Advances in Human-Robot Interaction, Rehabilitation Robotics, Design Methodology and BME Pedagogy

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What characterizes human-like motion and behaviour ...

https://www.youtube.com/watch?v=wYfYtV_2ezs
... and how to transfer human characteristics to robots?

collaboration

simulation

disability

therapy
Roadmap

1. Assistive robotics, gestures, human-robot interaction
2. VR simulation of human activities
3. Upper-limb therapy robotics
4. Roboethics as a design guide
5. Design methodology and pedagogy
6. BME EiS program innovation
Roadmap

1. Assistive robotics, gestures, human-robot interaction
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5. Design methodology and pedagogy
6. BME Program Innovations
1. Assistive Robotics and HRI

Human-robot interaction and gestures:
- Object Handovers
- Hesitation Gestures
- Importance of gaze in collaboration
- Collaborative lifting of large objects
- Learning of obstacle-free reaching motions
CARIS Lab: Object Handovers

Wesley Chan

VIDEO

Robot Controller for Object Handovers
Grip Force and Load Force in Human-to-Human Handovers

- Grip Force to Load Force relations exhibit strong linearity during object transfer
- Giver responsible for object safety, and receiver in charge of maintaining efficiency
Human-Robot Handover

Comparison of Prototype Controller with Existing Controller

![Graph showing load forces experienced by receiver during handover]

Displacement-based controller:
- Excessive force required to take the object from the robot.
- Robot drops the object when collision occurs at the arm.
- No recovery mechanism.

CARIS controller:
- Less force required to take the object from the robot.
- Smoother robot-to-human handovers.
- Robust to moderate collisions at the arm.
- When object slips due to small disturbances, robot recovers and regains stable grasp.

Resulting load force from our controller is significantly less than the displacement-based controller.
CARIS Lab HRI: Object Handover

CARIS Lab HRI: Hesitation Gestures

AJung Moon

https://www.youtube.com/watch?v=Jxuqhr8A0Qk

S-type successful reach
R-type hesitation
E-stop motion
No hesitation

https://www.youtube.com/watch?v=53FtaQa834E

https://www.youtube.com/watch?v=7EaG6Vd336w
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2. Virtual Reality Simulation

- Human balance in quiet stance (RISER: Robot for Interactive Sensory Engagement and Rehabilitation)

- Sit-to-Stand assist device and human asymmetry with healthy and post-stroke participants
UBC-CARIS Lab Balance Simulator

RISER: Continuous or Intermittent Control Model of Human Balancing?

Thomas Huryn, MASc

- **Continuous:**
  - Lower sway magnitude

- **Intermittent:**
  - Lower energy
  - State predictor is beneficial
Ankle proprioception reduces sway magnitude by 84%.

Second study, paper in preparation:

**Frequency dependency of semicircular canal neural signals over actual rotation of the body about a head-height axis using GVS.**

Tilt-Platform and Balancing

https://www.youtube.com/watch?v=hdydMdCQcUk
Robots for Human Study and Therapy: Understanding Stroke-induced Asymmetry in Sit-to-Stand

Jenny Sullivan

Is inaccurate perception a large part of the reason why we see asymmetric weight distribution in functional tasks such as sit-to-stand?

Use a robotic sit-to-stand assist to support a portion of a subject’s body weight during an attempt to rise with even weight distribution.

Asymmetry vs. Assist Level

<table>
<thead>
<tr>
<th>% of BW supported by subject</th>
<th>Force on paretic, non-paretic leg (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40%</td>
<td></td>
</tr>
<tr>
<td>55%</td>
<td></td>
</tr>
<tr>
<td>70%</td>
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Symmetry ratio, $\frac{F_{\text{paretic}}}{F_{\text{non-paretic}}}$

Constant symmetry ratio at all assistance levels: implies sense of effort dominating perception (normalized to MVC)
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3. Therapy Robotics

WHO: “15 million people suffer stroke worldwide each year. Of these, 5 million die and another 5 million are permanently disabled.”

