# Hybrid Assistive Knee Braces with Smart Actuators

W. H. Liao

Smart Materials and Structures Laboratory

The Chinese University of Hong Kong

# Exoskeleton

RoboKnee, http://www.yobotics.com

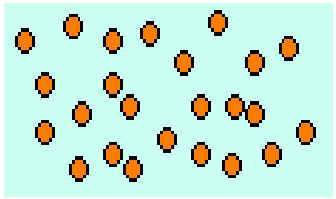
HAL, http://sanlab.kz.tsukuba.ac.jp

- Exoskeleton can enhance people's strength and endurance
- RoboKnee – one degree of freedom exoskeleton, powered by DC motor and batteries, can only work 30 – 60 minutes under heavy use
- HAL (Hybrid Assistive Limb) – a full body suit, also powered by DC motor and batteries, can work 2 hours and 40 minutes when fully charged

# Magneto-Rheological (MR) Fluids

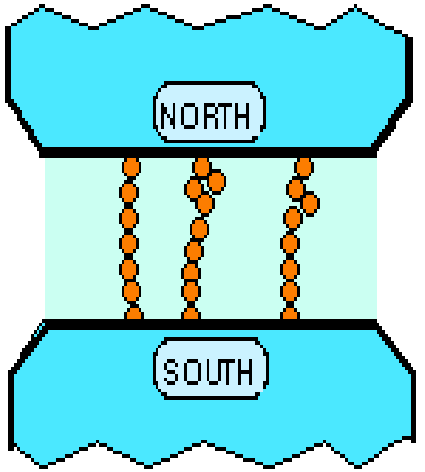
## What are they ?

- Micron sized, polarizable particles in oil



## What do they do ?

- Newtonian in absence of applied field
- Develop high yield strength when magnetic field is applied
- Provide means for a quiet, fast response interface between electronic control and mechanical devices



# Motivation

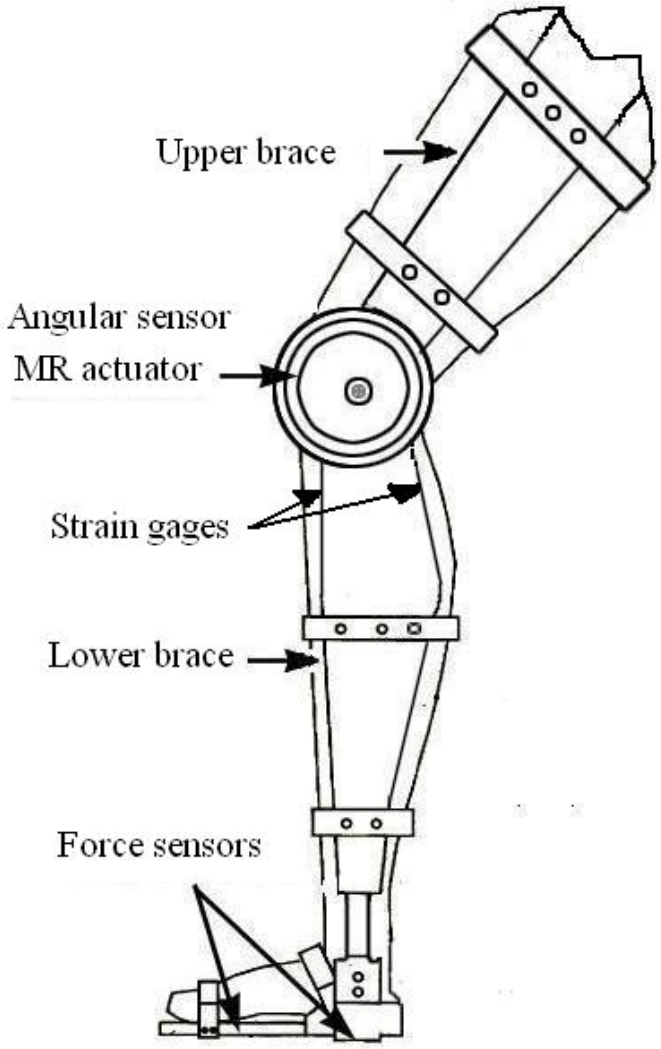
- The percentage of aged persons (older than 65) in society is increasing (for China, 7.7 % in late 2005; it is estimated to be 24% in 2050)
- Elderly people usually have the problem of weak muscle strength or osteoarthritis (OA)
- Adequate exercises would generate positive effects to OA patients, and prevent weakened muscle from been further deteriorated and become bedridden
- Devices that can provide assistance for people with mobility problems are in great need

