A BIO-INSPIRED HYBRID LEG-WHEEL ROBOT

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ABSTRACT

This work described the design and construction of a combination of a bio-inspired leg-wheel mobile robot platform. A locomotion method using legs and wheels mechanism was presented here. The insect hybrid leg-wheel robot was built with two front legs and wheels in the back. Each leg consists of two mechanisms which are six-bar and four-bar linkages driven by two motors. The robot movement was propelled by the two front legs pushed the wheel to go forward and backward. The robot controller hardware used the stampbox by Parallax. The joint angles was measured using potentiometer and the foot sensors was the on/off swich.

1. INTRODUCTION

In recent years, a number of development has been done on robots having different types of locomotion depending on the environment. The early studies has demonstrated that the locomotion of robots can be considerably improved when biological systems are combined into its mechanical design.

Raibert and his team successfully built monoped, quadraped, hopping robot by integrating the biologically inspired dynamics into their mechanical design [1]. Roboticists at Case Western Reserve University have also used the biological systems as a model for building a hexapod robot, a cockroach-like robot [2], [3]. Researchers at the Ohio State University also built the ASV (Adaptive Suspension Vehicle) which is a six-legged vehicle designed for sustained locomotion on unstructured terrain [4], [5].

As the previous work has shown that legged locomotion is highly agile and successful in maneuvering over a wide range of ground. Wheeled vehicles however have been developed for moving fast on smooth surface. Researchers at Tohoku University in Japan used the idea of combination of both leg and wheel to develop a leg-wheel type robot for the exploration [6], [7]. This paper also used the combination of leg-wheel would be a good solution for the robot since it can go fast on smooth surface by using wheels and walk on rough terrains by using legs.

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2. BIOLOGICAL OBSERVATIONS

This work used the biologically inspired kinematics of the insect's legs for designing the legs. A key feature of insect leg construction is its multisegmented nature. Segment joints can have a single or multiple degrees of freedom (DOF). The result is movement capability that enables successful walking. In general, the insect has six legs matched in pairs across the body [8]. Figure 1 shows the schematic of leg segment and the arrangement on the body. Due to the simplicity of the mechanical design, the two major leg segments: the femur and tibia are used as the model.

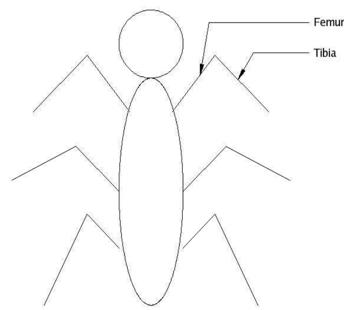

Fig. 1. **Insect's leg schematic**

The robot in this work used the biological principles of the two front legs swing alternatively during the walking of the insect as the inspiration for the robot design. Figure 2 also shows movement of the two front legs during the insect walk

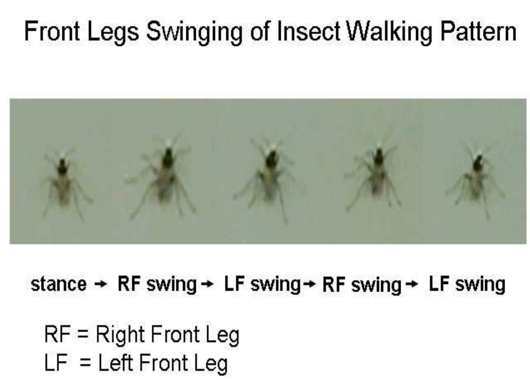

Fig. 2. **Insect walking**

3. DESIGN

The mechanics of a robot are important for the control mechanisms. The kinematic construction was similar to that of an insect so that its body was suspended from their legs. The frame design couples the degrees freedom to simplify the control.

