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EDITORIAL

The Importance of Central Pattern Generator in Simulation of Human Gait

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1. Concept of CPG

Humans walk and run, as well as changing their gait speed, through the control of their complicated and redundant musculoskeletal system. These gaits exhibit different locomotor behaviors, such as a double-stance phase in walking and a fight phase in running. The complex and redundant nature of the musculoskeletal system and the wide variation in locomotion characteristics lead us to imagine that the motor control strategies for these gaits, which remain unclear, are extremely complex and different from one another.

A large number of muscles contribute to the generation of human movement, and they show complex activation patterns. However, an analysis of Electromyographic (EMG) data shows that the linear combination of a small number of basic waveforms reproduces a large portion of the EMG patterns. This suggests that motor control in the Central Nervous System (CNS) utilizes this low-dimensional structure to solve the motor redundancy problem and that Central Pattern Generators (CPGs) in the spinal cord are responsible for controlling this low-dimensional structure.

The researchers have proved the existence of a central generator at the spinal cord level. This generator is a neuronal group that does Time alignment and spatial alignment before performing the next moves. This generator can be activated without environmental feedback. The researchers thought that many motion programs such as walking are located in CPG but they observed the evidence that an animal with spinal cord injury can move in their experiments.

On the other hand, various studies have proven that there are centers of control in the spinal cord which generate motion patterns for walking. Therefore, these centers, which are known as CPG, form an important part of models of the walking control system.

It is widely accepted that a CPG can produce the basic locomotor rhythm in the absence of rhythmic input from higher brain centers and peripheral sensory feedback. Although the neuronal organization of this CPG remains largely unknown, there appears to be at least one CPG for each.

Brain commands and sensory feedback cause a change in the pattern of motion by changing these attributes. In such a change, the involvement of brain commands is often more intense than sensory feedback. Therefore, the basic pattern is produced by CPG itself and its changes are done by brain commands and sensory feedback. Sensory information is applied in the form of feedback. That is, prediction is not conducted based on them but with regard to past experiences, decisions are made.

2. CPG and Human Gait

The use of CPGs in biped robots and gait simulations is very common since it has been known for quite some time that humans are likely to have locomotor CPGs. In contrast, the addition of an asymmetrical CPG in models is relatively new since this feature has been emphasized only recently.

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The contribution of reinforcing feedback to extensors has been demonstrated almost 40 years ago, yet its introduction in models and robots took some time. In robotics, a combination of CPGs with bioinspired sensory feedback was recently employed to generate gait in a 3D biped robot. It can walk stably with straightforward speed control. This robot uses a two-level symmetric CPG containing a Rhythm Generator (RG) and a Pattern Formation (PF) layer.

Although physiological studies provide meaningful insights for the underlying neural mechanisms for motor skills in humans, it is difficult to fully clarify them using only analysis of experimental data. To overcome such limitations imposed by a single perspective, modeling studies have recently attracted attention because physiological findings enable us to construct reasonably realistic motor control models and investigate their functional roles through the model structure and parameters. Furthermore, because locomotor behavior is well-organized behavior generated through dynamic interactions between the CNS motor control system, musculoskeletal system, and environment, investigating motor control models by integrating them with sophisticated musculoskeletal models in human gaits and robots has allowed us to approach deeper neural mechanisms.