# Objectives

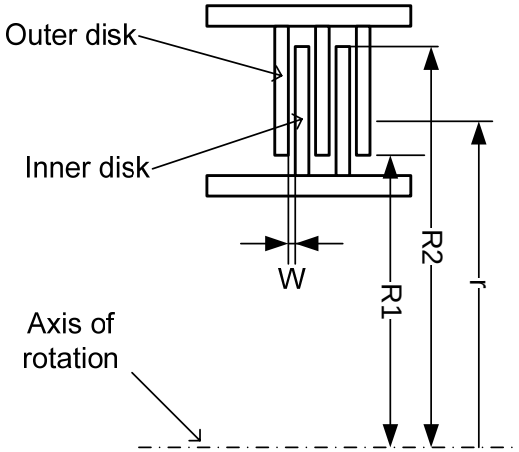
- Develop a new MR actuator that combines the advantages of MR brake (to produce large torque while requiring little power) and MR clutch (to transfer torque from motor to knee with better safety)
- Apply the new MR actuator into a leg exoskeleton to enhance people's performance or assist disabled people

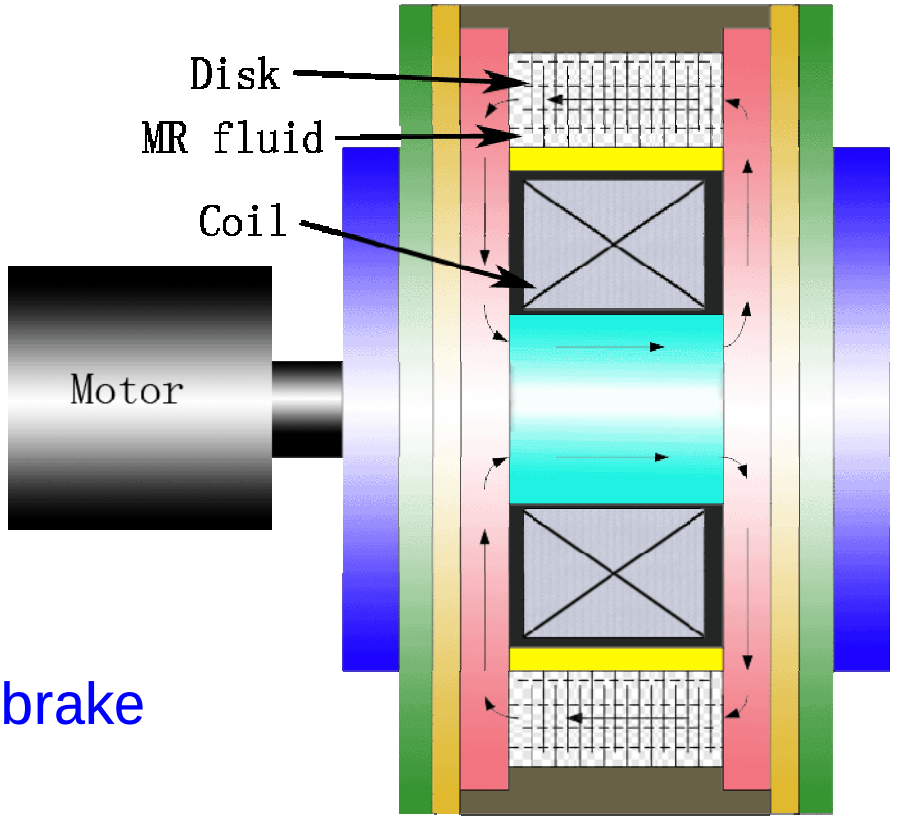
# System Configuration

- Braces
  - Upper brace
  - Lower brace
- MR actuator
- Sensors
  - Angular sensor
  - Strain gages
  - Force sensors