- Stroke is the leading cause of disability worldwide.
- The risk of stroke doubles with each decade after age 55.

North America

- Stroke
  - 800,000 cases per year incidence
  - 6,000,000 prevalence

- Cerebral palsy
  - 8,000 incidence
  - 400,000 prevalence
Gains in the upper-limb FM compared to spontaneous recovery patterns.

* Data from Duncan et al., Neuropharmacology 39 (2000) 835-841

Closed-loop control and adaptive exercise

- Kulić, Croft: Using affect to change robot trajectories
- Van der Loos, Shirzad: Using visual and force field distortions to change difficulty levels
- FEATHERS: Functional Engagement in Assisted Therapy through Exercise Robotics
Challenge point concept

Adaptation over time to maintain participant at challenge point


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**Desirable Difficulty**

Engagement in Task

Learning

Performance

Task Challenge
RREACH Lab: Task Difficulty Adaptation

Games matter! Making therapy engaging by promoting neuroplastic adaptation through movement controlled computer games

Navid Shirzad\textsuperscript{1}, Bulmaro Valdes\textsuperscript{1}, Keith R. Lohse\textsuperscript{2}, and H.F. Machiel Van der Loos\textsuperscript{1}

\textsuperscript{1}UBC Mechanical Engineering, \textsuperscript{2}UBC Kinesiology
What are the costs of stroke?

- Stroke is the most common source of long-term adult disability in North America. ¹
- Only 5-20% of people affected regain UE functionality. ²
- The “dose” of movements required for recovery is estimated to be in the thousands. ³,⁴
- But only ~30 repetitions of a movement are practiced in a usual therapy session. ⁵

³ [Sathian et al. NNR, 2011], ⁴ [Sawaki et al. NNR, 2008], ⁵ [Lang et al. APMR, 2009]
What are the strengths of games?

- 500 million people have installed Candy Crush™. *(That’s 1/14 of the people in the world!)*[^1]

- 58% of Americans play video games.[^2]

- 45% of gamers are female.[^2]

- Nearly half of adults over 50 play video games (computers, cellphones, consoles).[^2]

[^2]: [2013 Demographic and Usage Data, ESA]
How to help solve this big problem?

- Large quantities of practice lead to neuroplastic change and behavioural recovery.¹

- Practice needs to be challenging, progressive, and specific to the individual.²,³

- Can we use games to increase specific movements in the affected limb?

Smart controls for engaging therapy.

Design

Programming

Testing
**RREACH Lab: Functional Engagement in Assisted Therapy through Exercise Robotics (FEATHERS)**

- Enforce/encourage bimanual motions
- Use social media as a motivator
- Adapt game level
- Quantify motions
- Use of two input methods:
  - Kinect
  - PS Move

\[
|\Delta S| = \min(|\Delta S_R|, |\Delta S_L|)
\]

\[
S_{n+1} = S_n + \Delta S
\]

_Bulmaro Valdes_  
FEATHERs Team  
UBC

VIDEO
FEATHERS VIDEO

http://rreach.mech.ubc.ca/research/projects/feathers/
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6. Later – BME Program Innovations
Roboethics and Design Process Guidance

AJung Moon, Ergun Calisgan, Navid Shirzad

- Social issues related to acceptance
- Developing new behaviours
- Invasive rehabilitation devices
- New Ontological Category (NOC) for social robots?
ORi: Open Roboethics initiative

AJung Moon, Ergun Calisgan, Camilla Bassani, Fausto Ferreira, Fiorella Operto, Gianmarco Veruggio, Elizabeth A. Croft, H. F. Machiel Van der Loos

1. Knowledge Sharing and Informing Design
2. Design Sharing and Ethics Implementation

http://www.openroboethics.org/
http://robohub.org/
ORi: Open Roboethics initiative

