31YB: Lecture 4

Thu, 2nd Oct 2003

Lecture Overview

•Learning /Adaptation: Biological Analogy

•2-term (Hebbian) & 3-term (supervised) learning rules

•Issues of: Locality, Inductive learning & generalization

Learning /Adaptation & Biological Analogy

- What makes both real and artificial neural networks different is adaptation
  - that is, some aspect of the artificial neural network alters in response to
    - input
    - the result of the computation
    - some external force (or teacher)
- On the other hand, biological adaptation takes many forms
  - and runs over many simultaneous timescales
    - short-term: milliseconds, seconds
    - long term: many seconds to indefinite
  - and involves many different systems
    - alterations at synapses
    - hormones altering the whole neuron's behaviour
    - growth and decay
      - including growth of myelin sheaths (glial cells)

Learning: Model neuron adaptation

- Generally is applied at the (model) synapse
- For simple model neurons this means altering the weight associated with each synapse
- There are many possible ways of doing this
  - exactly how the brain alters synaptic efficacies is not clear
  - although there is considerable evidence that it does alter synaptic efficacies
- We will consider 2-term and 3-term rules
- 2-term rules:
  - the alteration depends entirely on
    - the presynaptic neuron and the postsynaptic neuron
- 3-term rules
  - the alteration depends on
    - the presynaptic neuron and the postsynaptic neuron and some external (teacher) signal

2-term (Hebbian) learning

- Hebbian learning rules are
  - Simple 2-term learning rules which depend on the output of the pre- and post-synaptic neurons alone
- Varieties
  - pure Hebbian
    - increase the weight when the pre-and post-synaptic neurons are co-active
  - variations on the above…
  - Stent-Singer rule
    - as pure Hebbian, and also decrease the weight when the pre-synaptic unit is inactive, but the post-synaptic unit is active
  - Pre-synaptic rule
    - as pure Hebbian, and also decrease the weight when the pre-synaptic unit is active, but the post-synaptic unit is inactive
  - There is biological evidence for forms of both of these rules
  - Hopfield rule
    - all three of the above conditions for altering the weight,
    - plus increase the weight when both units are inactive at the same time

3-term learning rules

- Depend on the values of the pre-and post-synaptic neurons
- AND on some external signal
  - frequently this signal is the desired output
- Often the desired output is used to generate an error signal:

$$E = (D - Y)$$

  - where E is the error signal generated,
  - D is the desired output
  - Y is the actual output
- The learning rule aims to make E as small as possible
- More later on this ..

Issue of Locality in Learning

- Locality of a learning rule means
  - all the information required to make the adaptation is local to the place where the adaptation occurs.
- Why locality?
  - Local adaptation rules are implementable
    - in the sense of being buildable
  - Non-local rules call for either
    - action at a distance
    - some mechanism for bringing the required information to the place where the adaptation occurs or is computed.
- Note that software implementations are not bound by locality!

Concept of Inductive Learning

***Deduction**:*

Given some general rules, apply them to specific examples to *deduce* outputs.

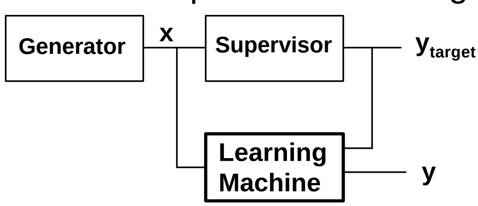
Induction:

Given specific examples, *induce* general 'rules' which can then be applied to novel examples.

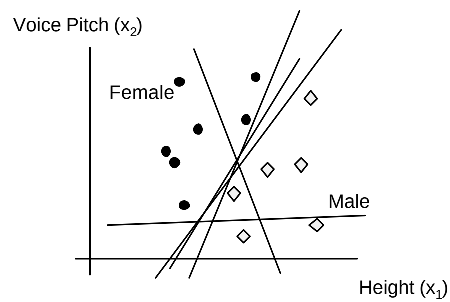
Learning & Generalization

- Learn from a *representative* set of examples
- Extract the 'essence' or underlying form (e.g. in the shape/form of a decision boundary)
- Given a novel (previously unseen) example, produce the *expected* output.

3-term or Supervised Learning



Training: Learn from training pairs (**x**, $\mathbf{y}_{target}$)
Testing: Given any **x**, output a value **y** close to the supervisor's output $\mathbf{y}_{target}$



Learning Problem: What is a good decision boundary ?
Next Lecture: More on 3-term Learning