# MR Actuator

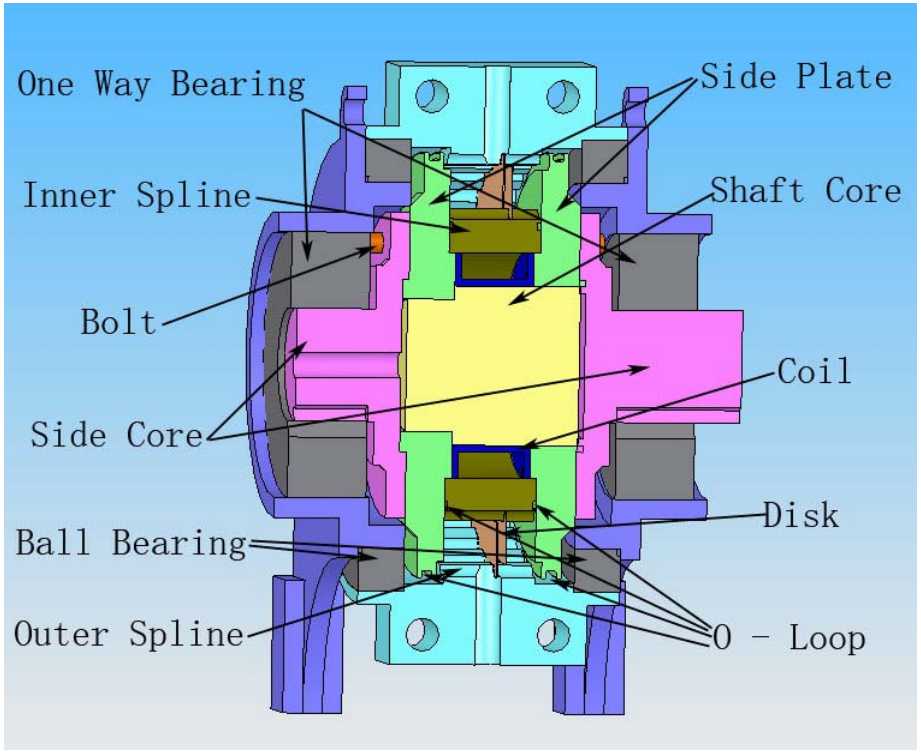



## Work conditions:

- MR actuator functions as brake
- MR actuator is off
- MR actuator functions as clutch

