Neural Networks

Course Outline:

Introduction and historical background, Feedback and Network Architectures, Learning, Perceptrons, Perceptron Convergence Theorem, Correlation Matrix, Least Mean Square Algorithm, Back Propagation, Multilayer Perceptrons, Cross Validation / Function Approximation, Adapting Learning Rates, Fuzzy Learning / Radial Basis Function, Radial Basis Function Networks, Hopfield Networks, Simulated Annealing, Boltzmann Machines, Mean Field Theory, Self Organizing Systems, Self-Organizing Feature Map, Information Theoretic Models, Introduction to Genetic Algorithm, Application of Neural Network to Image Processing and Power System Analysis

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References:

1. Simon Haykin, "Neural Networks: A Comprehensive Foundation", Pearson Education Asia, 2001.
2. Bart Kosko, "Neural Networks and Fuzzy System", Prentice-Hall of India Private Limited, 2001.
3. B. Yegnanarayana, " Artificial Neural Networks", Prentice-Hall of India Private Limited, 2001.
4. Robert J. Schalkoff, " Artificial Neural Networks", McGraw-Hill International Editions, 1997.

Evaluation

	External Examination:	**60%**
	Internal Examination:	**40%**
1.	**Assignment**	**10%**
2.	**Test**	**10%**
3.	**Project**	**10%**
4.	**Seminar Presentation**	**10%**

Human Brain

- Computers and the Brain: A Contrast
  - Arithmetic: 1 brain = 1/10 pocket calculator
  - Vision: 1 brain = 1000 super computers
  - Memory of arbitrary details: computer wins
  - Memory of real-world facts: brain wins
  - A computer must be programmed explicitly
  - The brain can learn by experiencing the world

Other Comparisons

ITEM	COMPUTER	BRAIN
Complexity	ordered structure serial processor	10^10 neuron processors 10^4 connections
Processor Speed	10,000,000 operations per second	100 operations per second
Computational Power	one operation at a time 1 or 2 inputs	millions of operations at a time thousands of inputs

Computer Operations

Traditionally computers execute a sequence of instructions to accomplish a set task

This is a powerful technique if you know the ‘algorithm’

It’s not very useful if you don’t !!

There are many interesting tasks where the algorithm is either unknown or unclear

- Recognizing handwriting - Pattern recognition
- Playing table tennis - Interacting with the environment
- Balancing activities - Optimization

The Question

Humans find these tasks relatively simple

- We learn by example
- The brain is responsible for our ‘computing’ power

If a machine were constructed using the fundamental building blocks found in the *brain* could it *learn* to do ‘difficult’ tasks ???

Definition

- ". . . Neural nets are basically mathematical models of information processing . . ."
- ". . . (neural nets) refer to machines that have a structure that, at some level, reflects what is known of the structure of the brain . . ."
- "A neural network is a massively parallel distributed processor . . . "

