Neural Networks and their Applications

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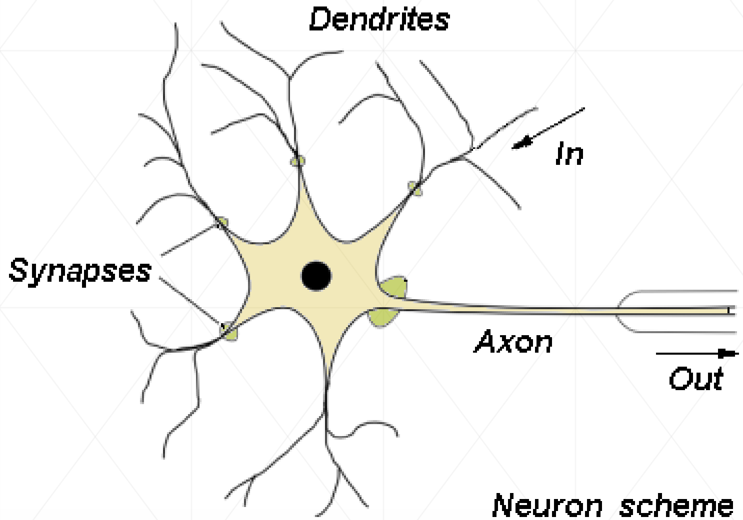
Introduction



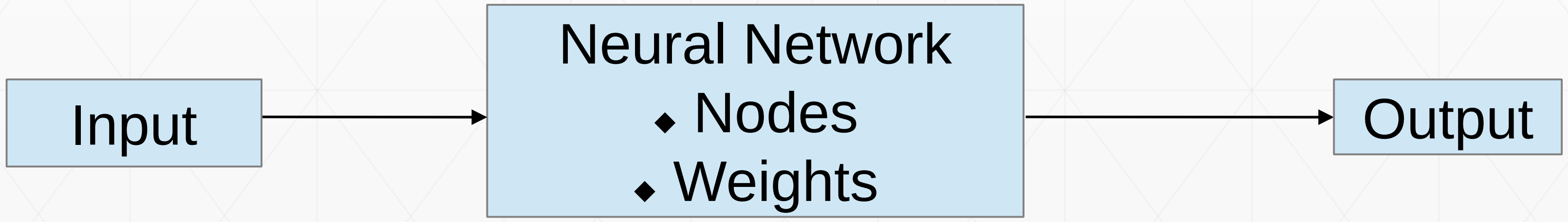
- Logical structures
- Nodes communicating through synapses
- Self-adjusting behaviour

Artificial Neural Networks (ANNs)

- Target applications that are hard to formulate explicitly
- Comparable to the biological nervous system but not perfectly equivalent
- Exhibit particular brain characteristics:
  - Learning from experience
  - Deriving from previous data to the new one
  - Extracting valuable data from input containing irrelevant data
- Generalise as a result of their structure, contrary to the classical idea of programs

How do ANNs work?

- Compute output neurons using the input and weights (synapses)
- Need to be trained to produce consistent and desired output
- Analogous to human brain memorising relevant information
- Training methods:
  - Supervised learning
  - Unsupervised learning



Supervised Learning

- Requires pairing of each input with corresponding target output (training pairs)
- Large number of such training pairs
- For each training pair:
  - Output is calculated with the current weights
  - Error between the target and calculated output is fed back to the network
  - Weights are adjusted to minimise the error
- Overall error should drop to an acceptable level
- Not the best representation of learning in biological systems

Unsupervised Learning

- Closer representation of learning in biological systems
- Does not require target output and error calculation
- Training set consists only of input
- Modifies behaviour to produce outputs consistent with each other
- Grouping similar inputs together by extraction of statistical properties
- Can be difficult to identify those properties without bias

Possible Drawbacks

- Awareness of their limitations
- Not quite duplicating the functions of the human brain (yet)
- The actual 'intelligence' is below the level of a tapeworm

