Decentralized control in natural and artificial legged systems

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***Abstract*—For legged locomotion, animals and humans rely more on decentralized feedback control than on the central control approach common in humanoid robotics. We present evidence that the decentralization does not hamper fidelity and may present an alternative approach to robust locomotion of legged robots from prosthesis to humanoids.**

Keywords-locomotion, decentralized control, bioinspiration

I. Introduction

Humanoids are becoming increasingly dextrous in locomotion tasks. This success is based on central control approaches that use kinematic and dynamic models of the entire robot. However, these approaches are difficult to transfer to powered prosthetic legs and exoskeletons, which form only part of the entire human-robot system. As a result, scientists and engineers in rehabilitation robotics face the challenge of having to identify alternative, decentralized control approaches to legged locomotion. This talk will present evidence that the challenge may rather be an opportunity, generating an alternative approach to robust locomotion in legged robots (Fig. 1).

II. Approach and Results

Three major functional tasks characterize bipedal systems governed by gravity: trunk balance, compliant leg behavior in stance [11, 1], and foot placement in swing [7, 6]. While the first task amounts to a separate inverted pendulum stabilization of a single body, the remaining tasks involve multiple segments whose individual controls are less clear. We show that these remaining tasks can robustly be realized using decentralized feedback control without giving up fidelity [5, 3]. We then interpret these feedbacks within computational models of the human neuromuscular system and find that these models not only demonstrate a range of human locomotion behaviors, but also generate muscle activation patterns similar to those observed in human experiments [9]. The similarity inspires decentralized, reflex-like control algorithms for artificial legs whose functionality may eventually approach the functionality of human limbs [4, 10].

III. Discussion

Collectively, the evidence presented here and obtained in animal experiments [2] suggests that humans and other legged animals decentralize control far more than common in humanoid robotics. Whether the difference is merely due to evolutionary constraints [8] or indicates a necessary shift in control paradigm for achieving high performance legged robots remains an open debate.

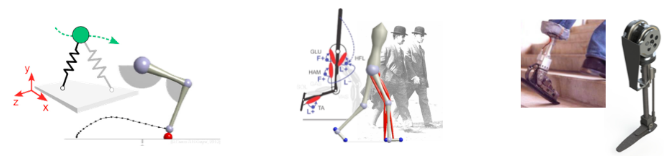

Fig. 1. Realizing major functional tasks of legged locomotion with decentralized control (left) leads to new hypotheses about the structure and function of muscle-reflex pathways (middle) and inspires control algorithms for assistive devices (right).

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