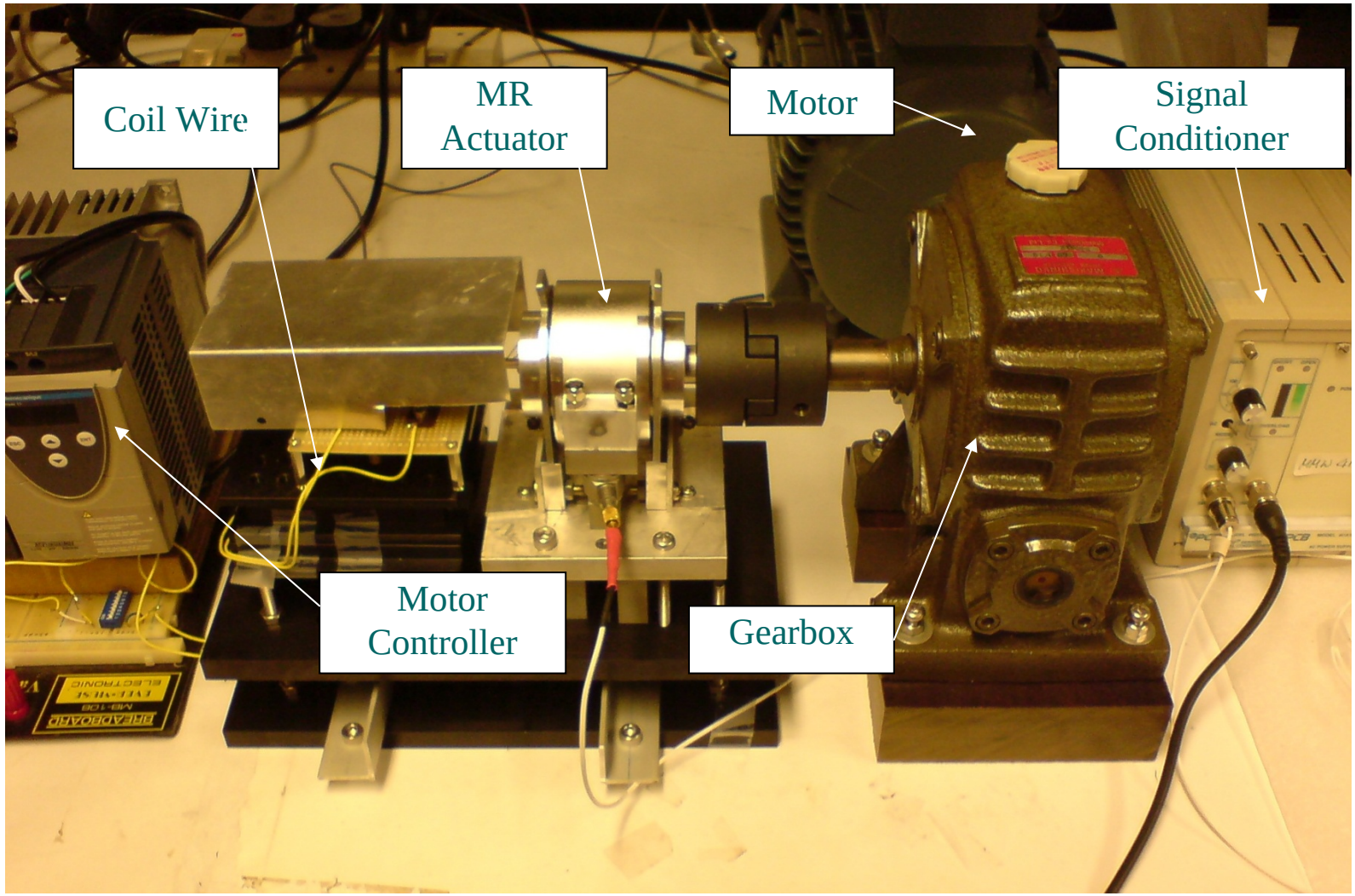
# Sectional View of MR Actuator



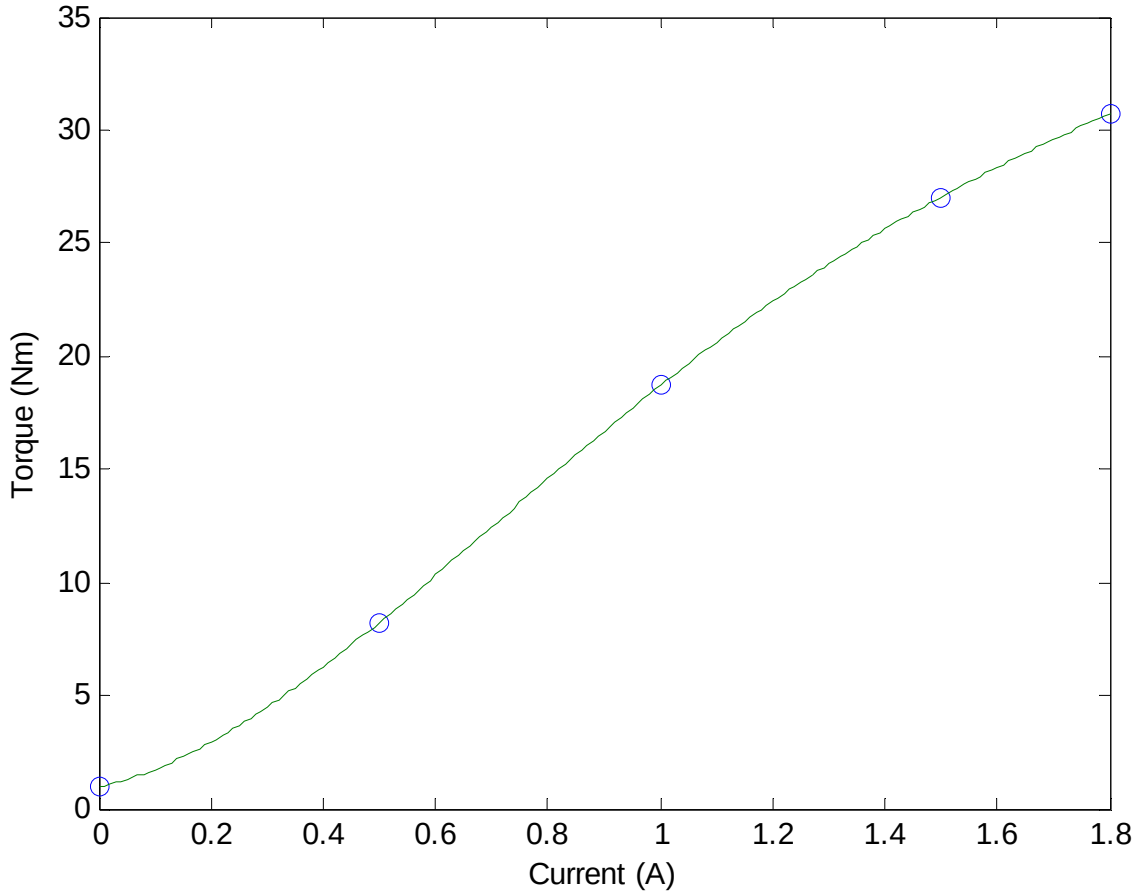

- Outer cylinder connects to upper brace, fork connects to lower brace, shaft core connects to motor
- One way bearings shift the MR actuator between brake and clutch