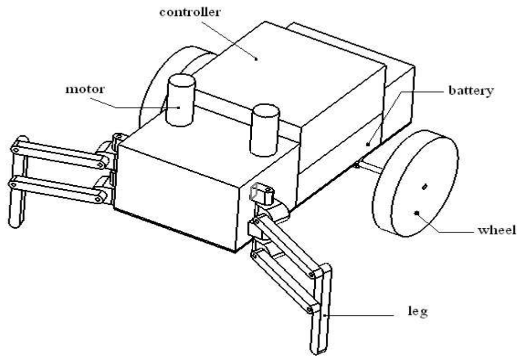

Fig. 3. Robot model

The robot has two front legs that will be similar in fuction to that of the insect's leg shown in Figure 2 However, the robot's legs will be kinematically simple that the insect to simplify the mechanical design.

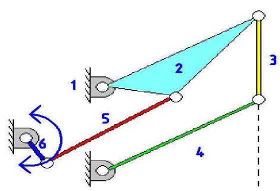

Fig. 4. Front view kinematic diagram of the left leg

Each front leg was designed with two degrees of freedom (DOF). The leg arrangement will allow the robot to navigate over rough terrains. The robot will also have the capability for moving over large obstacles and traveling more quickly with less energy.

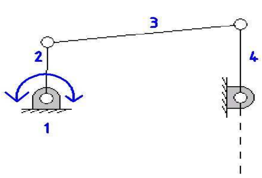

Fig. 5. Top view kinematic diagram of the left leg

The front view movement of the leg was based on the six-bar linkages as shown in Figure 4. This permits the rotation of the link 6 which connected to the gear motor to have the rotation at the joint of link 2 and link 3. The top view movement of the leg was based on the four-bar linkages in which link 2 is the driving link shown in Figure 5.

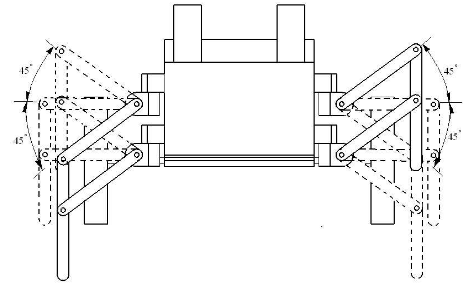

Fig. 6. Front view of the leg movement

Figure 6 and 7 show the movement of the two front legs. The leg can move total of 90 degree from the top view angle similar to the front view angle.

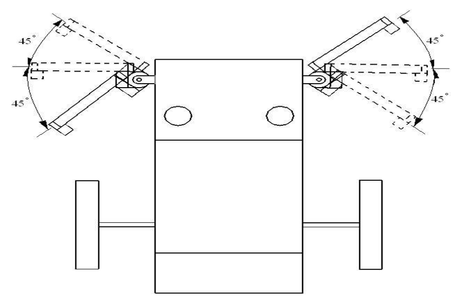

Fig. 7. Top view of the leg movement

The hybrid leg-wheel robot was completely constructed as shown in Figure 8. The robot dimensions are approximately 14 cm long, 7cm wide(not included the two wheels span which is 4 cm on each side), and 9 cm high.

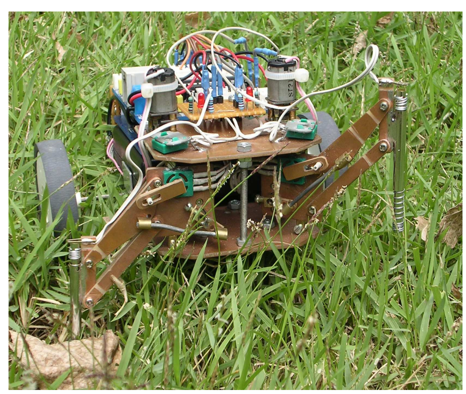

Fig. 8. Hybrid leg-wheel robot

4. CONTROLLER HARDWARE

The controller developed for the robot front legs was based upon a simple feed-forward design. The feed-forward controller, programmed on a basic stampbox by Parallax, sends signals to the 5V DC gear motor type 12GW from Teraware,Inc. in Japan to drive the links. Two types of signal sent to the motors are the clockwise rotation and conterclockwise rotation.