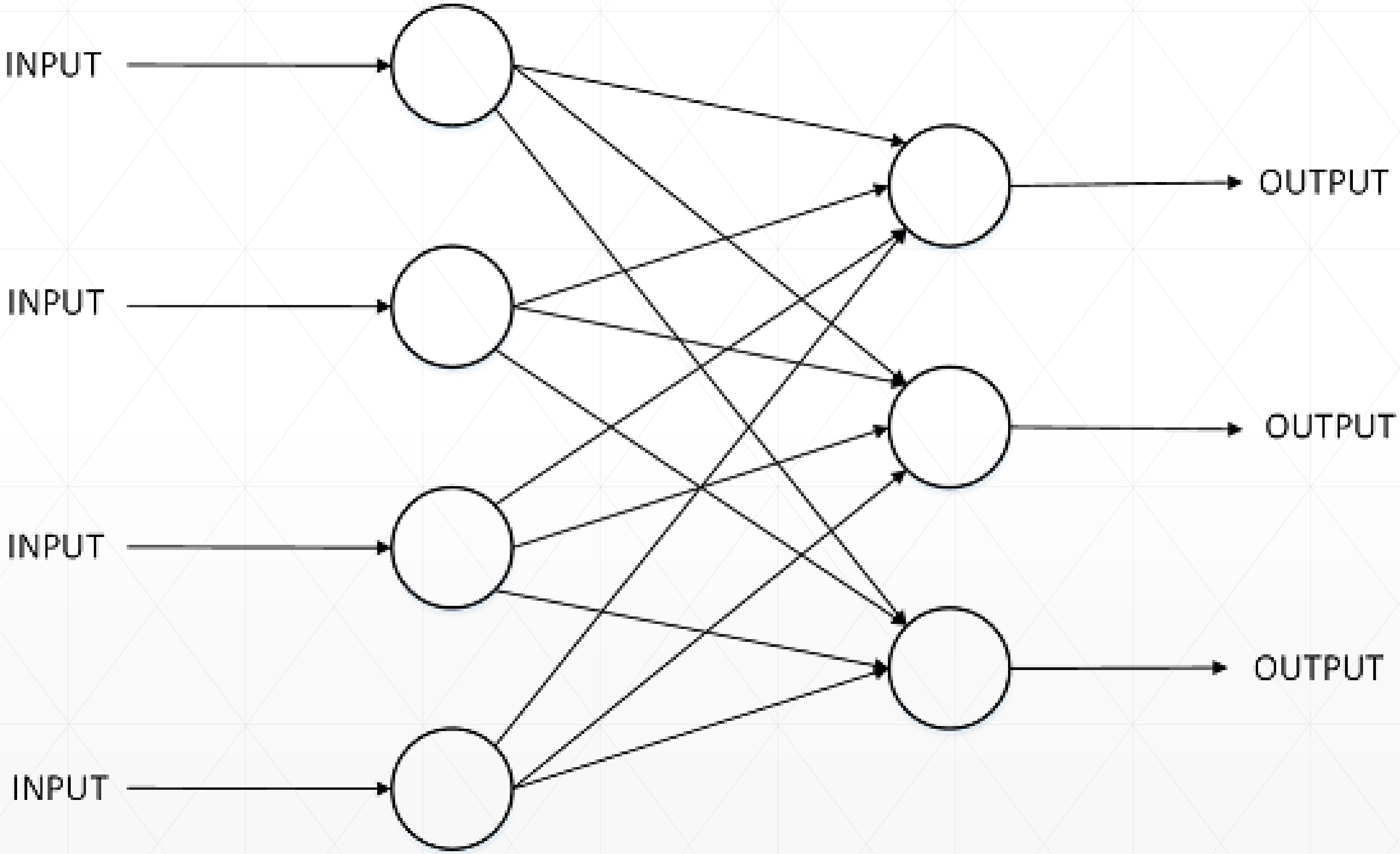
However:

- Brain-like performance in certain situations
- Should not be underestimated (again)
- Help to develop deep understanding of human intelligence

Perceptron – A Brief History

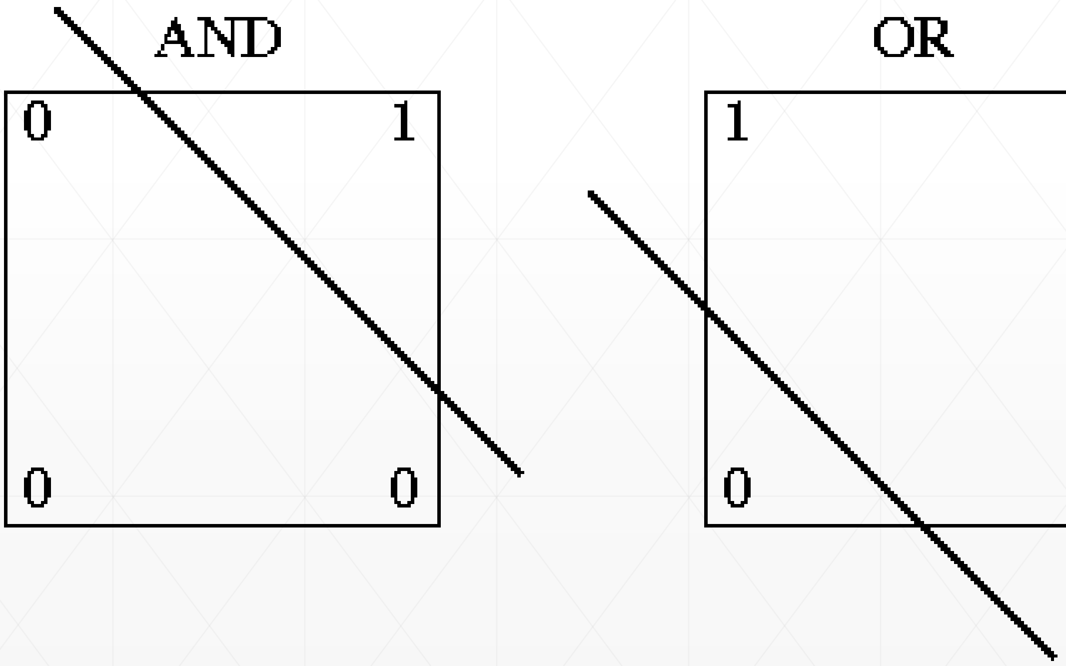
- 1940’s – Warren McCulloch and Walter Pitts introduced the first neural network model – The MP Neuron
- 1949 – Donald Hebb introduced Hebb’s Rule which explains a model for learning within the brain
- 1957 – Perceptron, the first artificial neural network is invented by Frank Rosenblatt