# Photos of MR Actuator

# Experimental Setup

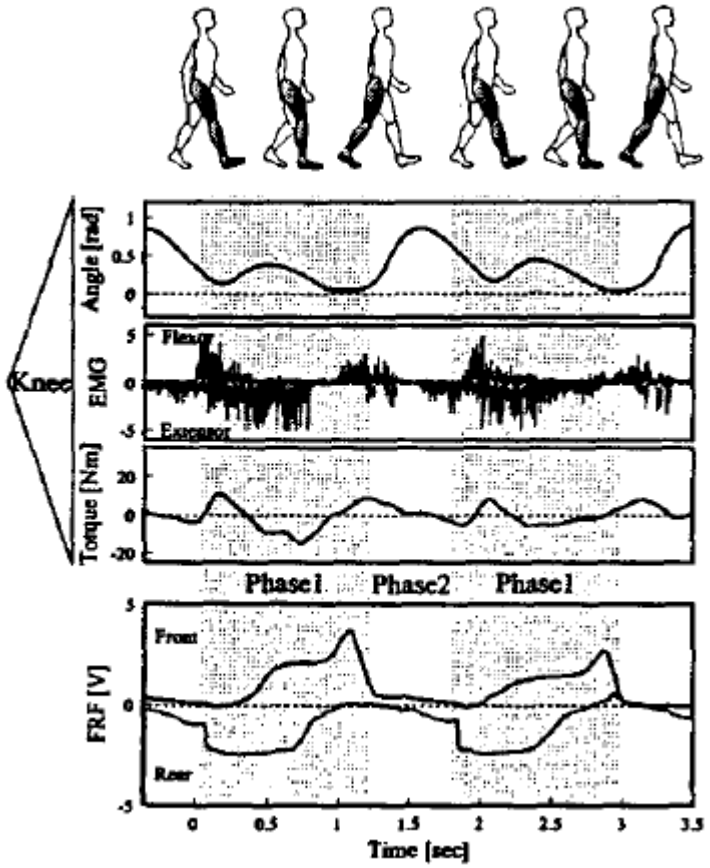


# Torque vs. Current

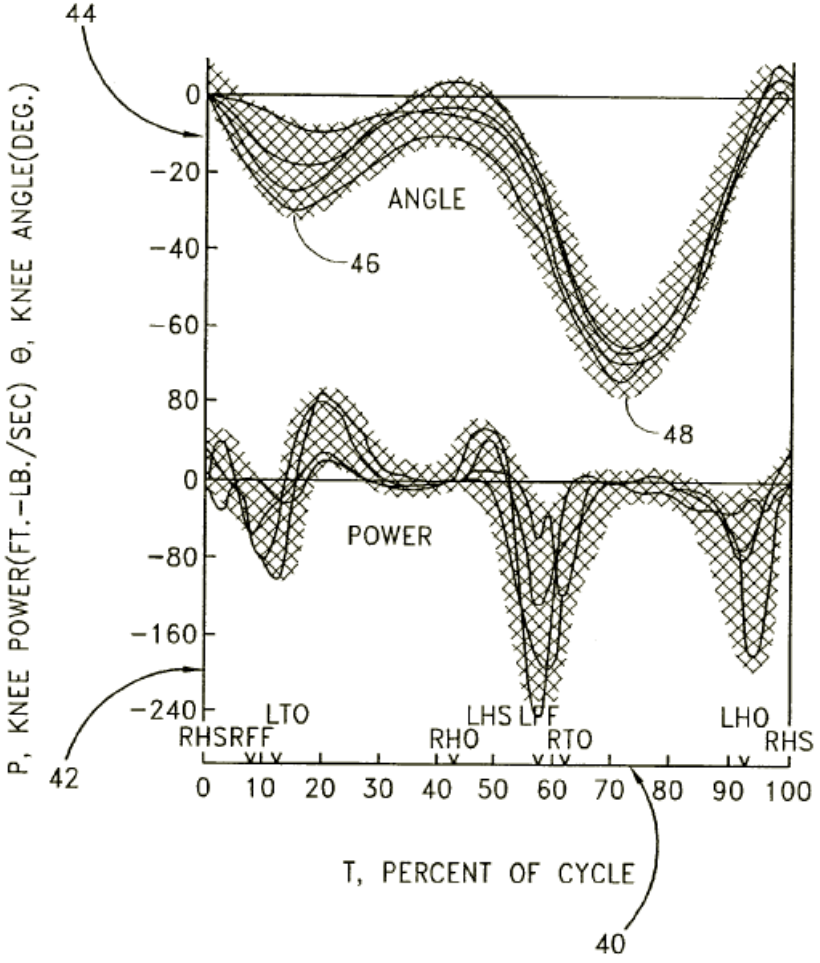



