CSE 490i
Lecture 3
Neural Control of Movement
Part 1
1/23/2007
Announcements

- PS3 due Thursday morning 10:30am
- PS4 (reading assignment) posted today
- Lab2 writeup due this week (before your lab session electronically)
- Lab3 this week
- Guest lecture by Kai Miller on Thursday.
- Feedback?
Human Closed Loop System

brain
spinal cord
peripheral nerve
muscles
joints
movement
skin

sensory feedback

reflex!
another layer of sensory feedback

muscle sensors (length and force)

see
touch
Roles of Components in Human Movement Control

Muscles: contracts (and shortens) with electrical signals

Peripheral nerves: conducts electrical signals

Spinal cord: conducts signals to muscles from brain from sensors to brain reflex signals comes back and **calculate** appropriate actions reflex required because the neural conducting time is slow

Brain: computes motor output (motor cortex) converts tasks/goals to desired output signals (premotor cortex) processes error correction (cerebellum) adapt to the environment/tasks, etc (everywhere)
So what do the researchers in Neurobotics study?

Physiology: How do the muscles/sensors work? Is there a way to mimic for robots or implants?

Dynamics: How do multi-joint limbs get controlled? Modeling of dynamic behavior

Brain Anatomy: Which part of the brain is in charge of different function? Lesion (hole) studies, patient studies


Brain-Machine Interface:
Superman Suit
Prosthetics
Brain-Computer Interface
External device induce new control/adaptation
Anatomical Terms of the Central Nervous System (CNS)

- Motor signals
- Sensory signals

Paraplegic: lower than T2. Quadriplegic: higher than C4. In between: a variety of deficits.
Brain (with motor systems)

Cerebral Cortex (mostly called cortex):
Evolved faster than the skull
Different areas in charge of different function.

Gray matter: lots of cells (neurons)
6 layers with different type of cells
While matter: lots of fibers

Basal Ganglia:
Reinforcement learning
Lesion in BG causes:
slow movements
uncontrolled movement
hard to initiate movement
Ex: Parkinson’s disease

Cerebellum:
Heavily involved in motor coordination
Inputs: sensory inputs from spinal cord, motor signals
Outputs: movement plan, timing, patterns
Lesion in CB causes:
uncoordinated movements
lose balance
can’t learn error directed movements

Purkinje cells in Cerebellum
looks like this and takes these signals!

Pons and Medulla:
Regulation of blood pressure, respiration, etc

Desired Output (R)
Error (e)
Actual Output (Y)
Primary motor cortex (M1):
• Output port (neurons in M1 have wires that project down through spinal cord).
• Well studied and used for Neurobotics

Primary sensory cortex (S1):
• Input port (neurons in S1 have wires that come from spinal cord).

Primary visual cortex (V1):
• Visual input port

Primary auditory cortex (A1):
• Auditory input port

Premotor area (PMA):
• Motor sequence planning
• Projects to M1
• Active 200msec before movement onset

Prefrontal cortex:
• Plans voluntary movements
• Receives info from limbic system (related to motivation?)
• Projects to PMA

Posterior parietal cortex:
• Receives info from S1, V1
• Projects to PMA, prefrontal cort
• Coordinates sensory info for movement production --- perception
Box Diagram of Motor Systems in CNS

Cortex:
Prefrontal cortex -> PMA -> M1

Thalamus
Basal ganglia
Cerebellum
Brain stem
Spinal cord

Cortical loop delay: 120-180 msec
Muscle contraction and movement
Reflex loop delay: 40-100 msec
Sensory receptors
Sensory consequences of movement
Now in terms of engineering....

- Open loop: can’t keep the movement steady with perturbation
- Spinal feedback: can correct movements involuntarily (reflex)
- Cortical feedback: can correct movements voluntarily (but still can’t catch a ball)
- Feedforward control (allows anticipation): build a model of the environment/arm/muscles
- Adaptation: learn the environment model (always), learn plant model (growing up, etc.)
Motor/Somatotopic map

Penfield

There is a topological map in a specific order

Area size depends on the fine control ability (for M1) or sensitivity (for S1)

Specific lesions create specific deficits. Example: stroke

Contra-lateral side deficits
Brain-machine Interface (BMI)
Brain-Computer Interface (BCI)

• Stroke, Spinal cord injuries, amputees, etc
Movement augmentation

• Locked in
Communication assistance