Lecture 16: Prosthetics

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Types of Prostheses
prostheses
artificial devices that replace injured or diseased body parts

Ocular prosthesis  Visual prosthesis  Artificial kidney

Also: Craniofacial (hemifacial, auricular, nasal, dental), neck (larynx substitutes, trachea and upper esophageal replacements), internal organs (bladder, stomach, heart), etc.
limb prostheses

purposes range from cosmesis to function
reasons for amputation

• Trauma
• Burns
• Peripheral Vascular Disease
• Malignant Tumors
• Neurologic Conditions
• Infections
• Congenital Deformities
limb prostheses

Upper extremity:
- forequarter
- shoulder disarticulation
- transhumeral prosthesis
- elbow disarticulation
- transradial prosthesis
- wrist disarticulation
- full hand
- partial hand
- finger
- partial finger

Lower extremity:
- hip disarticulation
- transfemoral prosthesis
- knee disarticulation
- transtibial prosthesis
- Syme's amputation (through ankle joint)
- foot
- partial foot
- toe
PROSTHETICS
LOWER EXTREMITY

BELOW KNEE
KNEE DISARTICULATION
ABOVE KNEE
HIP DISARTICULATION
Prosthesis Design and Control
components
types of prosthesis control

No control

Cable operated (body powered)

Myoelectric

Robotic
myoelectric prosthesis control:

• Electrodes pick up microvolts of electricity produced by contractions in the muscles of the residual limb.

• Signals are amplified and thereafter they activate the motor.

• In operating a hand there may be two electrodes, one on extensor muscles and one of flexor muscles groups, for opening and closing the hand.
robotic prosthesis control: peripheral invasive
robotic prosthesis control: targeted muscle reinnervation
Courtesy of The Rehabilitation Institute of Chicago and DEKA
(http://www.youtube.com/watch?v=ddInW6sm7JE)
robotic prosthesis control: targeted muscle reinnervation

• Provides an **organized** afferent pathway
  • Offers strong causal link between sensation and perception
  • Minimizes need for CNS plasticity
• Provides a **natural** afferent pathway
  • Near-normal thresholds for temperature, light touch, sharp/dull and pressure have been demonstrated
• Yet, there are many challenges and unknowns:
  • Density and types of mechanoreceptors in reinnervated skin unknown
  • No evidence of kinesthetic sensing
  • Relevance to proprioception unclear
  • Sensation of fingerpads has not been reported
  • Relationship to reinnervated muscle unclear
robotic prosthesis control: brain implant
robotic prosthesis control: brain implant

https://www.youtube.com/watch?v=ZuATvhlcUU4
discussion:

what are additional design challenges and potential solutions?
Human Sensorimotor Control Considerations
Comparison to Teleoperation

user → haptic device ← teleoperated robot

motion and force signals
Transradial Electric-Powered Prosthesis User Preferences

<table>
<thead>
<tr>
<th>Rank Order of Priority</th>
<th>Item Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fingers could bend</td>
</tr>
<tr>
<td>2</td>
<td>Thumb moved out to side</td>
</tr>
<tr>
<td>3</td>
<td>Required less visual attention to perform functions</td>
</tr>
<tr>
<td>4</td>
<td>Thumb could touch each finger individually</td>
</tr>
<tr>
<td>5</td>
<td>Could hold small objects better</td>
</tr>
<tr>
<td>6</td>
<td>Wrist rotated terminal device</td>
</tr>
<tr>
<td>7</td>
<td>Could hold large objects better</td>
</tr>
<tr>
<td>8</td>
<td>Could use it in vigorous activities</td>
</tr>
<tr>
<td>9</td>
<td>Wrist moved terminal device up and down</td>
</tr>
<tr>
<td>10</td>
<td>Middle joint of thumb could bend</td>
</tr>
</tbody>
</table>

effect of visual and haptic position feedback on human control of proxy movement.

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INTRODUCTION

Healthy adult humans are amazingly adept at controlling the motion of their own body parts. Extensive research has documented the importance of visual and haptic position feedback during such tasks unsighted. The sense you employ in such cases is proprioception and contact. Section II provides a very general overview of the contribution in prosthetics.

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Fig. 1. Prosthesis signal flow. Photograph used with permission of Reuters/Jason Reed.
role of vision and proprioception

haptic feedback

Normal force
(e.g. “force reflecting” interface)

Vibration
(e.g., voicecoil)

Shear
(e.g., rotating wheel)

Local Shape
(e.g. pin array)

Contact Location
(e.g. moving roller)

Thermal
(e.g. Pelletier)

Images courtesy Ed Colgate, Northwestern University
discussion:

what are additional sensorimotor control challenges and potential solutions?
future of prosthetics:

• Solving problems of cost, power, weight
• Direct human sensorimotor control
• Autonomy (or partial autonomy)
• Other ideas?