A Neural-Inspired Universal Controller for Comprehensive Lower Limb Motion Mapping.

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Summary

Predictive neuromuscular models based on neural controllers are versatile for evaluating hypotheses about the sensorimotor control. However, these controllers are generally task-specific and struggle to modulate their behaviour with simplified control. Recently, we presented the Internal Model-based Modular Controller (IMMC). This architecture combines internal models and motor synergies to replicate Stand-To-Walk behaviour with low-dimensional control. Here, we demonstrate that its capabilities can be extended to Walk-To-Stand transitions and backward walking. The success of the IMMC suggests that this architecture has the potential to become a universal lower-limb controller.

Introduction

Current neural controllers such as the one presented by Song & Geyer [1] are successful in relating sensory afferents with walking generation while maintaining physiological accuracy. However, these controllers are task-specific, normally present a high-dimensional control, and are constrained to replicating a unique motor behaviour.

The IMMC [2] is intended to overcome these limitations with a unified architecture. This controller could generate Stand-To-Walk transitions (STW) with physiological accuracy and low-dimensional control. Now, by adding new internal models, the IMMC can replicate Walk-To-Stand transitions (WTS) and backward walking (BW).

Methods

The musculoskeletal model and the controller were implemented in MATLAB 2022a/Simulink. The controller consists of four layers: 1) MLR in the control layer sends control signals. 2) The internal models in the Planner layer group motor synergies in task-specific packs according to these signals. 3) The synergies generate motor control in the synergistic layer. 4) The motor pools in the premotor area integrate inputs from synergies and sensory afferents to activate the muscles (Figure 1).

Results and Discussion

Besides STW, the IMMC can now replicate WTS in a single simulation. Additionally, it can transition from standing to BW. Kinematics, muscle activation profiles, and ground reaction forces are consistent with physiological data. This control is exerted by the MLR using unidimensional control signals.

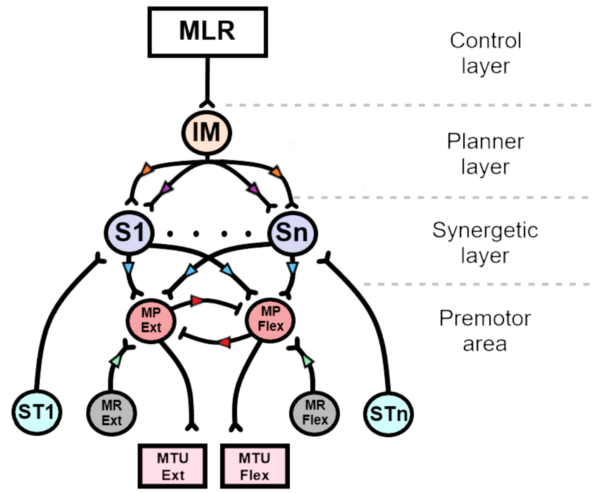

Figure 1: Scheme of the IMMC.

Conclusions

IMMC has demonstrated the ability to produce multiple lower-limb motions while maintaining a lower control dimensionality. Given this practical versatility, IMMC can be considered a potential replacement for current models and proposed as a universal lower-limb controller.

Future development includes developing Walk-To-Run transitions and perturbed walking. Additionally, we expect to integrate motor adaptation. Specifically, we aim to replicate the split-belt treadmill [3] and the robot-induced perturbation [4] experiments. We believe this achievement could establish a new standard for predictive neuromuscular modelling.

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References

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