- Output torque increases as the input coil current increases

# Estimated Knee Torque

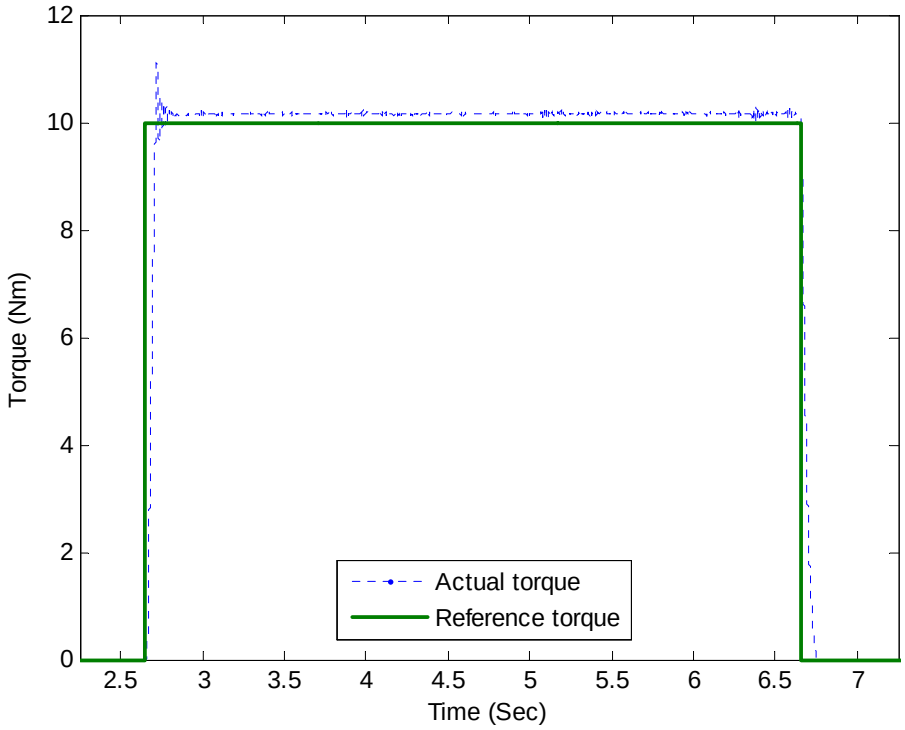


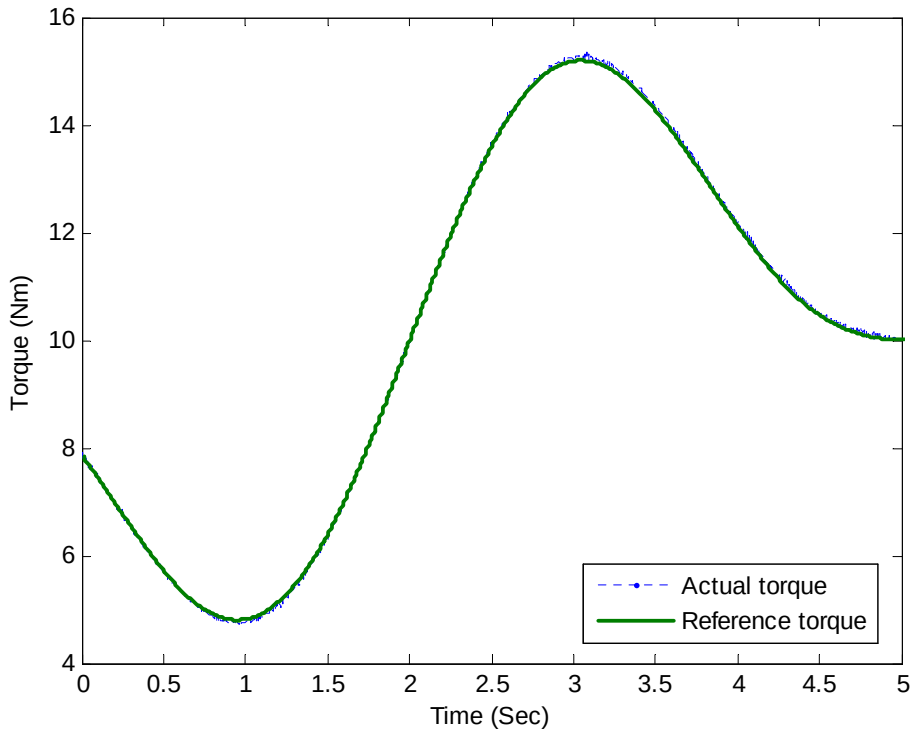

Angle, myoelectricity signals and