Single-Layer Perceptron

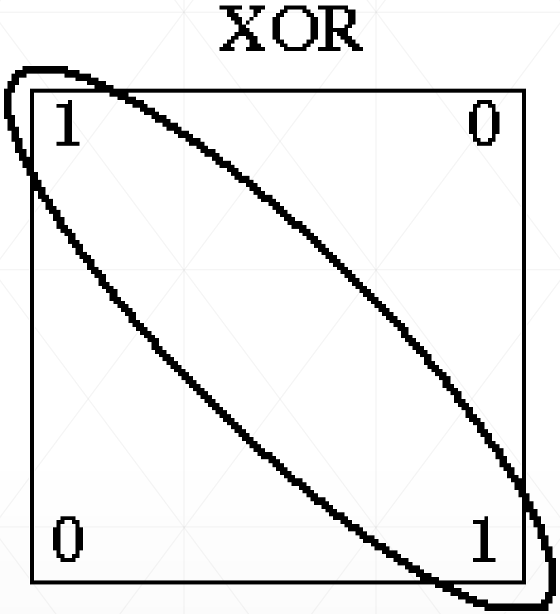


Limitations

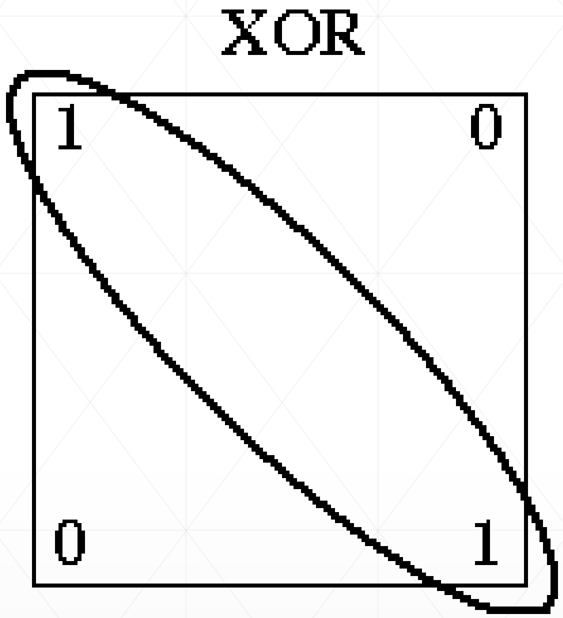
- Output can only be a definite true or false with no in-between
- Can only recognize linearly separable patterns



