Neural Prostheses for Grasping Tasks

Lecture 7: EE 546 Winter 2020

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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 pertubations
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
- 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