A Lower Limb Powered Orthosis for Improved Rehabilitation Training

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Technology description

Physical training is often needed for patients to relearn how to walk after a stroke, or other neurological damage. However, the frequency and availability of physical training are limited by finite medical resources: most lower-limb rehabilitation orthoses are stationary and only available in a limited number of clinical settings, due to their large size and high cost. To address this, researchers are investigating powered lower-limb orthoses to relieve the repetitive, physically-tasking duties of therapists as well as to improve patient recovery efficacy. Past research has focused on the use of a high-ratio transmissions, resulting in high mechanical impedance, which means that the user cannot move their joints without help from the orthosis. For patients who still have some control of their legs, a backdrivable orthosis – one that allows users to drive their joints without a high resistive torque - can promote user participation and provide comfort during physical therapy. Although high torque output and backdrivability are typically considered tradeoffs in wearable robots, the presented orthosis successfully balances the core requirements of rehabilitation training: backdrivability, torque control, high torque density, and low-weight.

The University of Texas at Dallas presents the validated design of a light-weight, mobile, powered knee-ankle orthosis for gait rehabilitation training. By designing the orthosis with a torque dense motor and low-ratio transmission, intrinsic backdrivability and high torque and power output are achieved with a simple structure. With the use of a frameless motor and a custom transmission, all core components are integrally designed with the mechanical structure to further reduce the weight of the orthosis to only 4.88 kg. This orthosis provides a sufficient output torque for gait training, and has been demonstrated to maintain and track a high torque output at a high walking speed. These advantages affirm that the presented orthosis is a suitable platform for testing different rehabilitation control strategies and for developing novel powered knee-ankle orthoses. The presented design may be applied to develop lower-limb orthoses for mobile, human-friendly, and low-cost rehabilitation training towards improved patient recovery efficiency.

Technical Summary:

The presented powered knee-ankle orthosis achieves high output torque without a high-ratio transmission and precise torque control and backdrivability without series elastic components. This actuator design achieves the required torque output by increasing the torque density of the electrical motor rather than the ratio of the transmission, dramatically reducing the reflected inertia. A distributed low-ratio transmission is designed to reduce the mechanical impedance and allow the user to easily move their joints, achieving intrinsic backdrivability without any sensing or control. One of the potential benefits of low-ratio transmissions is a more constant transmissions efficiency for more accurate current-based torque control. Experimental results demonstrate that high torque output during stance phase and low backdrive torque during swing phase can be achieved without using a clutch or variable transmission.

Since the actuator is nearly a direct drive system, it demonstrates several advantages, such as improved dynamic performance, reduced intrinsic backdrive torque, and an almost linear torque constant. By using the double-closed-loop torque controller, the backdrive torques were further reduced. If intrinsic backdrive torque can be further decreased in the design, it will be possible to control the actuator's output torque with motor current feedback instead of torque sensor feedback. The electrical system of the lower-limb orthosis has two main parts: a high-level gait control system and a low-level actuator drive system. To guarantee safety and smooth transitions, we applied a fading process when switching between phases, i.e., using the weighted sum of the stance and swing torque laws.

Value Proposition:

The presented partial-assist orthosis demonstrates an effective model for a fundamentally different approach to developing improved gait rehabilitation training orthoses at a lower-cost. Furthermore, this design bridges the gap between rigid full-body exoskeletons – which are mobile, but inhibit voluntary motion for gait training – and body-weight support harnesses – which allow free leg motion, but are stationary and only assist the center of mass – enabling the advantages of both forms of rehabilitation with a simplified model.

Publication:

Zhu, Hanqi, et al. "Design and Validation of a Torque Dense, Highly Backdrivable Powered Knee-Ankle Orthosis." 2017 IEEE International Conference on Robotics and Automation (ICRA), 24 July 2017, doi: 10.1109/icra.2017.7989063.

Related Links:

Locomotor Control Systems Laboratory - Link

Comex (UTD 17030) Up and Go Demonstration

Application area

Powered lower-limb orthosis

Rehabilitation robots and assistive devices

Advantages

Human-friendly– Mobile Design; adjustable internal/external alignment for comfort; distributed actuator design provides better inertial properties for the user; reduces physically-tasking duties of therapists; reliable foot contact detection

Backdrivable– Provides more natural locomotion; promotes participation & comfort for patients with some control of their legs; intrinsically achieved without cost/complexity of variable transmissions, clutches, and/or series elastic components

Lightweight- The 4.88 kg orthosis utilizes frameless components and light materials, such as aluminum alloy and carbon fiber, to reduce its mass

Safe– Controller design implements several safety features, including a fading process to ensure smooth transitions when switching between phases; hard stops for joint range of motion

Institution

University of Texas, Dallas

Inventors

Hanqi Zhu
Graduate Researcher
Electrical Engineering
Robert Gregg
Assistant Professor
Bioengineering

手 机：13414935137
邮 箱：yeyingsheng@zf-ym.com