Robot designs informed by Roboethics discussions

Open Roboethics initiative

Roboethics discussions informed of today’s technology
Roboethics and Design Process Guidance
AJung Moon, Ergun Calisgan, Navid Shirzad

https://www.youtube.com/watch?v=tIBXoS9u3RM
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4. Design Methodology

- Medical Device Design in Resource-limited countries
- Changes in the Curriculum of MECH 45X
Medical Device Design Methodology
Florin Gheorghe, Shalaleh Rismani

EiS (CREATE)  
Vancouver General Hospital  
Vancouver, Canada  

Mulago National Referral Hospital  
Kampala, Uganda
Goals and Methodology

Research Goals:
1. Understand what makes an African surgeon unique
2. Test and refine methods for design in this context
3. Identify opportunities for innovation
4. Develop and evaluate a technology solution for one specific area

Ethnography: Observation, Interviews, Focus Groups

22 Ugandan participants (+)
- 5 Nurses
- 5 Consulting Surgeons
- 12 Resident Surgeons

9 Canadian participants (+)
- 3 Nurses
- 4 Consulting Surgeons
- 2 Resident Surgeons
Anthony Ulwick, What Customers Want: Using Outcome-Driven Innovation to Create Breakthrough Products and Services, McGraw-Hill, 2005
Two Methods, Two Perspectives

1) Outcome Driven Innovation (ODI):
   - 350+ sub-goals and desired outcomes
   - Narrowed down to 150 tangible goals
   - Prioritized by 30 Ugandan and 15 Canadian users to reveal top 10 problems to focus on (turning qualitative to quantitative)

2) Qualitative User Research:
   - 17 reflection journals, 300+ photos, 40+ formal and informal interviews, and observations

ODI: Outcome Driven Innovation

Outcomes

<table>
<thead>
<tr>
<th>Outcome</th>
<th>I</th>
<th>S</th>
<th>Opp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimize blood loss during operation</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Increase visibility in operating field for operating team</td>
<td>7</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Minimize damage to patient’s soft tissue</td>
<td>8</td>
<td>1</td>
<td>15</td>
</tr>
</tbody>
</table>

Opportunity = Importance + max (Importance – Satisfaction, 0)
Engineers in Scrubs (EiS)  
Biomedical Engineering Graduate Program

• “[I]nventive users [frequently clinicians] are the principal driving force behind most medical device innovations.”¹

• Innovation requires ongoing interaction between clinicians and technologists.²

• Radical innovation requires a clinical lead user with high intrinsic motivation to solve a problem, awareness of and openness to new technologies, and access to both interdisciplinary know-how and resources to pursue development.³

• We therefore need training programs that deliberately put engineers into close contact with clinicians.

• UBC has recently (2011) implemented a new 4-credit graduate sequence, *Engineers in Scrubs*, for this purpose.


Funding by the EiS CREATE Grant, A. Hodgson PI, NSERC
MedTech Cafés: Clinical Advances From Engineering

1: Problem Identification. 2: Need prioritization
3: Requirements: need finding and screening
4: Concepts: generation, winnowing and selection
MedTech Cafés:
Clinical Advances From Engineering

5: Prototype testing
6: Development planning
EiS Projects

- Drill cover design
- Barrel autoclave
- Bone fixation nail cutter
- 2-cortex drilling depth gauge
- Intermedullary nail length gauge
- Electrocautery smoke evacuator
Summary:
HRI and Rehabilitation Robotics

- Innovations in HRI
- VR Simulations
- Therapy Robotics
- Roboethics
- Design Methodology
Future Directions

- What characterizes “more effective therapies” and “better” HRI?
- In using VR, how can we implement translational research to move from basic neurophysiology to clinical application?
- How can Roboethics guide the design of robot behaviours to enhance robot effectiveness in a societal context?
- How can the application of a “Design Thinking” mindset frame our approach to critical, world-relevant problems?
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