Proceedings of the 1993 IEEE/RSJ International Conference on Intelligent Robots and Systems Yokohama, Japan July 26-30, 1993

Centipede type multi-legged walking robot

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Key words: walking robot, vehicle robot, multi-legged robot.

Abstract: ~~In this paper, we~~ The authors propose a centipede type multi-legged walking robot, which has 10 legs or over. Since the centipede type walking robot has more legs than other type robots, a centipede type walking robot transport more heavy payload than an other type robot. The walking sequence of this robot is different from conventional multi-legged walking robot that has a half cycle difference between the front and rear neighbor legs. A lateral pair of legs makes a unit, and a unit follows the movement of the front neighbor unit with a quarter delay of the walking cycle. Thus, this robot walks with statically stable condition. This robot also differs from conventional walking robots that have a controller to control movement of whole robot legs. This centipede type walking robot has computers for each pair of legs. These computers control legs and communicate the front and rear neighbor computers. No computer of these computers controls the whole robot. All legs without the head pair of legs follow the movement of the front neighbor legs with quarter walking cycle delay, then the whole robot walks with static stability.

1.Introduction

Walking robots has availability for moving on rough terrain. Recently many types of walking robots were developed[1-3]. About almost multi-legged walking robots two legs which are neighbor each other on one side of robot move at a half cycle difference on the walking cycle. And each almost walking robots has a computer that controls whole system of robot. To increase the payload of a robot or to decrease the load per one leg, a walking robot needs more legs. Thus, we proposed a centipede type multi-legged robot. This robot has 10 or more legs and has no computer to control the whole robot but has many computers to control each pair of legs. The motion of a leg is similar but with a quarter cycle delay of walking cycle against the front neighbor leg.

In this paper we mention the walking sequence of the centipede robot in section 2, the hardware and the software of the robot in section 3, the experiment result of the prototype walking robot in section 4 and the conclusion of this paper in section 5.

2.Walking Sequence

At most insects and spiders walking, a leg moves with half cycle difference against the front or rear neighbor leg's motion[1-8]. A centipede walks by moving legs like a wave[8]. In this motion a leg moves with less half cycle delay against the neighbor front leg motion[5]. Fig.1 and Fig.2 show the difference of these walking style. Fig.1 shows the insect type walking sequence and Fig.2 shows the centipede type walking sequence. The legs of the insect type walking robot are divided in two groups that move simultaneously at walking cycle motion. The triangles wrote by using broken line in the Fig.1 shows the legs companyed with each other. One of these groups must contact ground to support the robot statically at each moment. Fig.2 shows the motion of the centipede type

