The Chinese University of Hong Kong
Department of Biomedical Engineering

Graduate Seminar – PhD Oral Defence

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Date	***:***	8 April 2025
Time	***:***	10:00 am
Venue	***:***	Room 1122, William M W Mong Engineering Building, CUHK

Title: Fluid-driven Artificial Muscles for Wearable Robotics: Design, Sensing, Upper Limb and Lower Limb Applications

Soft actuators, or artificial muscles, are gaining attention in robotic exoskeleton research for their inherent compliance and safety. However, existing artificial muscles either require large volumes for high output force or lack sufficient force in compact designs. Challenges such as inefficiency, slow response times, and reduced wearability complicate their practical use. Thus, a muscle that combines high output force, efficiency, compactness, and compatibility with human anatomy has yet to be developed. The proposed ExoMuscle mimics the structure of skeletal muscle at the sarcomere level, enabling it to replicate various muscle architectures, including parallel and pennate designs. This artificial muscle employs a biomimetic winding method, converting tube expansion into fiber contraction efficiently. ExoMuscle outperforms skeletal muscles in several metrics, achieving actuation stress of 0.41–0.9 MPa, 50% strain, and power density of 10.94 kW/kg with 69.11% efficiency. Its adjustable architecture allows variable actuation stress while maintaining high efficiency, making it well-suited for wearable robots.

Current soft robotic systems primarily use numerous strain sensors, often overlooking tension sensing, which is essential for controlling assistance forces in wearable exosuits. The proposed triboelectric tension sensing filament, inspired by Golgi tendon organs, provides ExoMuscle with tension feedback capabilities similar to those in skeletal muscle. It offers high sensitivity and reliability for artificial muscles and smart textiles, laying the groundwork for effective assistance force control in future wearable applications.

The ExoMuscle is then applied in a wearable elbow exosuit. This exosuit employs a novel wrapping and modeling method to get its static design parameters to achieve significant output torque while maintaining a slim profile. The testing validated theoretical calculations of assisting torque and demonstrated a 37.5% reduction in muscle effort for users lifting weights. The proposed wrapping method and static modeling method forms a basis for future applications in various joints using ExoMuscle. In the lower extremities, stroke survivors often face hemiplegic gait challenges. With the previous basis of tension sensing, wrapping method for static design, and proposed dynamic modeling method to gain appropriate parameters of air control circuit, the ExoMuscle application in a hip exosuit has shown promising results, improving speed and balance for stroke survivors, demonstrating its viability for large joint applications and enhancing functionality in everyday activities.

***** ALL ARE WELCOME *****

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