INTEGRATION OF RULE BASED AND SENSOR BASED CONTROL FOR A SIX-LEGGED INSECT-LIKE ROBOT

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Abstract: This paper proposes the rule based and sensor based control strategies for a six-legged insect-like robot. This control scheme emulates the well-known insect behavior called "the reflex action." Three types of sensors are embedded in the body of the robot, which are infrared sensors, ultrasonic sensors and limit switches for tracking performance, collision avoidance, and touching perception, respectively. The walking and acting features are driven by servomotors using sets of common-sense instructions or rules. The results show that the satisfactory performance is achieved with this control approach. This implies that the designed robotic system can be used to perform inspection, maintenance or repair in construction tasks.

Keywords: insect-like robot, reflex control, walking robot, rule based control, sensor based control

1 INTRODUCTION

During the past years mobile robots have been used to inspect, repair, and maintenance in construction. The robots can navigate through the hazardous environment. They can also be used to inspect inaccessible places for human such as in a 500-millimeter pipe or repair some crack on the given surfaces [1]. Most of mobile robots are designed as wheeled systems that may get difficulty when navigate through some terrain. If this is the case, the walking systems should be considered and would be appropriated to implement.

Implementation of sensory systems for walking robots has been initially developed for such insect-like robotic systems [2]. Regarding the name insect-like robots, one might be questioned about the definition of them. Does the name of an insect-like robot imply its insect behavior or its appearance? The answer may be depended on the problem in hand. However, in this paper, the term "insect-like" is used because the robot in consideration is designed based on emulating insect features that typically have six legs and have reflex action behaviors [3, 4].

This paper considers the implementation of a control paradigm for a six-legged insect-like robot shown in Figure 1. The control approach used here is the integration of the rule based and sensor based control employed to imitate the reflex action behavior and sensor organs of insects such as vision, audition, and nervous systems. The inspiration of this approach emerges from the question that, while in motion, whether insects determine legs' torque or forces from the pole placement or poles-zeros cancellation methods. In fact, they don't even know their mathematical modeling or their transfer function. There are insects such as real cockroaches do not know their coordinate or frame of references unless their lateral sides touch something. With sensory organs and the natural responses under the law of the nature, insects are capable to navigate through their world. Detailed synthesis will be intuitively given in the following sections.

This paper is organized as follows: Section 2 describes the hardware description as mechanical elements and functional components of our robot. Section 3 proposes the control scheme. Section 4 shows experimental results and discussion. The last section, Section 5 summarizes the results and introduces some development that needs to be done for the future work.

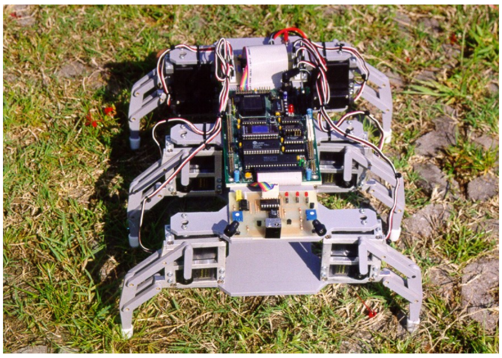

Figure 1. A prototype of the six-legged insect-like robot used in this research.

2. STRUCTURE DESCRIPTION

The system is a six-legged robot made of PVC plastic with 5.2-inch height x 11-inch width x12-inch length as shown in Figure 2. The weight of the robot is 2 kg. Each leg is designed as a Pantograph type having Futaba RC-servomotor model FP S148 at the upper thigh, which can be independently moved within 2-inch maximum radius. The movement of the legs can be classified as lifting, extending and rotating position.

There are three types of sensors used as the sensory organs of the robot. The limit switches located at the end of each leg are used as feelers. The infrared and ultrasonic sensors represent audition, and tracking systems. The electronic board equipped with the Motorola 68HC11 chip is embedded at the back of the robot to serve as the central nervous system. The programming code is written in Assembly language. The power supply is a 7.2V 1.7 A/hr battery.

The open-loop behavior leads unsatisfactory corporation among sensors and actuators. A closed-loop control law ensuring acceptable performance should be realized.

3. CONTROL SCHEME

This study employs the primitive behavior called reflex action and applies to the behavior of the six-legged robot. The reflex action occurs when an external stimulus causes an insect to act reflexly while simultaneous sense appears as attraction or repulsion to the stimulus. Actions such as chew, swallow, or changing body direction can be considered as reflex actions as far as they reflexly occur. The category of this low-intelligent behavior can be simply realized as the integration of rule-based and sensor-based control shown in Figure 3.