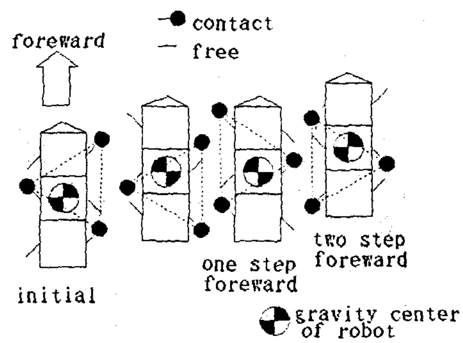


fig.1 the walking sequence of a insect type (6 legged) robot

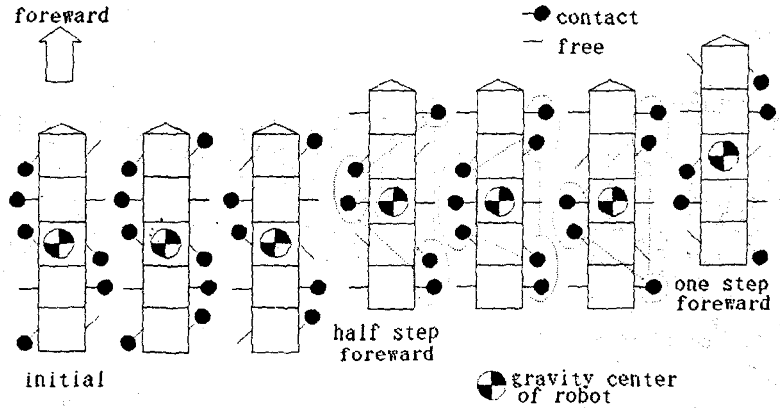


fig.2 the walking sequence of a centipede type (10 legged) robot walking robot. It is different from the insect type walking robot about its leg motion. The sequence of figures from left to right in Fig. 2 shows the half cycle of walking motion. Investigating neighbor two pairs of legs, the rear side pair's motion followed the front side legs with a quarter cycle delay. All pairs of legs without the head end pair imitate the front neighbor pair of legs. Thus, only the computer that set up on the head unit make the walking sequence. The figure wrote by broken lines in Fig.2 shows the envelope of contacting legs positions. Always the position of gravity center of the whole robot locates in these figures. It means that this robot walking sequence is statically stable.

3.Apparatus

To realize the walking sequence mentioned in above section, we made the multi-legged robot that has 10 or above legs. In this section, we will mention the detail of this robot. This robot is consisted of three part, mechanisms, sensors, computers to control each units and the control algorithm for this robot.

3.1 Mechanism

Fig.3 shows the survey of the mechanism of a unit. One leg needs two DOFs (degree of freedom) to walk straight. One of these DOFs makes the leg to move along the walking direction and other makes the leg to move the foottip vertical. A leg of this robot can move along the axis of walking direction with translational movement and move vertically with rotation movement along the walking direction axis. To make the translational motion for each leg, a ball spline bar is used for a guide and a geared motor and pulleys with a timing belt to actuate each leg.

