Artificial Neural Networks:
Complex solutions or complex confusion?

1. Definitions

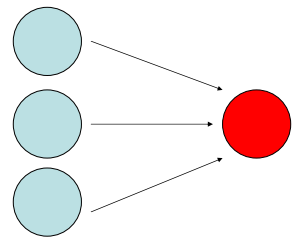
- Neural Network [1]-
  - "An interconnected assembly of simple processing elements, units or nodes, whose functionality is loosely based on the animal brain. The processing ability of the network is stored in the inter-unit connection strengths, or weights, obtained by a process of adaptation to, or learning from, a set of training patterns."
- Cost Function [2] – "
  - *Given:* a function $f : A \to \mathbf{R}$ from some set A to the real numbers
  - *Sought:* an element $x0$ in A such that $f(x0) \leq f(x)$ for all x in A ("minimization") "

2. Structure

- Feedfoward system
- Recurrent system
- Linearly Separable
- Non-linearly Separable
- Auto-associator
- Hidden Layer

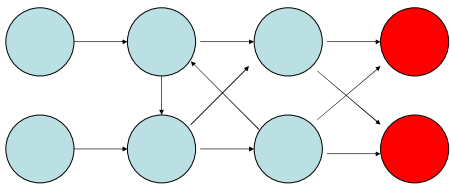
2. Structure: Feedforward

- Characterized by an acyclic graph that flows from input nodes to output nodes



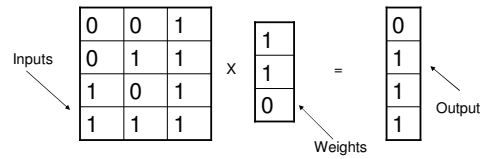
2. Structure: Recurrent

- Represented by a cyclic graph, which allows for feedback loops



2. Structure: Linear

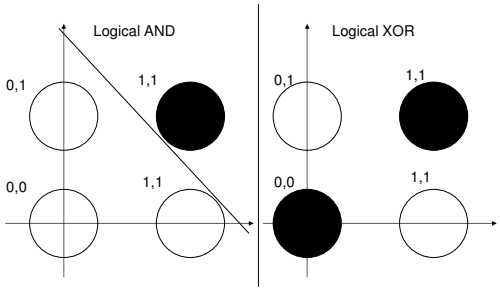
- The response function of a node is a linear combination of its inputs, like logical OR[3]



•Note: A seemingly nonlinear problem can often be rewritten as linear by adding inputs

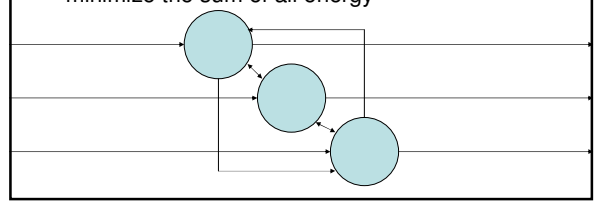
2. Structure: Non-linear

- Linearity refers to separation of solution space[3]



2. Structure: Non-linear

- A Hopfield network is a non-linear example [4]
- All of its nodes are symmetric without self loops.
- Each node has an energy associated with it.
- The network randomly turns nodes off and on to minimize the sum of all energy

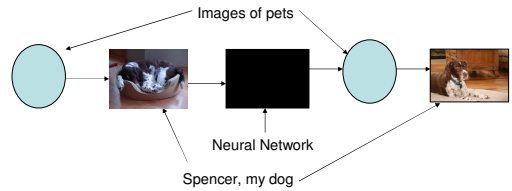


2. Structure: Non-linear

- In a Boltzmann machine, the amount of energy in a system affects the probability of whether a node is off or on. [5]
- As the network runs, the temperature decreases, and the process “anneals” or comes to a solution.

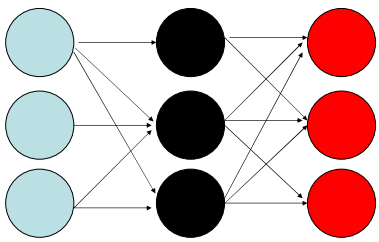
2. Structure: Auto-associator

- The prefix, auto, denotes self. Auto refers to input. The range of outputs is a subset of inputs. Basis of pattern recognition. [3]



2. Structure: Hidden Layer

- A hidden layer helps to minimize the error between the input and the responses



3. Learning Process

- Supervised Learning
- Unsupervised Learning
- Reinforcement
- Back-propagation

3. Learning Process: Supervised

- A series of inputs with known expected outputs are provided and the network attempts to minimize error.
  - Widrow-Hoff Learning for Linear Function
    - Initialize weights to 0
    - Until expected output matches network's output
      - Randomly select an input
      - Take cross product of weights with input
      - Calculate $delta_i$ for each w_i where
        $delta_i = w_i * (correct\ output - actual\ output) * input_i$
      - Add $delta_i$ to w_i

3. Learning Process: Unsupervised

- The neural network is given a cost function that is some function of the input and the neural network's output
- The network's goal is to find an optimal, but, in practice, relatively minimized, cost function

3. Learning Process: Reinforcement

- Instead of waiting until the output is evaluated, the neural network is given feedback on its progress throughout its evaluation of the data
- This feedback allows the network to strengthen or weaken links between nodes

3. Learning Process: Back-propagation

- Back-propagation is an example of supervised learning where something like Widrow-Hoff is used at each layer to minimize the error between the layer's response and the actual data
- The error at each hidden layer is an average of the previously evaluated error
- Hidden layer networks are trained this way

4. Outlook

- Arguments for neural networks
  - Well suited for pattern recognition [6]
  - Can fly a plane [7]
  - Turing-complete

4. Outlook

- Arguments against neural networks
  - Requires intense computational power
  - Nigh on impossible to translate into a meaningful model
  - Machine learning often requires we know the answer to the problem

References

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