Lecture 2: Neuroscience Basics.

Reading Assignments:

None
Soon, you will find there:

- Lecture notes: user “iLab” and password “cool”
- Reading assignments
- Grades
- General announcements
- Project topics
Projects

Two categories:

- Implement a neuromorphic vision algorithm, using the language, platform, and approach of your choice, e.g., “an edge detector that sees illusory contours”

- Write a review article on a vision topic, including both computer vision and visual neuroscience state of the art in this domain, and making suggestions for further interactions and improvements, e.g., “human-computer interfaces”
The brain is not the entire nervous system; there is also the spinal cord, many peripheral “ganglia” (small clusters of neurons), and neurons extend connections to locations all over the body (e.g., sensory neurons, motor neurons).
Autonomic Nervous System

- **Parasympathetic**
  - Stimulates flow of saliva
  - Slows heart beat
  - Constricts bronchi
  - Stimulates peristalsis and secretion
  - Stimulates release of bile
  - Contracts bladder

- **Sympathetic**
  - Dilates pupil
  - Inhibits flow of saliva
  - Accelerates heartbeat
  - Dilates bronchi
  - Inhibits peristalsis and secretion
  - Conversion of glycogen to glucose
  - Secretion of adrenaline and noradrenaline
  - Inhibits bladder contraction

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Axes in the brain

These axes rotate 90 deg in the brain stem
Medical Orientation Terms for Slices

sagittal  coronal  axial (horizontal)
Main Arterial Supply to the Brain
Arterial Supply is Segmented

Occlusion/damage to one artery will affect specific brain regions. Important to remember for patient studies.
**Ventricular System**

**Ventricules**: Cavities filled with fluid inside and around the brain. One of their functions is to drain garbage out of the brain.
Cortical Lobes

Sulcus ("fissure" if very large): Grooves in folded cortex
Gyrus: cortex between two sulci

1 sulcus, many sulci; 1 gyrus, many gyri
Brodmann Areas
Brodmann’s cytoarchitectural map of Cortical Areas

Lateral View
Brodmann’s Areas
(Medial View)
Brodman's areas - medial view
Anatomical Areas, Brodmann Areas, Functional Areas…
Neurons

**Cell body (soma):** where computation takes place

**Dendrites:** input branches

**Axon:** unique output (but may branch out)

**Synapse:** connection between *presynaptic* axon and *postsynaptic* dendrite (in general).
Electron Micrograph of a Real Neuron
Grey and White Matters

Grey matter: neurons (cell bodies), at outer surface of brain
White matter: interconnections, inside the brain
Deep nuclei: clusters of neurons deep inside the brain
Major Functional Areas

- **Primary motor**: voluntary movement
- **Primary somatosensory**: tactile, pain, pressure, position, temp., mvt.
- **Motor association**: coordination of complex movements
- **Sensory association**: processing of multisensorial information
- **Prefrontal**: planning, emotion, judgement
- **Speech center (Broca’s area)**: speech production and articulation
- **Wernicke’s area**: comprehension of speech
- **Auditory**: hearing
- **Auditory association**: complex auditory processing
- **Visual**: low-level vision
- **Visual association**: higher-level vision
Major Functional Areas
Motor and Somatosensory Homunculi
Somatosensory Localization
Supplementary Motor Area (SMA) and Premotor Area

- Superior Frontal gyrus and Middle frontal gyrus (Brod. Area 6)
- Activated by complex motor tasks (touch all four fingers in a given sequence)
Activation of Broca’s Area

- Operculum and triangular parts of inferior frontal gyrus (Area 44, 45)
- Activated by word generation tasks - lateralizes to dominant side
- Covert word production
Cortical Regions - Language

- Area of motor cortex concerned with articulation and phonation
- Frontal operculum
- Broca's area (opercular language area)
- Sylvian fissure
- Central sulcus
- Supramarginal gyrus
- Arcuate fasciculus
- Angular gyrus (area 39)
- Higher order visual cortex (area 18)
- Primary visual cortex (area 17)
- Wernicke's area (perisylvian language area, area 22)
Sites where stimulation interferes with speech
Activation of Auditory Areas

- Primary (A1) and auditory association areas (A2, Wernicke’s)
- Increasing word presentation frequency increases response
Activation of the Visual Cortex

- Primary visual area (V1) Area 17
- Visual association areas (V2-5) Area 18,19
- Stimulus activates banks of the calcarine sulcus
- Retinotopic
Cognitive Tasks

- Silent (internal) speech
- Mental imagery of prior motor or visual task
- Memory load activation of prefrontal cortex (2 back paradigm)

Cohen et al Human Brain Mapping 1:293-304, 1994
Cortex “inside” the brain.
Involved in emotions, sexual behavior, memory, etc (not very well known)
“Flat map” representation

Goal: unfold all circonvolutions in cortex, so that exposed as well as usually unexposed (in sulci) areas are well visible.
Flat Map of Monkey Brain

Note how the monkey brain has less developed frontal lobe and fewer circonvolutions (grooves) than human brain.
Brain activity as seen on brain slices is difficult to put together in brain areas...
Use of Flat Maps: Visual Cortex Mapping

but becomes much easier with at least partial unfolding…
Comparison Across Species

Frontal cortex most developed in humans.

Relatively speaking, association areas (involved with more complex / higher-level processing) are larger in humans, compared to primary (sensory, motor, visual, etc) areas.
Major Functional Areas (other source)
Visual Input to the Brain
Human Visual System
Primary Visual Pathway
Layered Organization of Cortex

Cortex is 1 to 5mm-thick, folded at the surface of the brain (grey matter), and organized as 6 superimposed layers.

