Growing into Motion: Bioinspired Morphological Development in Muscle-Actuated Bipedal Systems

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Summary

Inspired by the robustness, adaptability, and learning abilities of humans, this study examines the influence of concurrent morphological and cognitive development in motor skill acquisition. We explore the impact of morphological growth on motor learning in simulated muscle-actuated bipedal systems, comparing two growth strategies: one inspired by human ontogeny and another applying uniform scaling. Both strategies enhance motor performance over non-developmental approaches, leading to improvements in efficiency and robustness, with potential implications for musculoskeletal models, motor control development and rehabilitation technology.

Introduction

Human motor development is a dynamic process where movement abilities evolve alongside biomechanical growth, contributing to the exceptional adaptability and learning in human movement. Replicating this in artificial systems is challenging, especially in muscle-actuated systems, which require sophisticated control to coordinate muscle pairs and handle muscle dynamics. Our work [1] proposes bioinspired morphological development, where body structure evolves with learning, as a promising solution to mimic human motor performance.

Methods

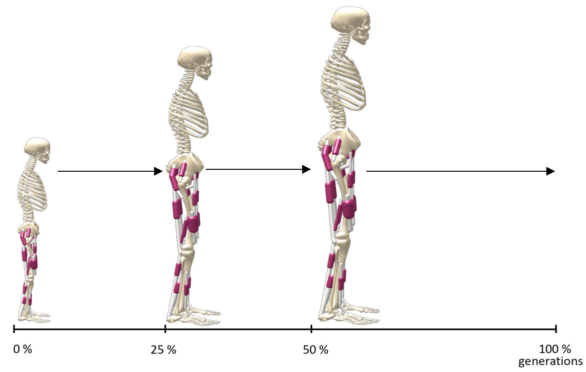
In SCONE [2], we scale down the body segments and muscle lengths, adapt the maximal muscle forces and reduce joint stiffnesses to create models of 4-year-olds and 12-year-olds [3, 4]. We design two variations of these models — one closely reflecting human ontogenetic development and another applying uniform scaling to all segments and related parameters. These strategies are compared to a non-developmental approach.

Results and Discussion

Preliminary results, optimizing the control policy with Covariance Matrix Adaptation Evolution Strategy (CMA-ES) [5], demonstrate that developmental strategies improve performance in balance and squat jump tasks. In the balance task, both developmental strategies exhibit enhanced robustness to perturbations post-optimization, with similar muscle activation levels across all strategies. In the squat jump, developmental strategies achieve higher jumps with reduced muscle activation compared to the non-developmental approach.

Conclusions

Our findings highlight the role of morphological development in enhancing performance across both high- and low-power tasks. Future work will include further ablations across various scenarios to contribute to a broader understanding of motor adaptation through developmental stages. These insights could also support the design of biorobotic systems and rehabilitation technologies.



(a)

(b)

Figure 1: Morphological development compared to non-development [1].

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