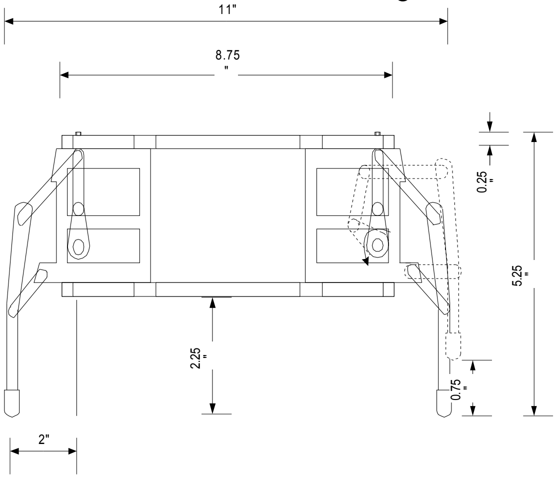

Figure2. Front view of the robot.

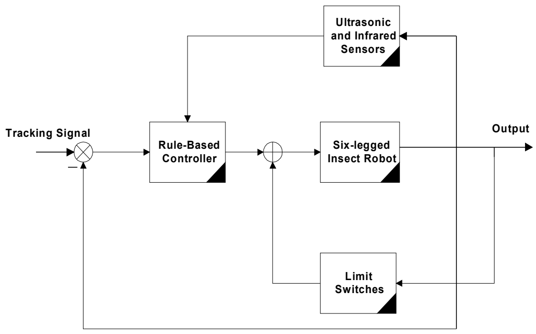

Figure 3. The control structure for a six-legged insect-like robot.

From Fig. 3, functionally, the control scheme comprises of two levels of feedback loops (structurally appeared in three loops); the inner loop is a rapid response level of control process called the lower level and the outer loop is the upper level functioned as an adaptive level based on the control rule bases. The basic idea of the lower level is that the motor organs act immediately upon receiving signals from the sensory ones. For example, if a robot's leg gets stuck or being touched by an obstacle object, the servos will promptly be activated to make it moved in the direction away from the difficulty.

Like insect being, the control rule bases are developed imitating the response of insects. Various functions of insect organs such as using eyes for tracking their foods or having lateral nervous systems for touching as a part of reflex action circuits will be intuitively considered and functionally imitated. The following common sense rules are used for tracking tasks.

Rule 1:
IF the robot orientation is in the direction toward the target
THEN move to the target.

Rule 2:
IF the robot does not oriented in the direction toward to the target
THEN turn the robot to the direction toward the target
AND move to the target.

Rule 3:
IF the robot moves toward to the target
AND the robot speed is greater than the speed of the target
THEN retain moving to the same direction.

Rule 4:
IF the robot moves toward to the target
AND the robot velocity is less than the velocity of the target
THEN retain moving in the same direction
AND increase the speed of the robot.

Rule 5:
IF the target is located within the operation range
THEN activate the catching mode.

These rules can easily be fined tuning as desired. In an escaping mode or collision avoidance, it is easy to see that the above rules can be modified in the reverse situation and the control decision may be reversibly applied. The above control scheme is adopted and the results is presented in the next section.

4. EXPERIMENTAL RESULTS

To validate the proposed control scheme, three types of experiments are conducted. The first type is a test for the reflex action of the robot legs in which the limit switches as feelers are embedded. This type of the test simulates the situation when legs of insects perform reflex action. A result is shown in Figure 4.

In this test the left feelers are continuously stimulated causing the insect robot moves in circular motion with the frequency of 0.01, 0.015, and 0.02 Hz for the steps of 7, 15, and 18 degrees, respectively. The radius of the circular motion is about 20 cm. The measurement of the movement is recorded by attaching three pencils as shown in Figure 4.

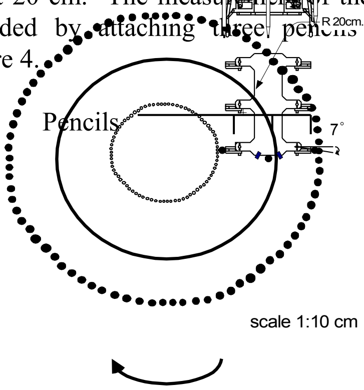

Figure 4. Reflex action test.