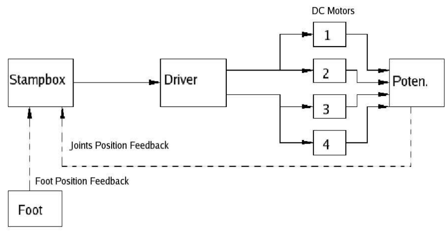

Fig. 9. **Control diagram**

There are a total of four motors in the robot where two motors installed on each leg. Wheels movement run by the driving force of the two front legs. The stampbox takes the feedback signals from the four joint sensors which are potentiometers. The foot sensors are just the on/off switch to return the foot state whether is on or off the ground.

5. EXPERIMENT

Two experiments was tested on the robot. The first was a simple jont excursion test which the leg runs through a walking motion which is similar to the front legs movement of the insect. The robot was also able to walk over rough terrain which used the table cloth. The robot can move with the speed of 10 cm/s as shown in Figure 10.

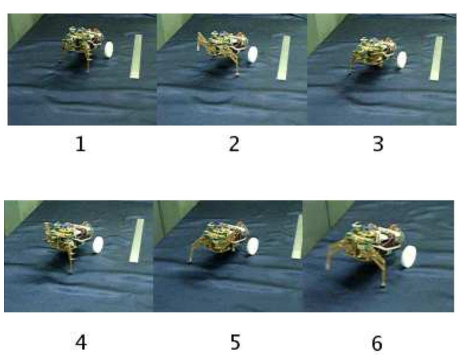

Fig. 10. **Hybrid leg-wheel robot walking**

6. CONCLUSIONS

We have successfully constructed the bio-inspired leg-wheel hybrid robot. The test results showed that the robot is capable of moving over rough surface with the speed of 10 cm/s. The legs movement was also similar the the two front legs in the insect. In future work, we will put more tests on the robot such as climbing up and down the ramp, moving over obstacles.

7. ACKNOWLEDGMENT

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8. REFERENCES

[1] M. H. Raibert, *Legged Robots That Balance*. Cambridge, Massachusetts: The MIT Press, 1986.

[2] K. S. Espenschied, R. D. Quinn, R. D. Beer, and H. J. Chiel, “Biologically based distributed control and local reflexes improve rough terrain locomotion in a hexapod robot,” in *Robotics and Autonomous Systems*, vol. 18, 1996, pp. 59–64.

[3] G. M. Nelson, R. D. Quinn, R. J. Bachmann, W. C. Flannigan, R. E. Ritzmann, and J. T. Watson, “Design and simulation of a cockroach-like hexapod robot,” in *Proceedings ICRA 1997 IEEE International Conference on Robotics and Automation*, Albuquerque, New Mexico, April 1997.

[4] S. M. Song and K. J. Waldron, *Machines That Walk*. The MIT Press, 1989.

[5] K. J. Waldron and R. B. McGhee, “The adaptive suspension vehicle,” *IEEE Control Systems Magazine*, pp. 7–12, 1986.

[6] N. Eiji and N. Sei, “Leg-wheel robot: a futuristic mobile platform for forestry industry,” in *IEEE/Tsukuba International Workshop:Can Robots Contribute to Preventing Environmental Deterioration?*, November 8-9 1993, pp. 109 – 112.

[7] Y.-J. Dai, E. Nakano, T. Takahashi, and H. Ookubo, “Motion control of leg-wheel robot for an unexplored outdoor environment,” in *Proceedings of the 1996 IEEE/RSJ International Conference on Intelligent Robots and Systems*, vol. 2, November 4-8 1996, pp. 402–409.

[8] S. Laksanacharoen, A. Pollack, G. Nelson, R. Quinn, and R. Ritzmann, “Biomechanics and simulation of cricket for microrobot design,” in *Proceedings ICRA 2000 IEEE International Conference on Robotics and Automation*, vol. 2, April 24-28 2000, pp. 1088 – 1094.