Neural Net Concept

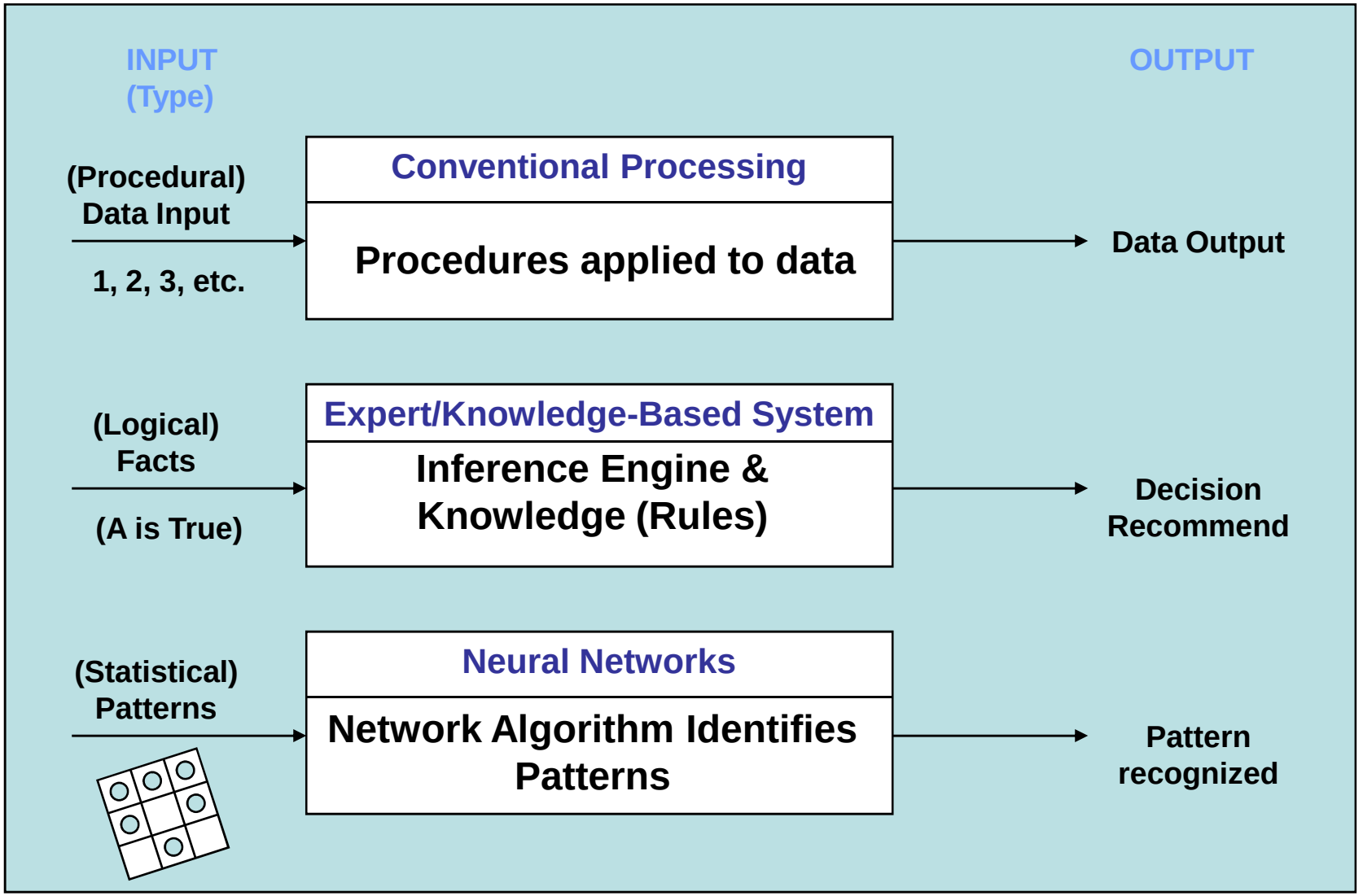
- Artificial Neural Systems are called:
  - neurocomputers
  - neural networks
  - parallel distributed processors
  - connectionists systems

- Basic Philosophy
  - large number of simple “neuron-like” processors which execute global or distributed computation

Neural Nets vs Standard Computing

- NN are different from
  - **Parallel Processors - if you look at one processor in a typical parallel system, its work makes sense**
  - **Contemporary AI – no algorithms**

Processing Comparisons



History of NN

- Creation:
  1890: William James - defined a neuronal process of learning
  1911: Ramon y Cajal (1911) introduced the idea of a neuron (brain cell)

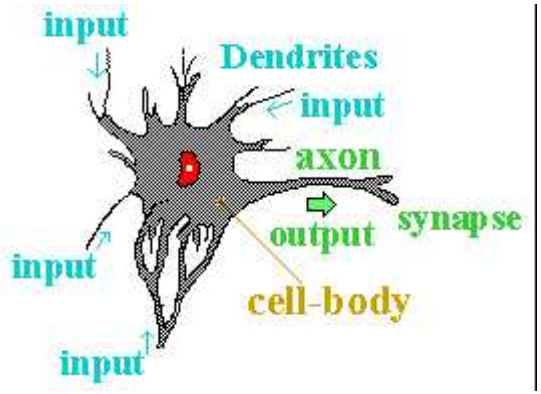
  Promising Technology:
  1943: McCulloch and Pitts - earliest mathematical models
  1954: Hebb and IBM research group - earliest simulations
  1958: Frank Rosenblatt - The Perceptron