Layer names:
1: Molecular layer
2: External granular layer
3: External pyramidal layer
4: Internal granular layer
5: Internal pyramidal layer
6: Fusiform layer

Basic layer functions:
Layers 1/2: connectivity
Layer 4: Input
Layers 3/5: Pyramidal cell bodies
Layers 5/6: Output
Layered Organization of Cortex
Slice through the thickness of cortex
**Columnar Organization**

Very general principle in cortex: neurons processing similar “things” are grouped together in small patches, or “columns,” or cortex.

In primary visual cortex…

as in higher (object recognition) visual areas…

and in many, non-visual, areas as well (e.g., auditory, motor, sensory, etc).
Retinotopy

Many visual areas are organized as retinotopic maps: locations next to each other in the outside world are represented by neurons close to each other in cortex.

Although the topology is thus preserved, the mapping typically is highly non-linear (yielding large deformations in representation).

Stimulus shown on screen... and corresponding activity in cortex!
Neurons and Synapses
**Transmembrane Ionic Transport**

*Ion channels* act as gates that allow or block the flow of specific ions into and out of the cell.
Gated Channels

A given chemical (e.g., neurotransmitter) acts as ligand and gates the opening of the channel by binding to a receptor site on the channel.
At rest, the inside of the cell rests at a **negative potential** (compared to surroundings)

Action potential consists of a brief “**depolarization**” (negative rest potential decreases to zero) followed by “**repolarization**” (inside of membrane goes back to negative rest potential), with a slight “**hyperpolarization**” overshoot before reaching rest.
**Action Potential and Ion Channels**

- **Initial depolarization** is due to opening of sodium (Na+) channels.
- **Repolarization** is due to opening of potassium (K+) channels.
- **Hyperpolarization** happens because K+ channels stay open longer than Na+ channels (and longer than necessary to exactly come back to resting potential).
Channel activations during action potential

<table>
<thead>
<tr>
<th>PHASE</th>
<th>VOLTAGE-GATED Na⁺ CHANNELS</th>
<th>VOLTAGE-GATED K⁺ CHANNELS</th>
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Saltatory Conduction along Myelinated Axons

Schwann cells wrap around axons, yielding an insulating myelin sheet except at regularly spaced locations (nodes of Ranvier). Provides much faster conduction of action potentials.
Serial Processing

Relay stations

Diagram showing the path from receptors to the thalamus, then to the neocortex, through primary, secondary, and tertiary areas, finally leading to motor areas.
Parallel Processing

multiple routes to cortex
1) geniculostriate and tectopulvinar systems
Interconnect

Felleman & Van Essen, 1991
Interconnect… (other source)

### More on Connectivity

|   | V1 | V2 | VP | V3 | PIP | V3A | PO | V4 | MT | V4t | VOT | DP | LIP | VIP | MSTd | MSTi | PITd | PITv | STPp | CITd | CITv | STPa | AITv | FEF | TE | 46 | FST | AITd |
|---|----|----|----|----|-----|-----|----|----|----|-----|-----|----|-----|-----|------|------|------|------|------|------|------|-----|-----|-----|-----|
| V1 | /  | /  | Ø  | /  | /   | /   | /  | /  | /  | /   | /   | /  | /   | /   | /    | /    | /    | /    | /    | /    | /    | /    | /    | /    | /    |
| V2 | /  | /  | Ø  | /  | /   | /   | /  | /  | /  | /   | /   | /  | /   | /   | /    | /    | /    | /    | /    | /    | /    | /    | /    | /    | /    |
| VP | Ø  | /  | Ø  | /  | /   | /   | /  | /  | /  | /   | /   | /  | /   | /   | /    | /    | /    | /    | /    | /    | /    | /    | /    | /    | /    |
| V3 | /  | /  | Ø  | /  | /   | /   | /  | /  | /  | /   | /   | /  | /   | /   | /    | /    | /    | /    | /    | /    | /    | /    | /    | /    | /    |
| PIP| /  | /  | Ø  | /  | /   | /   | /  | /  | /  | /   | /   | /  | /   | /   | /    | /    | /    | /    | /    | /    | /    | /    | /    | /    | /    |
| V3A| /  | /  | Ø  | /  | /   | /   | /  | /  | /  | /   | /   | /  | /   | /   | /    | /    | /    | /    | /    | /    | /    | /    | /    | /    | /    |
| PO | /  | /  | Ø  | /  | /   | /   | /  | /  | /  | /   | /   | /  | /   | /   | /    | /    | /    | /    | /    | /    | /    | /    | /    | /    | /    |
| V4 | /  | /  | Ø  | /  | /   | /   | /  | /  | /  | /   | /   | /  | /   | /   | /    | /    | /    | /    | /    | /    | /    | /    | /    | /    | /    |
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| V4t| /  | /  | Ø  | /  | /   | /   | /  | /  | /  | /   | /   | /  | /   | /   | /    | /    | /    | /    | /    | /    | /    | /    | /    | /    | /    |
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| DP | Ø  | Ø  | Ø  | Ø  | Ø   | Ø   | Ø  | Ø  | Ø  | Ø   | Ø   | Ø  | Ø   | Ø   | Ø    | Ø    | Ø    | Ø    | Ø    | Ø    | Ø    | Ø    | Ø    | Ø    |
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