estimated torque for left knee joint during walking (Hawamoto et al., 2002)



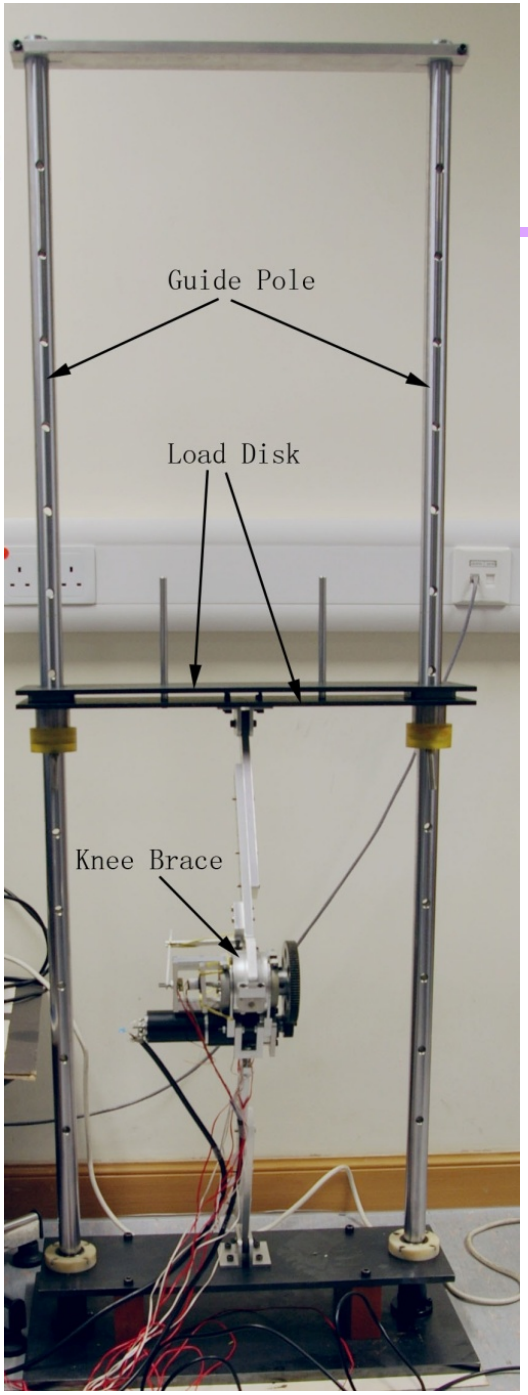

Knee power vs. knee joint during walking (Herr et al., 2003)

