Human-Machine Interaction with Mobility Enhancing Soft Exosuits

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http://biodesign.seas.harvard.edu
Soft Exosuits to Assist Movement

ENHANCE MOBILITY OF HEALTHY INDIVIDUALS

RESTORE MOBILITY OF PARTIALLY IMPAIRED PATIENTS
Exosuit Program Advances

Functional Textiles

Adaptive Controllers

Efficient Actuation

Biomechanics Science


Medical Opportunity

- Rigid exoskeletons such as those by ReWalk have made significant advances in providing **total support** for individuals with complete spinal cord injuries.

- However, these rigid suits do not meet the needs of people with limited mobility.
  - These patients would benefit from a much lighter, compliant suit.
  - **Goal:** *supplementing existing walking ability* rather than replacing it.
Medical Exosuit

Medical Focused Textiles

Controllers for Impaired Gait

New Actuation Requirements

Clinical Biomechanics
Exosuit for Stroke Patients

- Comfortably worn on different body types
- Lightweight body-worn actuator
- Integrated sensor in textile
- Minimal materials on distal part

**Bae, J., De Rossi, S., O’Donnell, K., Hendron, K., Awad, L., Teles dos Santos, T., De Araujo, V., Ding, Y., Holt, K., Ellis, T., Walsh, C.** Soft exosuit for poststroke gait assistance. 14th International Conference on Rehabilitation Robotics (ICORR), Singapore, August 11-14, 2015. [Runner up Best Paper]
Human-Machine Interaction with Mobility Enhancing Soft Exosuits

**Patient-in-the-loop CPS** including offboard **actuation**, wearable **sensors**, **feedback control** and measurement of patient mobility

**Challenge:**
- Rigid exoskeletons not suitable for many stroke patients with limited mobility

**Solution:**
- Safe, robust and adaptable system where the physical system (i.e. the suit) is soft, flexible and extremely lightweight
- Co-operative controllers that adapt in real-time to the patient to ensure safety and reliability

**Scientific Impact:**
- Understand how forces are transmitted to wearer to generate assistive torques at the joints
- Understand how stroke patients respond to assistance timing and magnitude

**Broader Impacts:**
- Community-suitable solution for >50% of the 800,000 patients a year who suffer a stroke and have gait deficits
Parallel Tech Dev and Basic Science

Improving the mobile system performance

Study the science of assisting human walking

Inform system design
Biomechanical and Physiological Measurements

Motion capture system

Actuation and control unit

Oxygen consumption and muscle activity

Instrumented treadmill
Improving Suit-Human Stiffness

• Structured textiles ➔
  Even force distribution over body

• Contour textile to create direct load paths

• Wide areas of fabric coverage decrease pressure
Suit-Human System


Quinlivan, B., Asbeck, A., Wagner, D., Ranzani, T., Russo, S., Walsh. C. Force transfer characterization of a soft exosuit for gait assistance. in Proceedings of the ASME IDETC/CIE 2015, August, 2015, Boston, MA, USA.
Improved Suit Stiffness
Quantifying suit force distribution

- Measuring pressure distributions to begin quantifying suit fit and comfort
Cyber: Improving Poststroke Gait
Exosuit actuation timing
Two negative peaks are observed close to TO and HS.

Lau Et al, The reliability of using accelerometer and gyroscope for gait event identification on persons with dropped foot, Gait & Posture, 2008

Gait event detection

Gyroscope signal (°/sec)

S1: Zero velocity
S2: Detecting TO peak
S3: Initial-Mid swing
S4: Detecting HS peak
Individualized trajectory generation
Improvements in Symmetry

Overhead view

Improvements:
- Active vs. Baseline
  - Stance: 11%
  - Swing: 7.9%

Graphs showing stance and swing metrics for paretic and non-paretic conditions.
Questions?

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