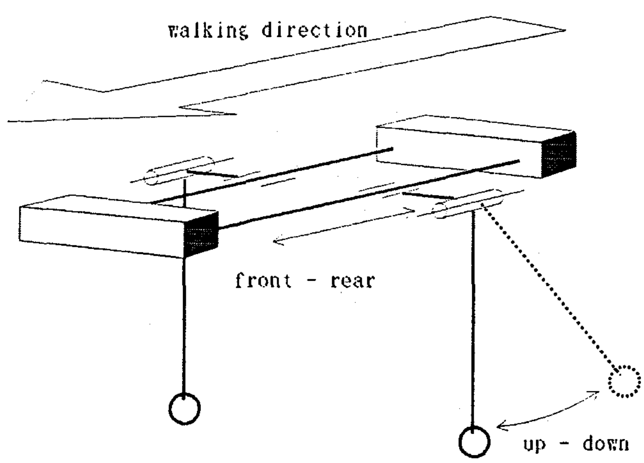


fig.3 the survey of one unit

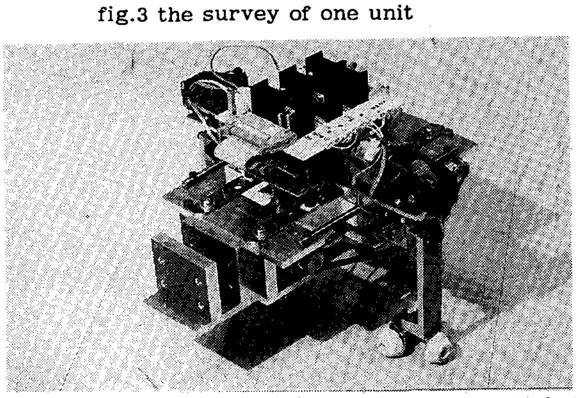


fig.4 the photo of one unit of the centipede type robot

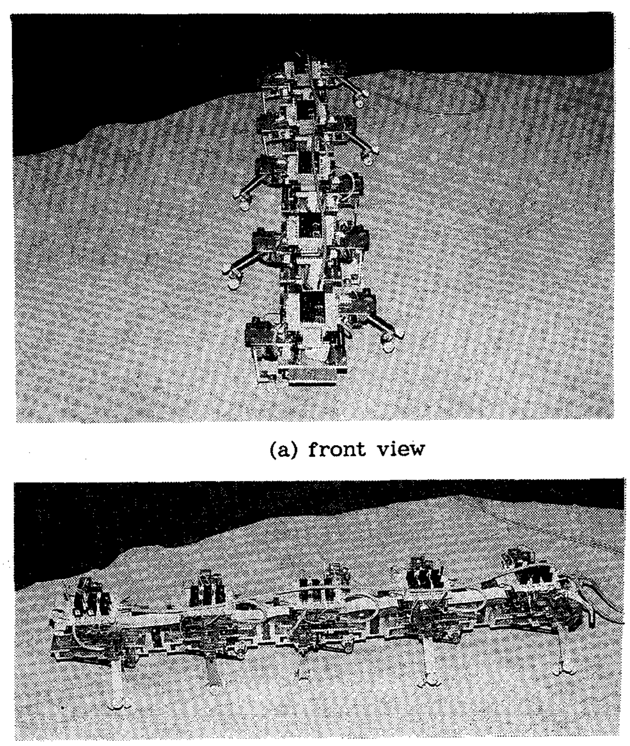
And to make the rotational motion, a geared motor is directly connected with the rotation axe. One unit has two legs that have 2 DOF respectively. Thus, a computer must control four motors to walk. To control the motor, four full bridge motor driver IC sis used for the interface between the computer and the motors. Using this IC, the computer controls the motors condition one of four conditions, which consist of free, lock, forward and backward. Fig.4 shows the photo of the one unit. Fig.5 shows the photo of the prototype of a centipede type walking robot consisted of same five units. The size of this robot is shown in Table 1.

3.2 Sensors for motion detection

To detect the state of the leg, five sensors are set up for a leg. Fig.6 shows the location of these sensors. To detect the highest and lowest position of a leg, two micro switches are set up at each end of the motion range. When a leg reaches at one of both ends, the switch at the end changes the state from off to on. And to detect the front end, rear end and center position on the translational motion, two micro switches and a photo interpreter are set up. These two micro switches are used for detection of the arrival of a leg on the motion end similarly as rotational motion, and the photo interrupter is used for detection of a leg on the center position of translational motion range. Detecting center position of translational motion is used to stop the advancing motion because of half stroke difference between neighbor units. Each signal for these sensors is obtained by the computer through the parallel interface. And the computer has the communication line with front and rear neighbor units through 4 bit parallel lines.

3.3 Computer for control

To control the legs motion of this robot, this robot has one board computers with a Z80 CPU on each unit. These



(a) front view

(b) side view

Fig.5 the photo of the centipede walking robot table 1. the size of the centipede robot

width	270 [mm]
length	200 [mm/unit]
	1160 [mm] (5 units robot)
height	150 [mm] (without electric parts)
	180 [mm] (with electric parts)

computers are used to move legs, to detect the condition of legs and to communicate with neighbor units, front and rear. To communicate these peripherals, each computer has three interface LSI with 72 bits parallel input/output ports. The set of the programs is delivered by PROM ICs on the computer boards and starts at the moment of power on as a trigger. Fig.7 shows the whole construction of the control hardware for one units. Each unit of this robot has the hardware to control the unit itself and to communicate neighbor units without power supply.

3.4 Control algorithm

In each computer on this robot, same programs are delivered. Firstly the head unit and the tail units detect that it is positioned at the head and tail end by detecting that the communication line is open in communication initialization. From the head unit to tail unit, each units is numbered by order from head as 0, 1, 2, 3, 0,... The number of units is cyclic, and units with same number move each legs simultaneously. In initializing legs state, each unit initializes its legs to initial position that specified the unit's number respectively. In walking state, the head unit makes the transition signal to the next unit. This signal is relayed to the end unit through each unit, and each unit moves legs of itself to next mode of walking cycle. When this motion is completed, the tail unit makes a finish signal for the next front unit. When a midway unit received the finish signal and its motion has completed, the unit sends the finish signal to the next front unit. When the head unit receives the finishes signal and the motion of it has completed, the computer of the head unit recognizes that the motion of the whole robot is completed. Thus to continue these operations, the robot walks continuously.

4.Experiment

Fig.8 shows the sequence of walking motion. This figure shows that the motion of each pair of legs has the quarter cycle delay against the neighbor front pair of legs and that the robot walks straight with static stability. We made the robot longer, from five units to six units, to certify the flexibility of this control method. In this condition, this robot walks straight similarly as the five units robot with no change of the software.

