Robotics, Control

New technology for maneuverable and efficient walking of multi-legged robots using instability

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Abstract

Multi-legged robots have many legs, which makes them highly tolerant of falling and leg malfunction during locomotion, and they are expected to be used in a wide variety of scenarios. However, it was very difficult to plan and control the movement of many legs interacting with complex environments. We developed a multi-legged robot composed of many body segments and legs. The body segments are connected by a joint with a torsional spring. We clarified that the straight walk becomes unstable through the pitchfork bifurcation depending on the spring stiffness, and transitions to the curved walk, whose curvature depends on the stiffness. We introduced a variable stiffness mechanism and controlled the instability and the curvature of the curved walk to approach the target. As a result, we succeeded in achieving maneuverable and efficient walk, without complex calculations and with low energy consumption.

Background & Results

Multi-legged robots have many legs, which makes them highly tolerant of falling and leg malfunction during locomotion, and they are expected to be used in a wide variety of scenarios. However, it was very difficult to plan and control the movement of many legs interacting with complex environments. In particular, many contact legs are physically constrained to remain on the ground to support the body, which impedes maneuverability. Maneuverable locomotion for multi-legged robots remains challenging. We developed a multi-legged robot composed of many body segments (Fig. 1). Each body segment has a pair of legs and the segments are connected by a joint with a torsional spring. We clarified that the straight walk becomes unstable through the pitchfork bifurcation depending on the spring stiffness, and transitions to the curved walk, whose curvature depends on the stiffness (Fig. 2). Since instability in motion means that the motion cannot be continued, it is common in robot control to design the control system to eliminate instability, but it has been suggested that instability is actively used in animal motor control. We used the instability in our robot to create maneuverable locomotion. Specifically, we introduced a variable stiffness mechanism (Fig. 3) and controlled the instability and the curvature of the curved walk to approach the target. As a result, we succeeded in achieving maneuverable and efficient walk, without complex calculations and with low energy consumption.

Significance of the research and Future perspective

We achieved the maneuverable and efficient walking of a multi-legged robot using a simple controller. In the future, it is expected to be used in a variety of situations, such as working on behalf of humans in hard-to-reach places. In addition, improving motor function by exploiting the dynamics of instability and bifurcation would be useful in the future development of various artificial objects and provide important insights into understanding intelligent motor control in animals.

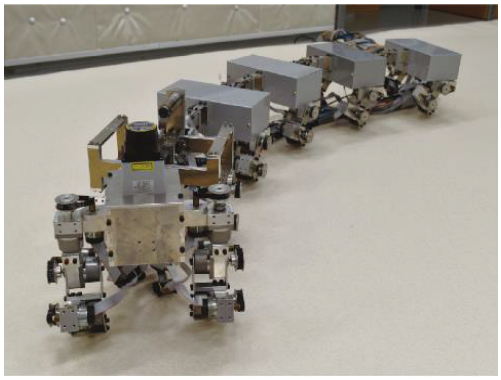

Fig. 1 Multi-legged robot

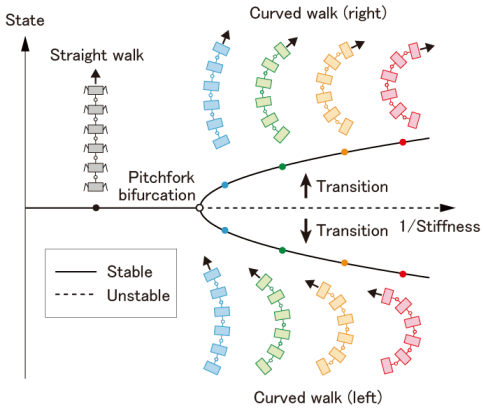

Fig. 2 Stable and unstable walking patterns depending on the spring stiffness

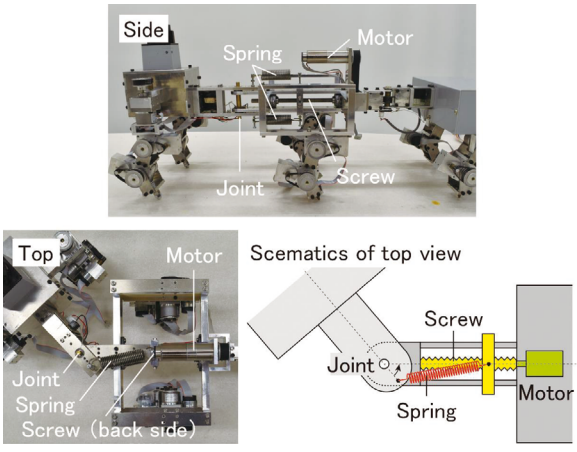

Fig. 3 Variable stiffness mechanism

Patent

Treatise
Aoi, Shinya; Yabuuchi, Yuki; Morozumi, Daiki et al. Maneuverable and efficient locomotion of a myriapod robot with variable body-axis flexibility via instability and bifurcation. Soft Robotics. 2023, 10(5), 1028-1040. doi: 10.1089/soro.2022.0177
Aoi, Shinya; Tomatsu, Ryoe; Yabuuchi, Yuki et al. Advanced turning maneuver of a many-legged robot using pitchfork bifurcation. IEEE Transactions on Robotics. 2022, 38(5), 3015-3026. doi: 10.1109/TRO.2022.3158194

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Keyword multi-legged robot, maneuverability, instability, pitchfork bifurcation, variable stiffness mechanism