Neural Prostheses for Grasping Tasks

Lecture 7: EE 500N Winter 2017

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Importance of Grasping Tasks

- Kinds of grasping tasks of importance in everyday life
  - Eating
  - Drinking
  - Grooming (toothbrush, comb, razor, washcloth)
  - Work-related tasks
Importance of Grasp

- Restoration of grasping ability is critical to *increasing independence*
- This has benefits to individual, and to health care system
Grasp and Prehension

- Orient the hand
- Open hand so that object fits inside
- Contact object
- Form a firm grip
  - Applying forces when in contact with object
  - Applied in opposition to other hand surfaces or external objects
  - Need for stability—overcoming perturbations
5 Basic Grasps

Palmer (1- cylindrical and 3-spherical)
Tip (2-pinch)  Lateral (4-key)  5-Hook
95% of Tasks from 3 Grasps

- **Lateral (Key)** – side opposition in direction generally transverse to palm
- **Palmer** – palm opposition between hand surfaces along direction perpendicular to palm
- **Pinch** – pad opposition between hand surfaces along direction parallel to palm; surfaces are fingers and thumb at or near pads
When lifting and manipulating objects...

- Need to apply grip forces that are large enough to prevent slippage
- Not too large (to avoid damage to object and unnecessary muscle fatigue)
- Usually use tactile and visual feedback
Loss of Grasping Ability

- Spinal Cord Injury
- Head Injury
- Stroke
- ALS, MS

Depending on level and extent of injury, degree of sensory loss varies, and which muscles are voluntarily controlled will differ.
Loss of Grasp

Of particular SCI concern—loss of muscles that are innervated by nerves at the level of injury (those innervated from above are voluntarily controllable; those innervated from below injury are intact and can be stimulated)
Rehabilitation Methods

- External orthotics (bracing)
- Neurorehabilitation
  - Most applicable for Stroke, head injury
  - Retraining system to make use of remaining components— “re-learning”
  - Can involve electrical stimulation, external mechanical manipulation (by therapist or robot), biofeedback
Rehabilitation Methods

- Surgical interventions
  - To fuse joints, alter geometry
  - To transplant tendons ("tendon transfer"), muscles—changing which are either voluntarily controlled or can be controlled by electrical stimulation
Rehabilitation Methods

- Functional Electrical Stimulation
  - Strengthening of Atrophied Muscles
  - Facilitation of Voluntary Movement (often part of neurorehabilitation)
  - Moderation of Spasticity
  - Electrical Stimulation to Generate Controlled Motion
FES for Grasp

- Has motivated development of most of the implanted electrodes and feedback controllers described in previous lectures—including implanted stimulators
- Special sensor needs (for grasp contact force, hand position)
Target Population

- Individuals with upper arm control (and elbow control), but no wrist control or grasping capability
- Poor candidates for external bracing
- SCI, stroke, head injury—not ALS, MS
Command Sources

- Voice command (Nathan—Ben Gurion University)
- Contralateral shoulder movement (CWRU-Cleveland group)
- Respiratory activity (Handa—Sendai group)
- Wrist movement (Prochazka—U. Alberta)
- EMG activity of antagonist muscles
- Various switches (tongue, puff and sip)
- EEG pickup
- Potentially ECoG
Cosmesis Issues

- Strong Motivation for Implanted Systems (NeuroControl implanted stimulator’ “Freehand”)
- Implanted stimulator, sensors
Control of Grasp

- Most systems use Open Loop Control (stimulation profiles for each muscle)

The diagram of the stimulation profiles for four muscles providing the palmar and lateral grasp in a tetraplegic subject using the percutaneous intramuscular electrodes and a version of the Freehand system. The horizontal axis shows the position of the proportional interface controlled by the user: 0 - hand open, 100 - hand closed.
Grasp Synthesis Method

Fig. 5.57: The method of grasp stimulus synthesis called the external moment grasp synthesis procedure. Adapted from Kilgore and Peckham, 1993a © IEEE.
Feedback Control of Grasp

Using “stiffness controller”
Other Control Methods

- Neural Nets to generate muscle stimulation patterns (Lan, Fen, Crago 1994)
- Hand Grasp/Elbow Extension system (Cleveland group 1998)—using volitional control of non-paralyzed muscles