- Disenchantment:
  1969: Minsky and Papert - perceptrons have severe limitations

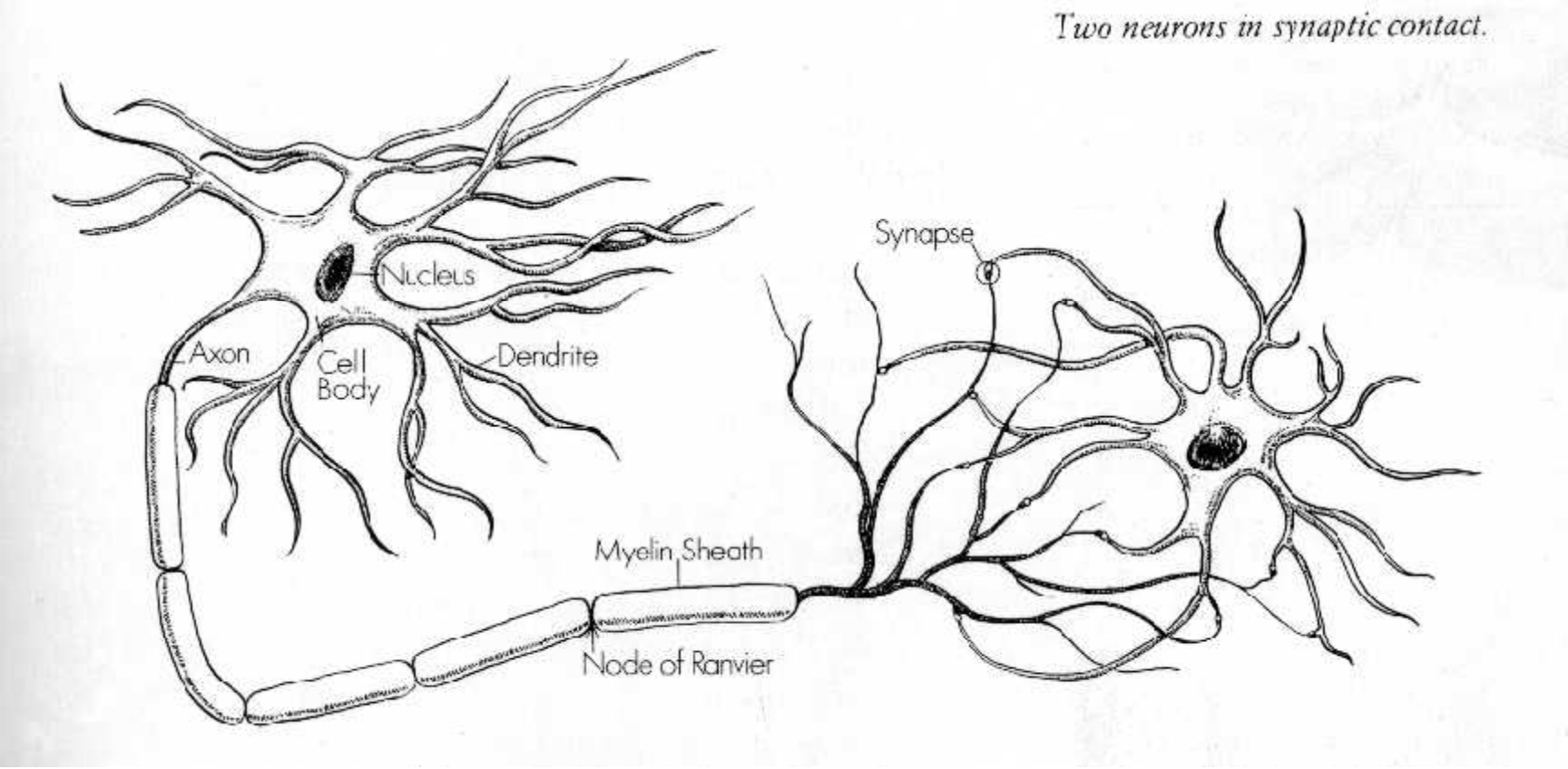
- Re-emergence:
  1985: Multi-layer nets that use back-propagation
  1986: PDP Research Group - multi-disciplined approach