The walking specification of this robot shown in table 2. Each unit of this robot is connected by a rigid block with neighbor two units. Thus, in walking sequence, this robot keep its orientation steadily.

5.Conclusion

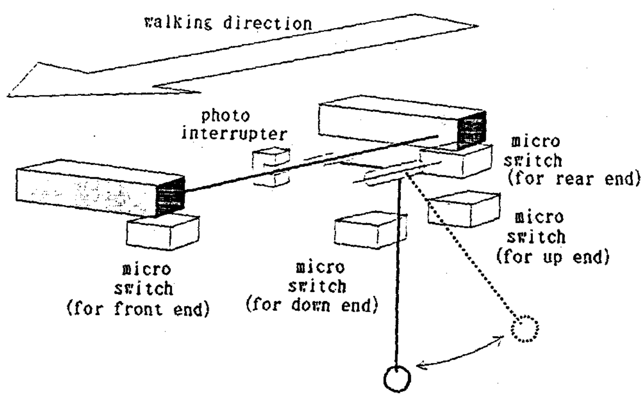


fig.6 the location of sensors on each unit

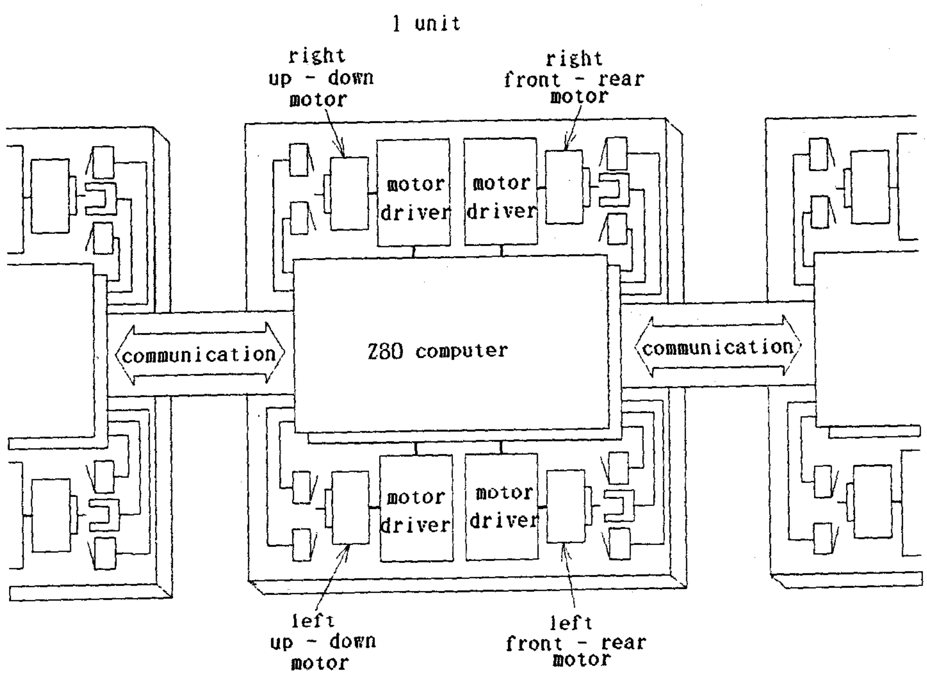


fig.7 the construction of control hardware

In this paper, we proposed the mechanism including the hardware for control and a control algorithm for the centipede type multi-legged walking robot. To realize this multi-legged robot with over 10 legs, one controller hardly controls whole legs' motion. Thus, we proposed a distributed control system for this centipede robot. To certify this algorithm we make a prototype robot with five units (10 legs). This robot has walked with stable state sequence. Then we added one unit to this robot, this robot that has six units (12 legs) walked similarly as a five units robot. We are investigating about this robot to make this robot walk along any trajectories. In the future we will make each unit shorter to increase the leg density against the length of the robot. It makes the robot to be able to walk soft surface area and to transport much object on itself.