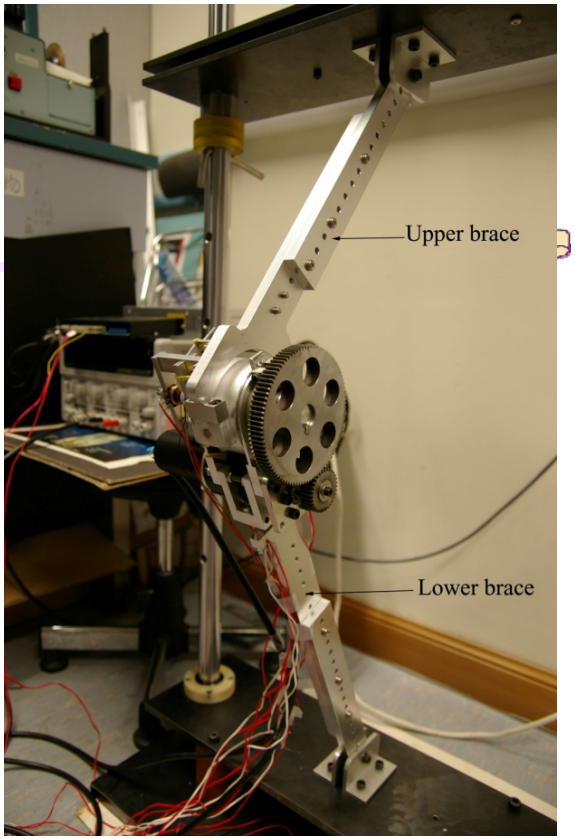
# Torque Tracking

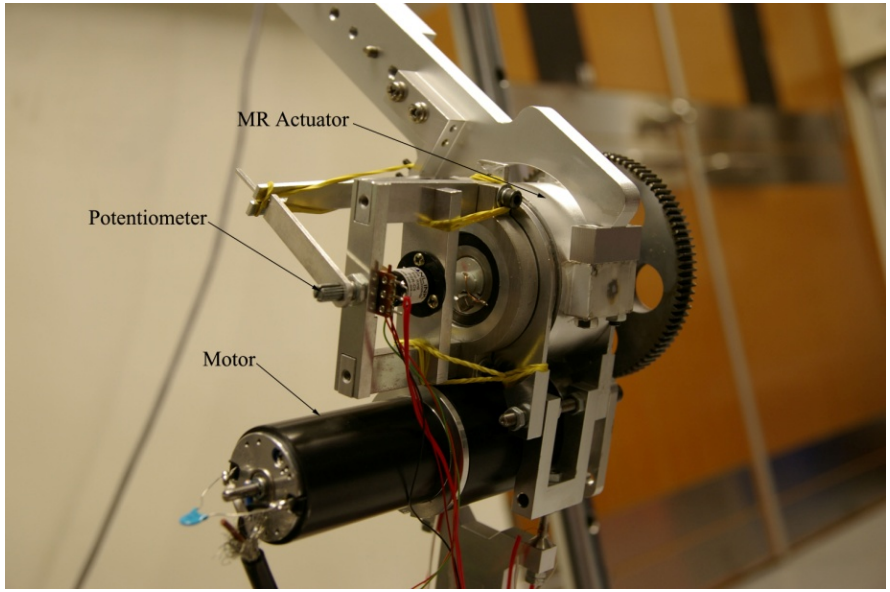



- Reference pulse signal is the same as the previous one
- Permeable tracking error: 0.5 Nm
- Good tracking performance, no overshoot


Guide Pole
Load Disk
Knee Brace


Upper brace
Lower brace


MR Actuator
Potentiometer
Motor

# Summary

- An MR actuator for assistive knee braces was designed, fabricated and tested
- The testing results showed that the MR actuator can provide sufficient torque for the knee joint
- An adaptive control algorithm was proposed to control the MR actuator
- Experimental results showed that the MR actuator has good torque tracking ability under adaptive control
- The assistive knee brace was fabricated and tested in a custom-built testing structure

# Acknowledgment

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