

31YB Lecture 2: Overview

- Why would anyone want a `new' sort of computer?
- Where/when can it help?
- Modeling how the brain works
 - Aims, basic features of biological neurons
- What is an Artificial Neural Network?
- Model neurons (McCulloch-Pitts model)
 - Elements of the model neuron: synapses, dendrites, axon

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Modelling how the brain works

- 1930's It's a telephone switchboard.
- 1940's It's Boolean Logic..
- 1960's It's a computer...
- 1970's It's a hologram
- 1980's The cortex is special purpose
'wetware' for constraint satisfaction
- 1990's+

Why would anyone want a `new' sort of computer?

What are (everyday) computer systems good at... ..and not so good at?

Good at

- Fast arithmetic
- Doing precisely what the programmer programs them to do

Not so good at

- Interacting with noisy data or data from the environment
- Massive parallelism
- Fault tolerance
- Adapting to circumstances

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Aims

Model biological neural networks

- hence a great deal of terminology is borrowed from Neuroscience
- *Issue of biological plausibility arises*

This course: Develop useful *learning machines (Artificial Neural Networks)*

- often biologically implausible!
- may be biologically inspired

Where can this new sort systems help?

- where we can't formulate an algorithmic solution
 - or for which an algorithmic description would be unrealistically complex:
e.g. sensory interpretation and many classification tasks.
- where we *can* get lots of examples of the behaviour (or classification) we require, e.g.
 - Controlling complex industrial chemical processes,
 - assessing complex situations automatically,
 - checking signatures, searching fingerprint databases,
 - analysing radar images, interpreting speech,
 - reading handwritten characters...
- where we need to pick out the structure from existing data.
- Exception: if a straightforward algorithm is available, then a programmed solution is almost certainly the right one to take.
- Note*:-Idea to build machines which would have brain-like capabilities is old:
 - indeed, it predates ordinary computers (see next slide)
 - Brains are adaptive: adaptive machines may have major advantages .
 - The systems *learn* in response to their *experience* – *much more later!*

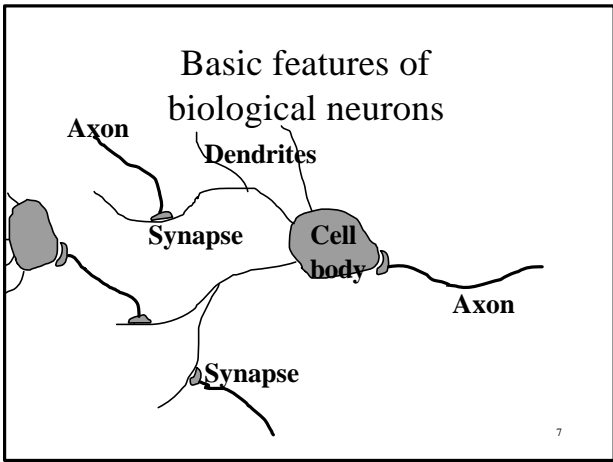
Neural Networks in the Brain

Human Brain= 10^{11} neurons, 10^{15} connections
INTEL 486 computer = 10^6 transistors

Idea of Artificial Neural Nets:

- Model a neuron
- Build interconnected networks
- Devise learning algorithms

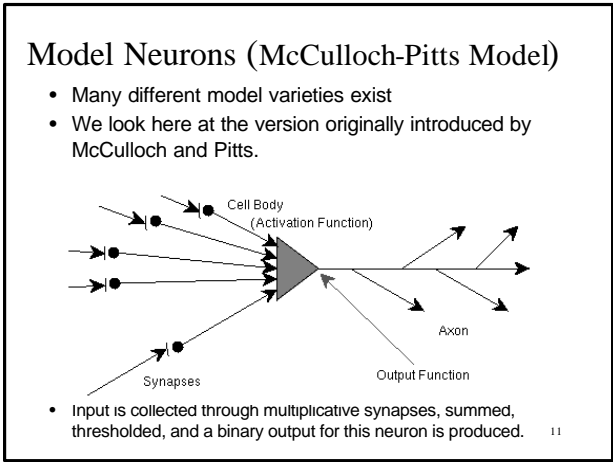
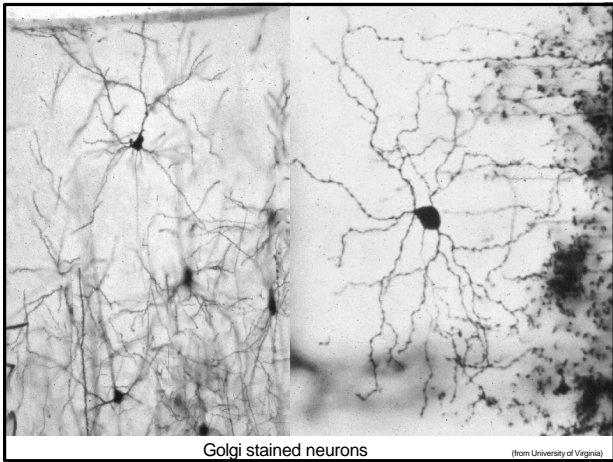
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So, what is an Artificial neural network?