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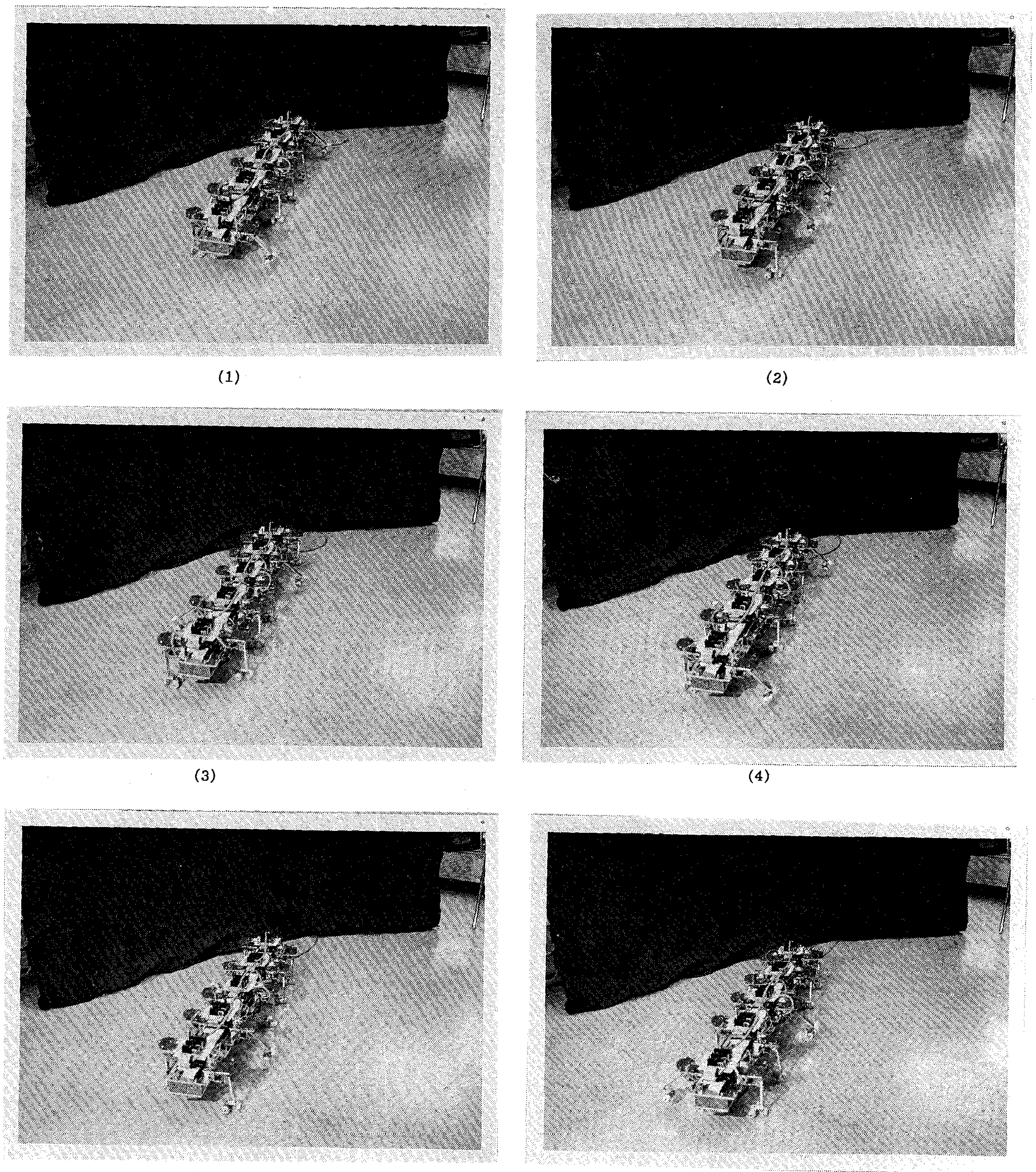
table 2. the spec of the robot

stroke of a leg	79 [mm]
period of one stroke	9.2 [sec]
walking speed	8.6 [mm/sec]



(1) (2) (3) (4) (5) (6)

fig.8 the photo of the walking sequence