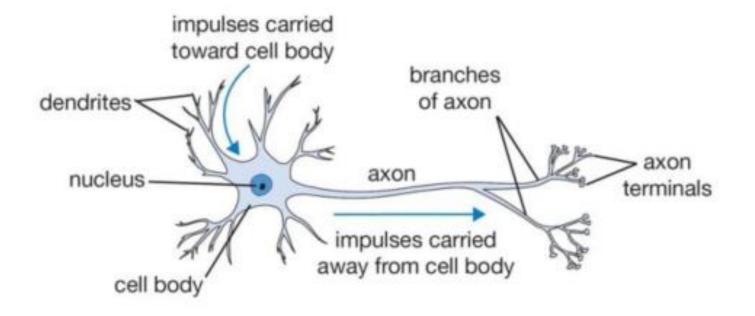
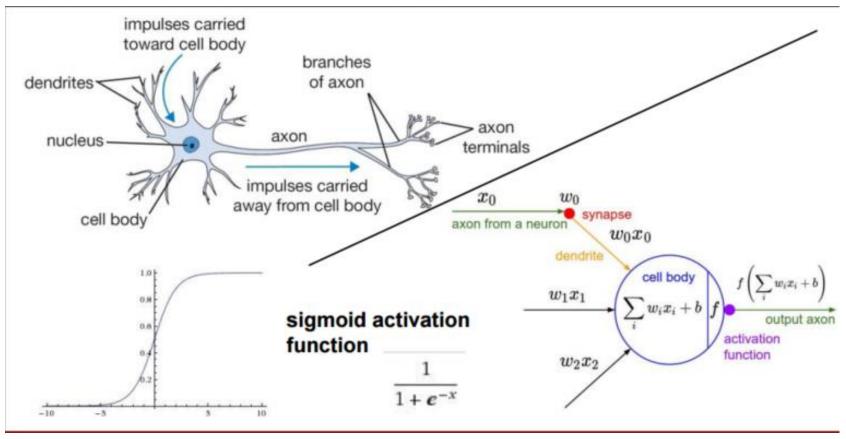
A Bit About Neuroscience



Slides from Geoffrey Hinton, Andrej Karpathy, Wlodzimierz Wojcik, Vedran Lovic

CSC411: Machine Learning and Data Mining, Winter 2017

Michael Guerzhoy

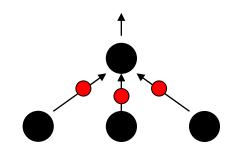


Andrej Karpathy

Only an Analogy

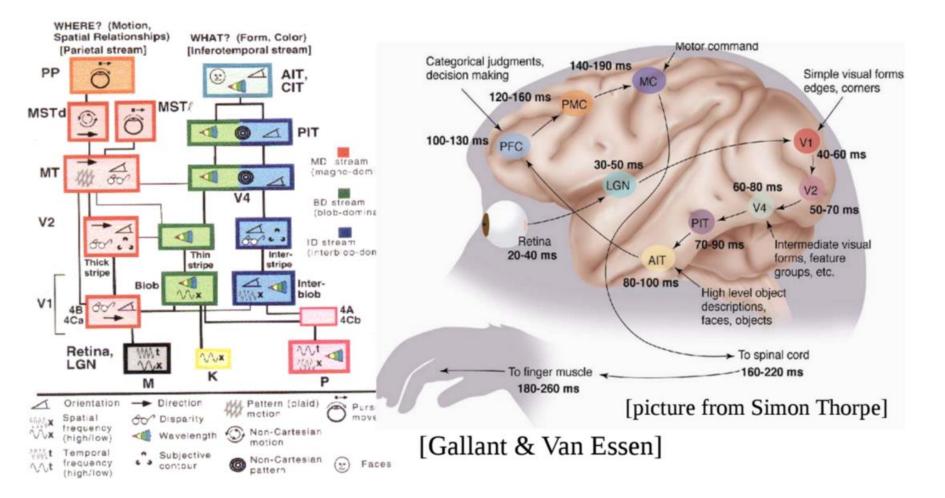
- Many different types of neurons
- The computations are not simply linear combinations of inputs transformed by the same activation functions
- Synapses are more complicated than a single weight
- The neurons don't output a real number: instead, they "fire" spikes at a (somewhat) regular rate

How the Brain Works



- Each neuron receives inputs from other neurons
 - Some neurons also connect to receptors
 - Cortical neurons use spikes to communicate
 - The timing of spikes is important
- The effect of each input line on the neuron is controlled by a synaptic weight
 - The weights can be positive or negative
- The synaptic weights adapt so that the whole network learns to perform useful computations
 - Recognizing objects, understanding language, making plans, controlling the body
- You have about 10^{11} neurons each with about 10^3 weights each
 - A huge number of weights can affect the computation in a very short time. Much better parallelism than a computer.