- **Recap:** Artificial Neural Networks are a different paradigm for computing:
 - von Neumann machines are based on the processing/memory abstraction of human information processing.
 - Artificial Neural Networks (ANNs) are based on the parallel architecture of human brains
 - field goes by many other names: connectionism, parallel distributed processing, neuro-computing, natural intelligent systems, machine learning algorithms, and artificial neural networks
 - It is an attempt to simulate within specialized hardware or sophisticated software, the multiple layers of simple processing elements called neurons
- One can also say, ANNs are a form of multiprocessor computer system:
 - collection of simple *processing elements* (PEs) which are highly interconnected
 - The PE's are modelled on neurons (e.g. McCulloch-Pitts Neuron Model - next)
 - the Interconnections are modelled on synapses
 - The elements have simple (scalar, or even binary) outputs
- Real brains, however, are orders of magnitude more complex than any artificial neural network so far considered (including in this course!).

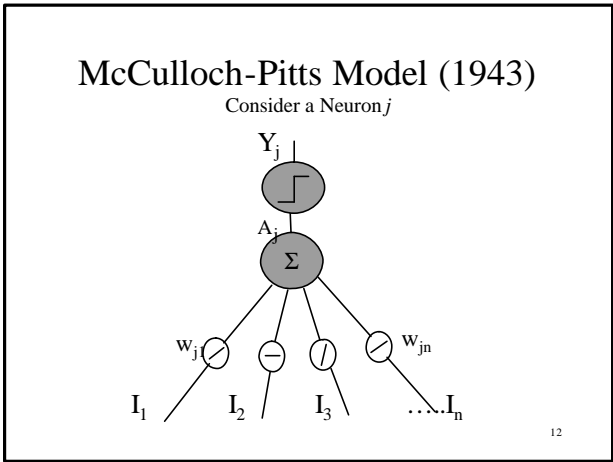
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Biological Neurons: Components

- Synapses are elementary structural and functional units that mediate the interactions between neurons. Signal transmission between neurons is chemical
- Axons act as transmission lines
- Dendrites act as receptive zones
- The majority of neurons encode their outputs as a series of brief voltage pulses (i.e. spikes or action potentials)
- A biological neuron may have as many as 10,000 different inputs, and may send its output (the presence or absence of a short-duration spike) to many (up to 200,000) other neurons.
- Neurons are wired up in a 3-dimensional pattern.

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How the model neuron works

- Each input I_i is multiplied by a *weight* w_{ji} (synaptic strength)
- These weighted inputs are summed to give the *activation level*, A_j
- This activation level is modified by an *activation function* to produce the neuron's output, Y_j

Elements of model neuron III:

Axon

- In this model, it simply transmits the neurons output to other, or even the same
 - neurons
 - May be system output
 - might, in other models, implement a delay
- The model's output function corresponds to the axon hillock of the real neuron
- Many different output functions have been used e.g. threshold, sigmoidal etc.
- For example, the model neuron may be a *threshold unit*
 - (as in the original McCulloch-Pits model),
 - with threshold θ (which could equal e.g. 0.5)
$$Y_j = 1 \text{ if } A_j \geq \theta_j \quad \text{or,}$$

$$Y_j = 0 \text{ if } A_j < \theta_j$$
 - This is a non-linear operation
- Another simple possibility is a linear unit

$$Y_j = k * A_j$$
 - which gives a purely linear unit

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Elements of the model neuron I: Synapses

- I_i is the input to synapse i
 - w_{ji} is the weight characterising the synapse from input i to neuron j
 - i.e. on the dendrite of neuron j (hence order of indices)
 - w_{ji} is known as the weight from unit i to unit j
- $w_{ji} > 0$ synapse is excitatory
 $w_{ji} < 0$ synapse is inhibitory
- Note that I_i may be
 - external input
 - or the output of some other neuron

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Aside: Other Output functions

- Logistic (or squashing) unit

$$Y_j = 1/(1 + \exp(-k * A_j + B_j))$$
- or

$$Y_j = \tanh(k * A_j + B_j)$$
- Note that k determines the slope, and B_j the output of the neuron for 0 input (which is termed the bias, usually a constant - see later).
- **More generally**, $Y_j = f(A_j) = f(\sum_{i=1}^n w_{ji} I_i)$
- Normally, a *monotonically increasing* function f is used. (Why? See later!)

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Elements of the model neuron II: Dendrites

- Gathers together (sums) the post-synaptic inputs
 - that is, gathers together the synaptic inputs
- Simplest form is linear summation.
- Writing A_j for the neurons's activation (depolarisation) for n external inputs:

$$A_j = \sum_{i=1}^n w_{ji} I_i = w_{j1} I_1 + w_{j2} I_2 + w_{j3} I_3 + \dots + w_{jn} I_n$$
- This represents a passive dendrite
 - linear
 - no interaction between the different inputs on the dendrite.

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Note!

- Real neurons are a great deal more complex
- Yet for most of the work we will consider, very simple neural models will suffice.
- NN systems gain their power by using a large number of very simple processing elements in concert.
- There is also a great deal of interconnection
 - and this is like the brain: there are miles of axon "wire" in every cubic cm of brain!

NEXT LECTURE: Decision Surfaces, Learning & generalization

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