Experiment-Free Exoskeleton Assistance via Reinforcement Learning in Simulation Saves Energetics During Human Locomotion

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***Abstract*—Exoskeletons have the potential to improve human mobility. However, the development of controllers of existing exoskeletons requires either lengthy human testing or complicated handcrafted control laws to assist versatile walking. We proposed a data-driven and dynamics-aware reinforcement learning control method and a comfort-centered mechatronics design of hip exoskeletons to address these challenges. Our controller was trained purely in simulation, deployed directly to our hip exoskeleton, and reduced 24.3% metabolic costs for walking (n=8) as compared with no exoskeleton conditions.**

I. INTRODUCTION

Exoskeletons have the potential to assist humans in walking. However, existing control methods require either hours-long human testing to identify the optimal assistance profile or complex handcrafted control laws to adapt to different locomotion. Here we proposed a data-driven and dynamics-aware reinforcement learning framework [1,2] and a comfort-centered design [3,4] to address these challenges. Our method eliminated the need for human testing and the controller was trained entirely in simulation. Yet, it can be directly deployed to a hip exoskeleton and produce an immediate continuous torque assistance for walking.

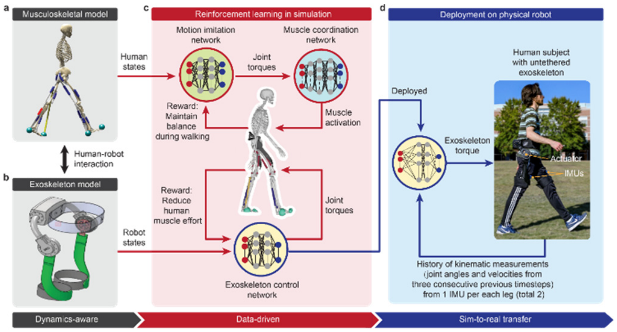

Fig. 1. Data-driven and dynamics-aware reinforcement learning framework to learn a controller from simulation that assists human locomotion.

II. METHODS

Our proposed method contains two parts: data-driven approach and dynamics-aware approach. For the data-driven approach, we used 3 interconnected neural networks (Fig. 1) to simulate the human musculoskeletal response to exoskeleton assistance. For the dynamics-aware approach, we incorporated a whole-body musculoskeletal model, physical model of the hip exoskeleton, and bushing element to account for human-robot interaction. The three neural networks were trained simultaneously to generate a controller for walking.

III. EXPERIMENTAL EVALUATION

We evaluated the performance of the trained controller on 8 able-bodied subjects for walking at 1.25 m/s. Results showed that the exoskeleton immediately reduced the metabolic cost by 24.3% (Fig. 2), which is the largest reduction among lower-limb exoskeletons.

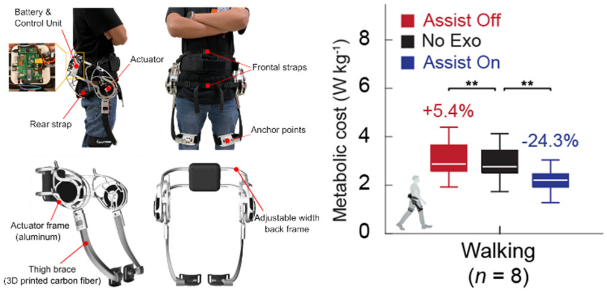

Fig. 2. Our hip exoskeleton consists of two quasi-direct-drive actuators, multi-strap wearable, and compact electronics, provides bilateral assistance in both extension and flexion with a total weight of 3.2 Kg and a peak torque of 18 Nm. Our controller reduced 24.3% metabolic rate in Assist On mode compared with No Exo mode for walking.

IV. CONCLUSION

We demonstrated that a controller trained completely in simulation can be deployed directly onto a comfort-centered hip exoskeleton and produce an immediate reduction in energy for walking. This opens up a new frontier in wearable robots to harness the power of learning, biomechanics, and simulation to improve human mobility and benefit people in community settings.

ACKNOWLEDGMENT

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