The second type is a test for the collision avoidance to evaluate the eyed function of the robot implemented by infrared and ultrasonic sensors. We found experimentally that this task cannot perform well by using only infrared sensors. According to our experiment, the reason is that the robot cannot avoid the given transparent objects since the infrared signal is transmitted through the objects rather than reflected back. That is why the ultrasonic sensors are added to the system for better performances. A result of the test is given in Fig. 5. In this test each legged-step of the robot is set to 18 degrees, the given dimension of the obstacle is 15 cm x 20 cm x 30 cm, and the detection range of the sensor is set to 40 cm. When the robot senses the obstacle, it would step back two or three steps depending upon the measured signals.

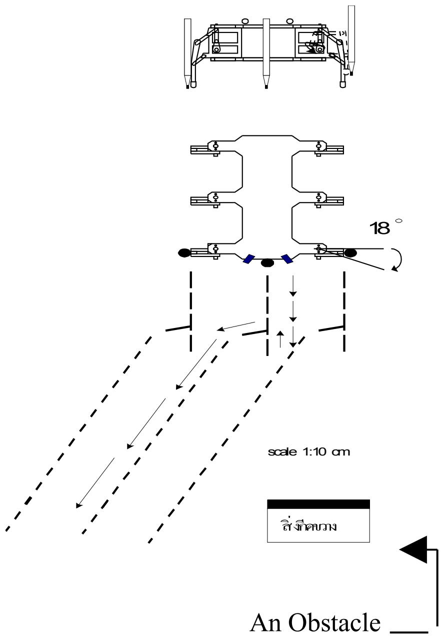

Figure 5. Collision avoidance test.

Another finding of this test is that the twist angle to avoid an obstacle depends on the speed of the robot. The faster the robot movement, the wider the angle will be. Figure 6 shows the twist angle for the collision avoidance performing in Figure 5.

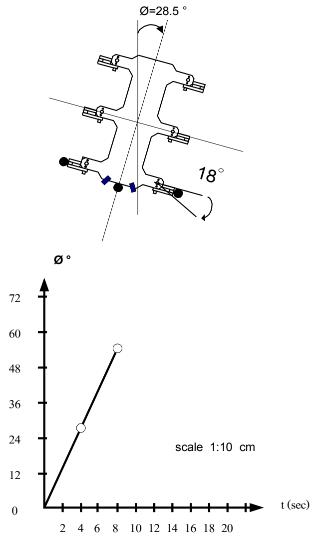

Figure 6. The twist angle versus time for collision avoidance.

The last type is a test for tracking performance. This test simulates the situation for which insects are catching or purchasing their food. With ultrasonic sensors, the insect robot can detect the movement of a prey whereas the infrared sensors can sense the color of the prey. A result of the test is shown in Figure 7. In this test, each leg can move about 18 degrees producing the robot speed at 5 cm/s. Hence the insect robot reaches the prey successfully in 20 seconds.

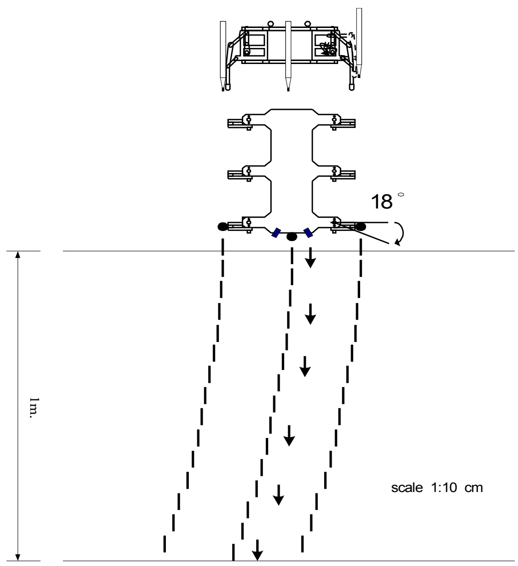

Figure 7. Tracking performance test.

5. CONCLUSION

We have proposed the rule based and sensor based control strategies for a six-legged insect-like robot. This control scheme emulates the well-known insect behavior called "the reflex action." Three types of sensors are embedded in the body of the robot, which are infrared sensors, ultrasonic sensors and limit switches for tracking performance, collision avoidance, and feelers, respectively. The walking and acting features are driven by servomotors using sets of common-sense instruction or rules.

The results show that the satisfactory performance is achieved with this control approach. However, it is a challenge to make this robot to perform more intelligent tasks, e.g. memorizing functions or path optimization. Integration of video camera and repair tools to the robot would also be a good topic for the future work.

Acknowledgments

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