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Insect Walking as a Model for Advanced Robotic Systems

J. Sandeep Kumar[1], G. Naga Harish[2], M. Kishan Tej[3], G. Krishna Reddy[4], M. Ashok Naik[5]

[1]Teaching Associate, Department of Entomology, SMGR Agricultural College, Udayagiri, ANGRAU

[2]Teaching Associate, Department of Entomology, SMGR Agricultural College, Udayagiri, ANGRAU

[3]Asst. Professor & Head, Department of Entomology, SMGR Agricultural College, Udayagiri, ANGRAU

[4]Associate Dean, SMGR Agricultural College, Udayagiri, ANGRAU

[5]Teaching Associate, Department of Agronomy, SMGR Agricultural College, Udayagiri, ANGRAU

*Corresponding Author: J. Sandeep Kumar

Abstract

Insect locomotors control could be used as a model for autonomous hexapod robot controllers. Insect movement control can be viewed as both modular and hierarchical. Walking speed and onset direction are controlled by the brain. The ganglia that regulate leg movements perform local coordination. The stepping movements of individual legs are often controlled by networks of neurons known as central pattern generators or CPGs that can produce alternating contractions of antagonistic muscles. The CPGs and sensory input from the moving legs work together to coordinate the legs. In addition to information regarding joint angles and foot contact, this peripheral feedback also offers information on leg load, position, velocity and acceleration. Furthermore, depending on the situation, both the central pattern generators and the sensory data that supplies them can be modified or altered. As a result, insects have incredibly resilient and flexible movement.

Insect walking is now again positioned to make a more important scientific contribution than the numbers of participants in the area might suggest, thanks to major cooperation between researchers studying insect walking and robotics engineers interested in building adaptive legged robots. Current understanding of the physiological underpinnings of insect locomotion, with a focus on recent advances in biomechanics and behavioural genetic dissection and the implications for robotics. In order to create walking robots with functioning controls and a physical design inspired by insect biology, engineers have started collaborating with neurobiologists. Such a method could improve biology by enabling real time and practical testing of important theories on how locomotors control is affected as well as engineering by enabling the development of more effective robots. In order to produce walking robots, the field of biorobotics needs adopt performance standards and an experimental methodology.

Introduction

Insects are among the most efficient and adaptable walkers in the natural world. For decades, scientists have been captivated by their abilities to navigate obstacles, climb steep surfaces, travel over complicated terrains and retain equilibrium. At the nexus of entomology and neuroscience, the study of insect locomotion focuses on the production and coordination of rhythmic motor rhythms. This information has motivated engineers to create walking robots that can carry out duties in hazardous or unreachable places like planetary missions, deep sea exploration and disaster areas. Scientists hope to create devices that are more reliable, flexible and effective by studying how insects walk. Despite their seeming simplicity, insects ability to move quickly across a variety of surfaces has long captivated biologists. Insects are able to coordinate their six legs with amazing accuracy and steadiness despite having a small body and brain. Because of this they are crucial models for comprehending how living things regulate their movement. Researchers have found that the neural system creates and refines the rhythmic patterns involved in insect walking through sensory feedback. Insects can quickly adjust to uneven terrain and unforeseen obstacles because to these movements. Engineer's interest in using these biological concepts in robotics has grown in recent years. Scientists are creating walking robots that can function better in challenging circumstances by analysing how insects move.

These robots in contrast to conventional machinery are designed to imitate the adaptability and flexibility seen in nature. Biorobotics is an interdisciplinary field that combines engineering and biology for mutual benefit. In addition to improving our understanding of animal behaviour, research on insect movement aids in the development of novel robotic systems. These robots might be helpful for investigating dangerous regions, disaster sites or isolated settings. Therefore, significant advancements in contemporary technology are being inspired by the minuscule movements of insects.

How Insects Walk: Basic Limb Movements

A number of synchronized leg movements are required for insect mobility. Protraction and retraction are the forward and backward movements performed by each leg. Lifting (levation), lowering (depression) and modifying the posture in relation to the body (adduction and abduction) are other motions. Insects are able to maintain stability while moving because their movements are not random, rather they adhere to exact patterns. In addition to distributing body weight and producing the forces needed for movement, the legs function as stiff supports.

Muscles and Control of Movement

The movement of insect legs is controlled by two types of muscles

- Extrinsic muscles, which originate outside the leg
- Intrinsic muscles, which are located within the leg

A sophisticated network of neurons controls these muscles. Fast, slow and inhibitory neurons provide impulses to each leg, enabling precise control over force and pace of movement. Opposing (antagonistic) muscles contract alternately to produce walking. One muscle, for instance elevates the leg while another gets ready to put it back on the ground. Smooth and effective movement is ensured by this synergy.