Visual Cortex

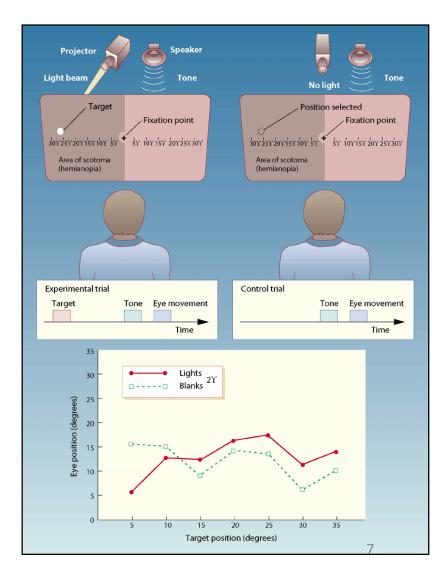


Modularity and the Brain

- Different bits of the cortex do different things.
 - Local damage to the brain has specific effects
 - Specific tasks increase the blood flow to specific regions.
- But cortex looks pretty much the same all over.
 - Early brain damage makes functions relocate
- Cortex is made of general purpose stuff that has the ability to turn into special purpose hardware in response to experience.
 - This gives rapid parallel computation plus flexibility
 - Conventional computers get flexibility by having stored programs, but this requires very fast central processors to perform large computations.

Blindsight

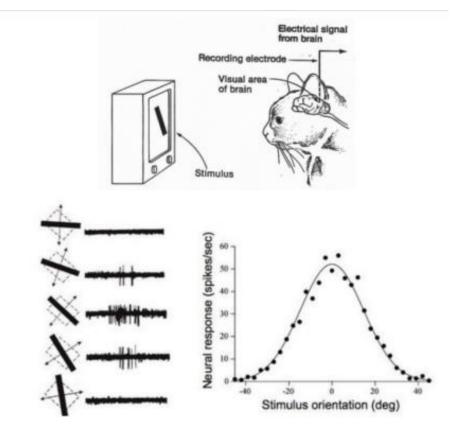
- Case D.B.
- Area around the right calcarine fissure was removed for treatment of angioma
- Reported not seeing anything in the left visual field
- Able to point out where the light was in the left visual field
- Blindsight residual visual abilities within a field defect in the absence of acknowledged awareness



Phineas Gage

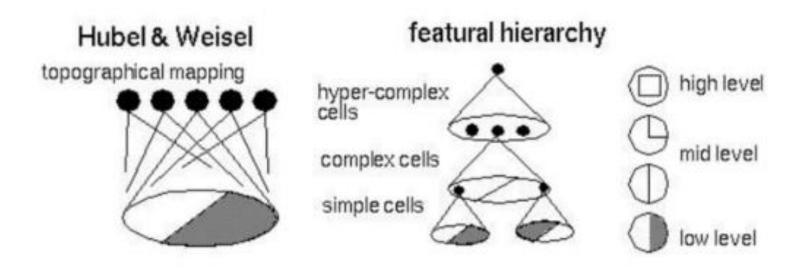
What Does V1 do?

- David Hubel and Torsten Wiesel (Nobel Prize recipients, 1981) showed that individual ("simple cell") neurons in a cat's V1 cortex fire in reaction to seeing lines at a certain angle in a certain location
- Other ("complex cell") neurons fired at lines regardless of orientation



• <u>https://www.youtube.com/watch?v=4nwpU7GFYe8</u>

Hierarchical Organization of Cells



The Invariance Problem

- Our perceptual systems are very good at dealing with invariances
 - translation, rotation, scaling
 - deformation, contrast, lighting, rate
- We are so good at this that its hard to appreciate how difficult it is.
 - Its one of the main difficulties in making computers perceive.
 - We still don't have generally accepted solutions.

The Invariant Feature Approach

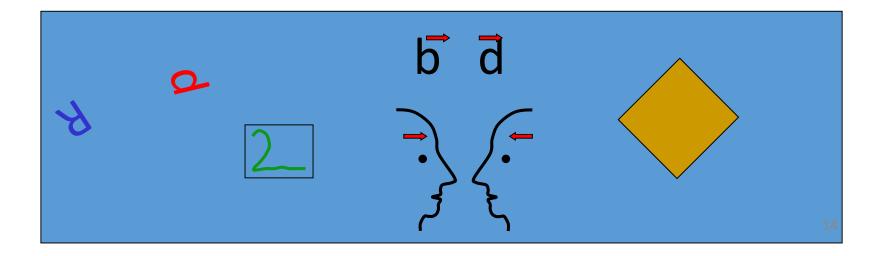
- Extract a large, redundant set of features that are invariant under transformations
 - e.g. "pair of parallel lines with a dot between them.



• With enough of these features, there is only one way to assemble them into an object.

The Normalization Approach

- Do preprocessing to normalize the data
 - e. g. put a box around an object and represent the locations of its pieces relative to this box.
 - Eliminates as many degrees of freedom as the box has.
 - translation, rotation, scale, shear, elongation
 - But its not always easy to choose the box



The Replicated Feature Approach

- Use many different copies of the same feature detector.
 - The copies all have slightly different positions.
 - Could also replicate across scale and orientation.
 - Tricky and expensive
 - Replication reduces the number of free parameters to be learned.
- Use several different feature types, each with its own replicated pool of detectors.
 - Allows each patch of image to be represented in several ways.

The red (and green/blue, respectively) connections all have the same weight.

