

# Hybrid Active-Passive Actuation For Human-Robot Collaboration and Rehabilitation



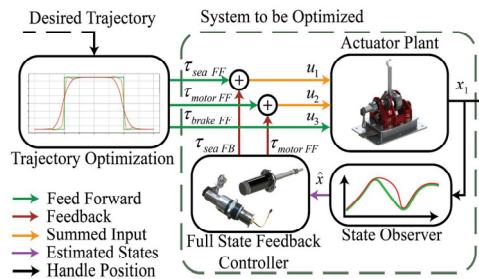
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**Challenge:**  
**Interactive Robots**  
Strong • Fast • Safe

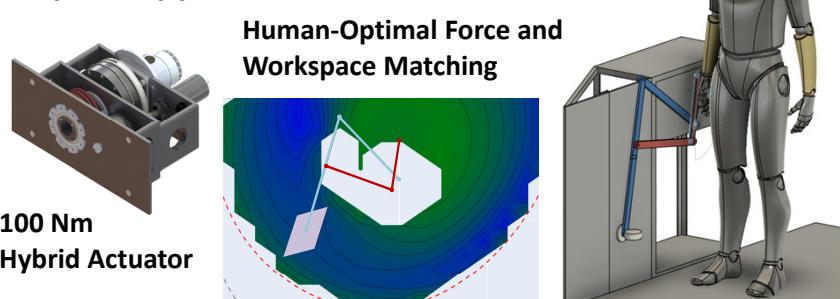
**Needs New Actuation!**

	Large Forces or Torques	Large Bandwidth Of Forces	Transparent	Variable Impedance Rendering	High Stiffness Rendering
Controllable Brakes or Shape Rendering	✓	✗	✓	✗	✗
Admittance Control Based Devices	✓	✗	✗	✓	✓
Series Elastic Actuator Devices	✓	✗	✓	✓	✗
Geared DC Motors	✓	✓	✗	✓	✓
Pneumatic and Soft Actuation	✓	✗	✗	✓	✗
Hybrid Actuation	✓	✓	✓	✓	✓

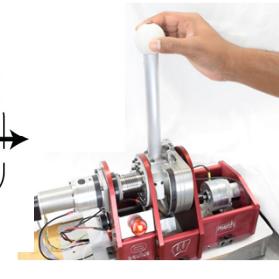
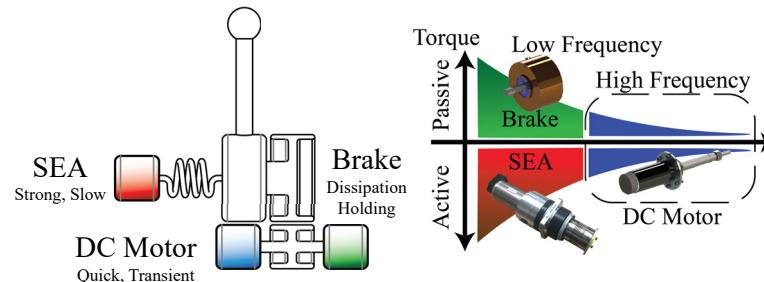
**Optimal Feedforward Control**  
Brake Model • Time vs. Energy vs. Effort Optima



**Impact Application: Rehabilitation Robot**



## Hybrid Active-Passive Actuation

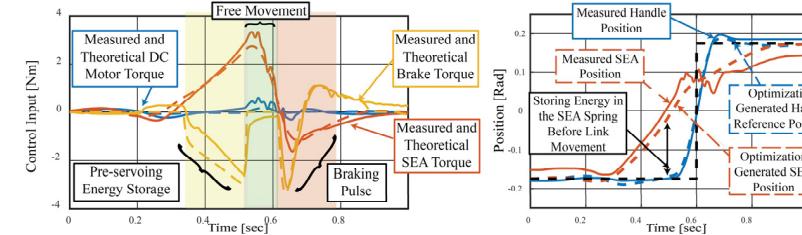


1-DOF Testbed

## Novel Results

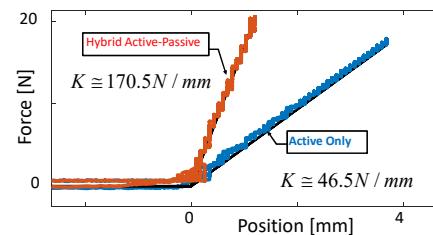
### Quicker Servoing

Quick Stops • Spring Preloading



### Stiffer Virtual Walls

#### Physical Stiffness of Brake



## Impact: Education

### Handheld Demo

- Feel Hybrid vs. Active Control
- Goal: Demo at Engineering Expo (3000+ students)



## Impact: Science and Technology

### Hybrid Active-Passive Actuators

- Design Rules
- Control Laws

### Human-Interactive Robotics

- Rehabilitation
- Materials Co-handling
- Fixturing