Special Types of Movement

In addition to walking, insects exhibit other forms of locomotion

Jumping

Grasshoppers and other insects store energy by flexing their legs, which they then quickly release to jump. Extensor muscles are activated while flexor muscles are abruptly relaxed.

Crawling

Caterpillars and other larvae move by contracting and expanding their body segments. They may move forward efficiently even without completely formed legs thanks to this wave like motion.

Role of Sensory Systems

Insect legs are equipped with advanced sensory systems that help them adapt to their environment. These include:

- Proprioceptors: Detect the position and movement of leg segments
- Mechanoreceptors: Sense touch and mechanical pressure
- Chemoreceptors: Detect chemical signals in the environment

Insects may modify their movements according to load and surface conditions thanks to special structures like campaniform sensilla which sense strain in the leg. Maintaining balance and coordination requires this sensory feedback.

Coordination and Neural Control

Central Pattern Generators (CPGs) are brain circuits that regulate the coordination of insect movement. Without constant input from the brain, these networks of neurons generate rhythmic movement patterns.

CPGs ensure that:

- Legs move in a coordinated sequence
- Muscle contractions alternate properly
- Movement remains stable even in changing conditions

Walking can be started, stopped or altered by higher level brain control and the movement is adjusted in real time by sensory feedback.

From Biology to Robotics

Robotics has been directly impacted by the study of insect locomotion. Robotics integrates computer, electrical and mechanical engineering and a robot is a programmable machine that can carry out tasks automatically.

Walking Robots

Advanced legged robots that can climb barriers, navigate difficult surroundings and move effectively over uneven and rocky terrain have been designed by engineers. They are particularly useful in circumstances when conventional wheeled devices would malfunction because of their capabilities. Because of this, these robots are frequently employed in space and ocean exploration where human access is restricted or dangerous, in military surveillance for reconnaissance in challenging or hazardous locations and in disaster rescue operations to find survivors in collapsed structures.

Biologically Inspired Robots

Many modern robots are inspired by insects:

- LAURON: A robot modelled after stick insects, capable of stable walking on uneven terrain
- GENGHIS: A simple robot with basic leg movements
- BILL-Ant-p: Based on ant anatomy with advanced sensing abilities
- Cockroach like robots (CRAM): Fast, flexible robots designed for search and rescue missions
- HECTOR: A hexapod robot with advanced sensors and adaptive movement

To enhance performance, these robots make advantage of biological concepts including distributed control, sensory feedback and flexible mobility.

Engineering Meets Biology

Engineering greatly benefits from biological ideas, especially when it comes to creating effective movement strategies, adaptive control systems and energy saving techniques modelled after living things. Engineers can create robots that are more adaptable, effective and capable of doing challenging jobs by researching how animals, particularly insects, move and react to their surroundings. At the same time, robotics makes a substantial contribution to biological research by providing platforms for testing animal movement theories, simulating intricate biological systems and producing cutting edge instruments that aid researchers in comprehending how living things operate. However, integrating biological principles into robots remains challenging due to the complexity of living systems.

Conclusion

Insect walking research has created new robotics opportunities. Researchers are creating devices that can move more effectively and adapt to difficult surroundings by fusing technical design with biological information. Strong cooperation between biologists and engineers is essential for future advancement. This fascinating topic of biorobotics will progress with clear goals, appropriate testing procedures and creative design strategies. In the end, learning from insects might result in more intelligent and capable robots that can help people in ways that were previously unthinkable.

References

Bares JE, Wettergreen DS. 1999. Dante II: technical description, results, and lessons learned. *Int. J. Robot. Res*., 18:621–49

Chapman, R.F. 1998. Chemoreceptors: the significance of receptor numbers. *Advances in Insect Physiology*., 16,:247–356.

Cruse,H. 2007. What mechanisms coordinate leg movement in walking arthropods. Trends in Neurosciences.,13: 15-21

Delcomyn F. 2004. Walking robots and the central and peripheral control of locomotion in insects. *Auton. Robots.*,7:259–70

Lewinger, W. A., 2005. “Insect-inspired, Actively Compliant Robotic Hexapod,” M. S. Thesis, Department of Electrical Engineering and Computer Science, Case Western Reserve University, Cleveland, OH, USA,.

https://hexyrobot.wordpress.com/2015/11/20/common-walking-gaits-for-hexapods/