HUMAN/MACHINE DESIGN LAB
Department of Mechanical Engineering
University of Minnesota
(www.me.umn.edu/labs/hmd/)

Haptic interfaces for virtual product prototyping, smart knobs for cars

Rehabilitation engineering
- Tele-rehabilitation
- Stroke rehab
- Driving simulators

Human assist machines
- Compact power sources
- Powered exoskeletons
- Natural control

Medical device design
- Evaluation of surgical tools

Muscle mechanics

Stimulated Muscles = Power
Brace = Trajectory guidance
Brake = Control, stability

Smart orthotics + electrical stimulation for gait restoration
HUMAN/MACHINE DESIGN
Virtual prototyping

- Apply virtual reality technology to create product prototypes
- Move beyond CAD-based visual rendering

See

Hear

Touch
Manual controls are everywhere

- Fixed in space, single d-o-f, low-force, simple graphics
- Sufficiently complex to enable exploration of research questions
System architecture

visual display

aural display

speakers

PC

PC

PC

haptic display

motor

green screen

network

motion, force, torque

servoamp

to visual PC

camera

PC

PC

PC
Experimental studies

- **Basic research**
  - Impact of display quality on realism and ability to do task
  - Sensory interaction in multi-modal virtual environments
  - Motor control theory to understand scientific basis for performance with manual controls
  - Designing control knobs that are faster and easier to operate

- **Applied research**
  - Replace dashboard clutter with single, configurable knob
  - Adaptive panel controls that adjust to capability and preferences of the user
  - Automobiles, aircraft, complex machines, persons with disabilities, ...
Probing experiments

- Compare virtual to real materials
- Sight/sound/touch
- With or without sensory conflict
- To understand multi-modal virtual environments

Diagram:
- TV monitor
- Green screen
- Motor
- Speakers
- Probe
- Reference materials
- Test material
- Camera
- Subject
- To SGI
Novel secondary controls for cars
REHABILITATION ENGINEERING

TECHNOLOGY FOR PERSONS WITH DISABILITIES
Driving simulators in rehab clinics

- Can a simulator be used to train/evaluate those with cognitive impairments?
- Compare on-road driving performance to simulator
- Multi-center clinical trial
Tele-rehab: services and treatment at a distance

- Motor relearning for stroke
- Tele-assessment

**Tele-assessment**

- Network
- Local laptop
- Remote laptop
- Webcam
- Dig goni
- Dig dyna
- Camcorder
- Speakerphone
- Mic/amp
- Audio line
- Private phone line
- Earbud
- Artificial BW limiting

**Tele-rehab services and treatment at a distance**

- Motor relearning for stroke
HOW FES WORKS

Brain

Spinal Cord

Stimulator

Limb
LOWER LIMB FES

Inputs → CONTROL → STIMULATOR

Measurements

$F_{\text{EXTERNAL}}$
BRACE (CBO) + FES

Stimulated Muscles =
Brace = Trajectory guidance
Brake = Control, stability
MUSCLE MODELS AND ID

Active Element

IRC

Activation Dynamics (2nd order)

CE Force-Length

CE Force-Velocity

Fsate

Passive Element

PE Force-Length

PE Force-Velocity

Force
Experiments on intact muscle

- Activate muscle with e-stim
- Measure force/motion output
- Use to parameterize model
YOU CAN PREDICT MUSCLE OUTPUT

INTACT, HUMAN MUSCLE

Experiment Simulation

Hip flexion (deg) vs. Time (sec)

Knee flexion (deg) vs. Time (sec)
Nonlinear properties of muscle twitch

- Doublet stimulation reveals hidden muscle properties
- Electrical and mechanical output

![Graph showing knee torque over time with different pulse intervals (PIs): 4, 10, 60, 2, 200, 100 msec PI. The graph shows the response of the muscle twitch to various stimulation intervals, demonstrating the nonlinear properties.]
Non-invasive muscle disease diagnosis

- Mechanical and electrical properties provide window into muscle excitation contraction
- Smart stimulation, smart system id can isolate subsystems
- Go beyond, “This muscle is weak, let’s biopsy.”

University of Minnesota Center for Muscular Dystrophy
Human assist tools

- Compact, internal combustion engine power sources
- Combustion to electrical, combustion to pneumatic, combustion to hydraulic
- Natural interface and control
- Tools and exoskeletons

Collaboration with Profs. Li and Kittelson
Exoskeletons for Human Performance Augmentation

DARPA

www.darpa.mil/dso/thrust/matdev/ehpa.htm
Human/Machine Design Lab

- Mechanical and electrical properties of normal and diseased muscle
- Electrical stimulation of muscle to restore gait
- Powered, self-contained exoskeletons and tools
- Telerehabilitation for assessment and treatment
- Driving simulators for rehab clinics
- Virtual product prototyping
- Haptic interfaces
- Multi-function virtual knobs
- Evaluation of hand tools for minimally invasive surgery

Mechanics, electronics, real-time control, design, fabrication, human-subject experiments