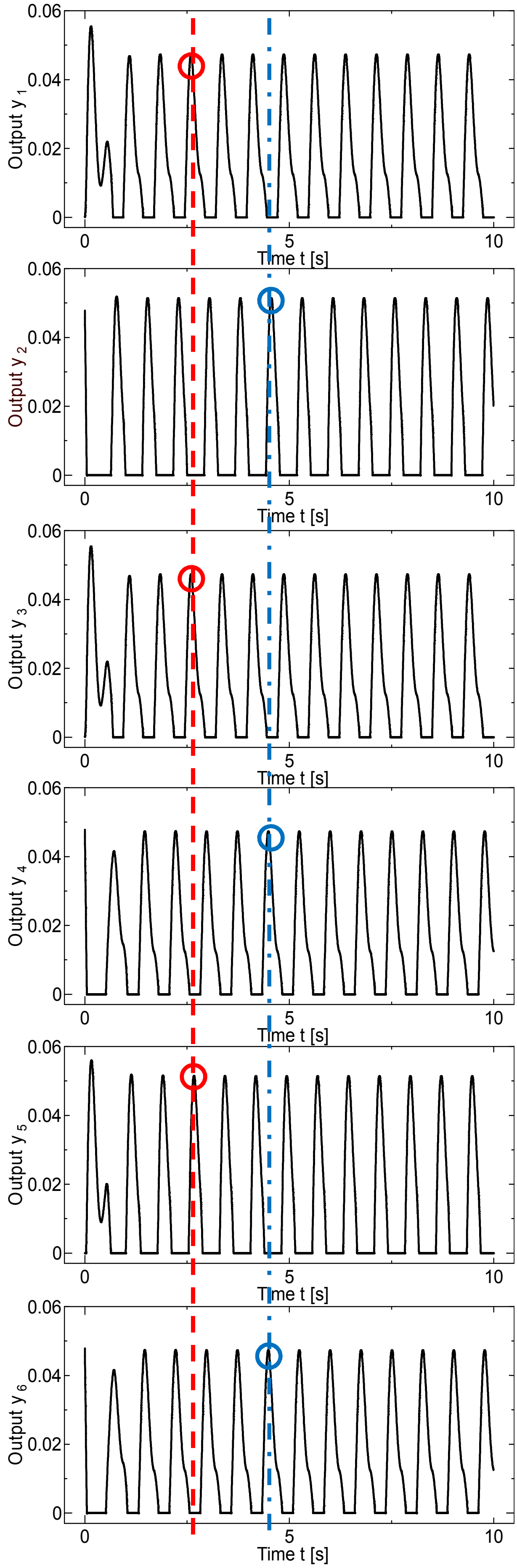

Fig. 6: Outputs of neurons