Hip Exoskeletons for Mobility Augmentation: Mechatronics Design

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Exoskeletons have been gaining attention as a promising technology for human augmentation and rehabilitation, enabling people to perform physical tasks beyond their own capabilities [1]. Actuation is a key component of exoskeletons, and the selection of actuation systems is a critical design decision in developing hip exoskeletons. Quasi-direct drive (QDD) actuation has emerged as a promising technology for wearable robots, offering advantages over conventional and series elastic actuation (SEA) systems. Fig. 1 compares the state-of-the-art actuation paradigms for hip exoskeletons, showing why QDD is advantageous for hip exoskeletons compared to conventional and SEA actuation strategies.

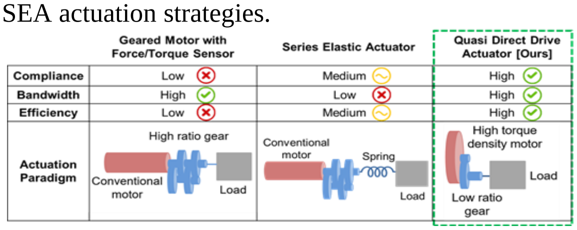

Fig. 1. Three actuation paradigms for hip exoskeleton. Conventional actuator paradigm employs an electric motor is coupled with high ratio transmission to generate required torque. Series Elastic Actuator paradigm also comprises of electric motor and high ratio transmission, but it leverages an elastic element to inject passive compliance. Quasi-direct drive actuator leverages high torque density motors paired with low ratio transmission, which allows for high compliance, high bandwidth and high efficiency.

QDD actuation provides direct transmission of torque to the joint, enabling high torque and high bandwidth with low friction and low backlash. These features are particularly useful for hip exoskeletons, which require high torque and power for supporting body weight and assisting walking movements. In contrast, conventional actuation relies on gears or belts, which introduce significant friction and reduce compliance, while SEA actuation requires additional springs or elastic elements, which add weight and complexity to the system. Fig. 2 show our portable QDD hip exoskeletons for mobility augmentation. The main challenges of QDD actuation include the design of efficient and lightweight transmissions and the management of electrical losses and thermal dissipation. Therefore, a thorough understanding of the advantages and challenges of QDD actuation is essential for designing effective and efficient hip exoskeletons.

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Fig. 2. Portable QDD Hip Exoskeleton Systems for mobility augmentation.

In addition to the actuator design, the selection of the computing platform for a hip exoskeleton depends on various factors, such as the computational requirements, power consumption, and cost. To achieve optimal performance, high computing power is required for real-time sensing, control, and actuation. The challenges include the need for accurate and reliable sensing of the user's intention and environment, real-time processing of sensor data, and efficient control of the exoskeleton's actuators. High computing performance can also be achieved through the use of parallel processing, distributed computing, and hardware acceleration, such as graphics processing units and field-programmable gate arrays. We proposed a powerful electronics architecture using a hierarchical structure with a high-level computer and a low-level microcontroller that can compute complex algorithms and improve the accuracy, speed, and efficiency of the exoskeleton's control system, leading to better performance, user experience, and safety. Fig. 3 describes our proposed electronics architecture.

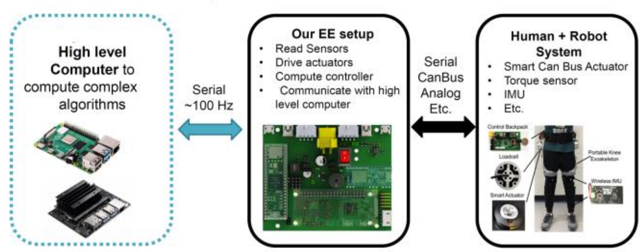

Fig. 3. We proposed an electronics architecture employs a hierarchical composition with a high-level computer (Jetson nano) and a low-level microcontroller (teensy).

References

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