Biological Neurons

- A neuron consists of two main parts:
  - Axon
    - one per neuron
    - excites up to 10^4 other neurons
    - all or nothing output signal
  - Dendrites
    - 1 to 10^4 per neuron

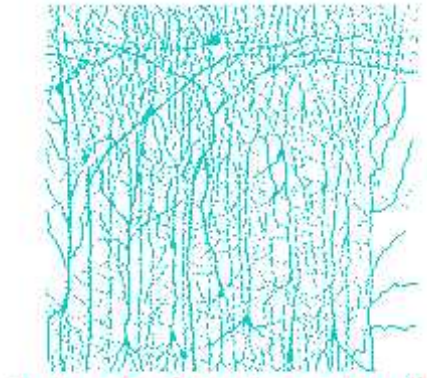


Two Neurons


Two neurons in synaptic contact.
Synapse
Nucleus
Axon
Cell Body
Dendrite
Myelin Sheath
Node of Ranvier

Properties of the Brain

- Architectural
  - **80,000 neurons per square mm**
  - **10^{11} neurons - 10^{15} connections**
  - **Most axons extend less than 1 mm (local connections)**
- Operational
  - **Highly complex, nonlinear, parallel computer**
  - **Operates at millisecond speeds**



A typical network of neurons

Interconnectedness

- Each neuron may have over a thousand synapses
- Some cells in cerebral cortex may have 200,000 connections
- Total number of connections in the brain "network" is astronomical—greater than the number of particles in known universe

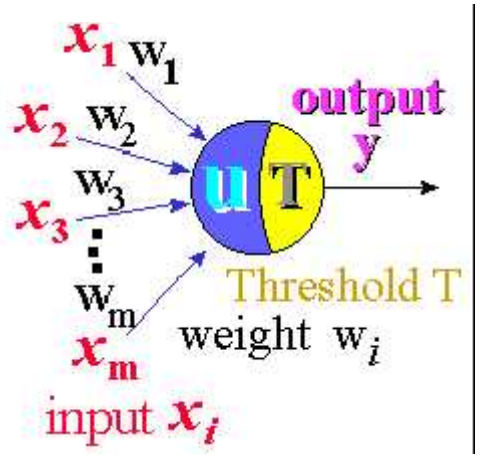
Artificial Neuron

- An artificial neuron is designed to mimic the first-order characteristics of a biological neuron

A set of inputs, x_i

Each input is multiplied by the corresponding weight, w_i

All of the weighted inputs are summed to determine the activation level



An activation function is applied to determine the neuron output

Mathematical Structure

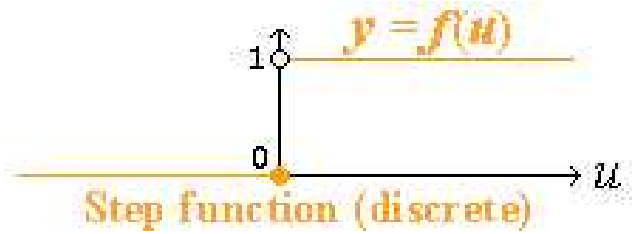
- A neuron is a simple sum and compare device

$$u = x_1w_1 + x_2w_2 + \ldots x_nw_n - T$$

$$y = f(u)$$

threshold

One possible function for y is a step function:

