

BIOMECHATRONICS AND INTELLIGENT ROBOTICS

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Lightweight and High Torque Hip Exoskeleton with Quasi-Direct Drive Actuation

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### **Motivation / Introduction**

- High-performance actuators are crucial to enable mechanical versatility of wearable robots, which are required to be lightweight, highly backdrivable, and with high bandwidth.
- State-of-the-art actuators, e.g., series elastic actuators (SEAs), have to compromise bandwidth to improve compliance (i.e., backdrivability).
- we create a lightweight bilateral hip exoskeleton to reduce joint loadings during normal activities, including walking and squatting.

# **Quasi-Direct Drive Actuation**

### •High Torque Density Motor

Property	Our motor	EC-90 Flat
Motors:		
Mass(g):	244	648
Nominal Power(W):	314	107
Nominal Voltage(V):	42	48
Nominal Current(A):	7.47	2.12
Nominal Torque(Nm):	2	0.5
Nominal Speed(RPM):	1500	2080
Nominal Speed(rad/s):	157	217
Power Density(W/Kg):	1145	165
Torque Density (Nm/Kg):	7.29	0.76

![](_page_0_Figure_13.jpeg)

# Human-Exoskeleton Coupled Dynamic Model

![](_page_0_Figure_15.jpeg)

•The bandwidth and backdrivability simulation result

![](_page_0_Figure_17.jpeg)

•Quasi-Direct Drive Actuator

![](_page_0_Figure_19.jpeg)

## **Portable and Versatile Hip Exoskeleton**

•Quasi-Direct Drive Portable and Versatile Hip Exoskeleton

![](_page_0_Figure_22.jpeg)

### Portable System: high performance, versatile assistance in the field

Specification Table		
Motor Torque	2Nm	
Motor Speed	1500 RPM	
Output Torque:	45 Nm	
Output Speed:	19.2 rad/s	
Range of Motion:	130 degree	
Gear Ratio	8:1	
Total Weight:	3 kg	

![](_page_0_Picture_25.jpeg)

### Acknowledgment

## Human-Exoskeleton Coupled Dynamic Model

Sate-based Algorithm, Markov Decision Process, No Dependency on Previous Stride Data
Explicit Calculation of Predicted Heel Strike

![](_page_0_Figure_29.jpeg)

# **Experimental Result**

#### •Motor Nominal Current Evaluation

#### •Exoskeleton Backdrive Torque Evaluation

![](_page_0_Figure_33.jpeg)

(a) Stator temperature over time for different current conditions; (b) Thermal image after 15 min of continuous 7.5 A current operation. The actuator surface reached the maximum temperature of 62.7 °C.

Exoskeleton Bandwidth Evaluation

![](_page_0_Figure_36.jpeg)

![](_page_0_Figure_37.jpeg)

The backdrivability of the hip exoskeleton in the unpowered mode. The maximum torque of the mechanical resistance is approximately 0.4 Nm

•Torque Tracking for Walking and Squatting Assistance

This work is supported by the National Science Foundation grant IIS 1830613, CMMI - Career 1944655, NIH R01EB029765, and Grove School of Engineering, The City University of New York, City College.

![](_page_0_Picture_41.jpeg)

### Reference

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![](_page_0_Figure_46.jpeg)