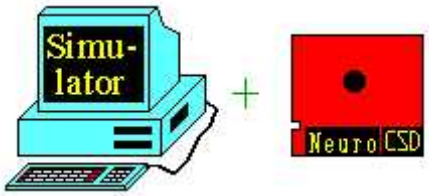


If the weighted sum of the inputs is greater than the threshold, then the neuron "fires"

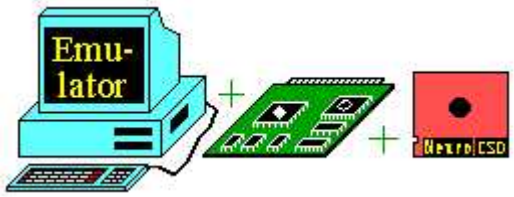
Applications of Neural Nets

Applications 1

- There are a variety of applications (both research and commercial) of neural nets



Simulations
special software that implements NN on standard computers



Hardware emulation
special hardware coprocessors

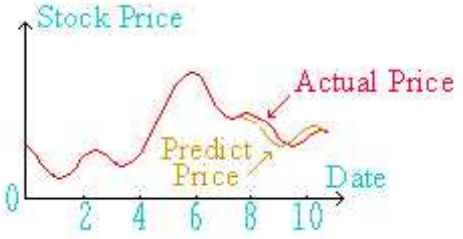
Applications 2

- **Diagnosis**
  - **Closest to pure concept learning and classification**
  - **Some ANNs can be post-processed to produce probabilistic diagnoses**
- **Prediction and Monitoring**
  - ***aka* prognosis (sometimes forecasting)**
  - **Predict a continuation of (typically numerical) data**
- **Decision Support Systems**
  - ***aka* recommender systems**
  - **Provide assistance to human "subject matter" experts in making decisions**
    - **Design (manufacturing, engineering)**
    - **Therapy (medicine)**
    - **Crisis management (medical, economic, military, computer security)**
- **Control Automation**
  - **Mobile robots**
  - **Autonomic sensors and actuators**
- **Many, Many More (ANNs for Automated Reasoning, etc.)**

Applications 3

- Other applications include:

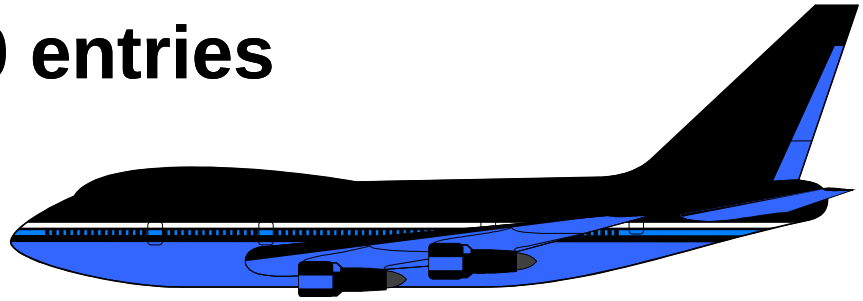
Stock Price Prediction:
Data for past stock prices are learned by neural networks, and their trends for one or a few days ahead are predicted.



Signature Check:
For checking a signature of a person, first we train the neural networks to recognize that signature by learning several writing features such as strength of the pen, direction, and any special point of that sample. After learning, the neural network can check whether a signature belongs to the same person or not.

Applications 4

- **The *Boeing Airplane Company* uses an ART-1 neural network system (NIRS) for the identification and retrieval of 2-D and 3-D representations of engineering designs.**
- **Avoids redesign of existing parts and tools**
- **Production solid model data base > 55,000 entries**
- **2-D data base > 95,000 entries**



Applications 5

- Credit Card Fraud Detection
  - The probability of fraud is calculated with a neural network with each card transaction. When the probability of fraud reaches a critical threshold, the case is sent to one of the retailer's fraud analysts for action.

Possible Quiz

What are the two parts of a neuron?

What is it that humans do much better than machines?

What is one application of a neural net?

SUMMARY

Introduction to Neural Nets

Applications of Neural Nets