Limitations – XOR Problem



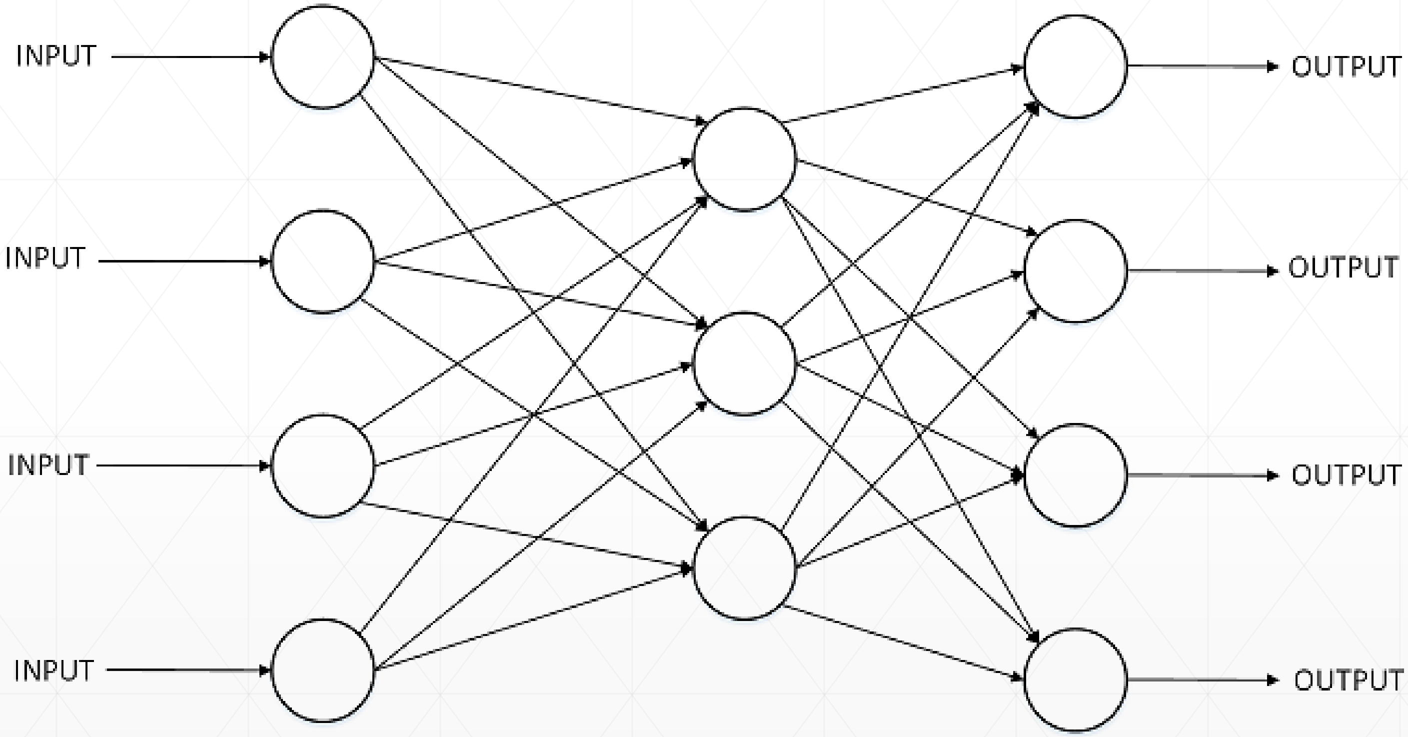
Limitations – XOR Problem



<u>Solution</u>

- Use a 3D plane in order to make the values separable by 1 line
- Multi – Layer Perceptron

Multi-Layer Perceptron

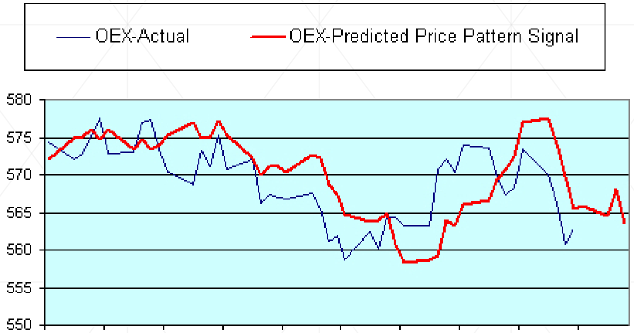


Multi-Layer Perceptron

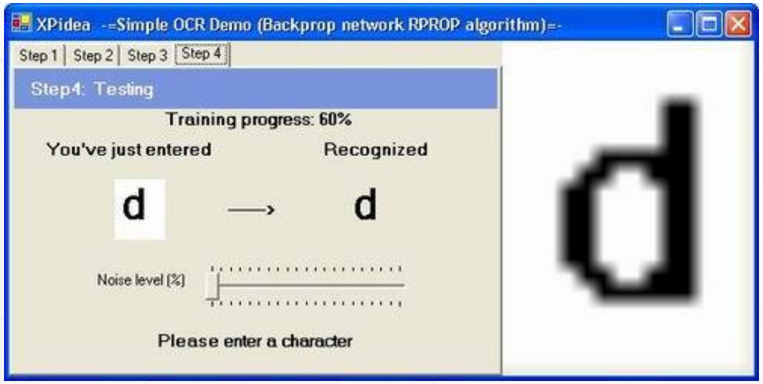
- Activation function – $\dfrac{1}{1+e^{-x}}$
- Needed to gain an advantage from the hidden layers
- Advantage – Can learn more complex patterns
- Disadvantage – Too many layers can make network slow and see irrelevant patterns

Applications

Image compression



Stock market prediction



Optical character recognition

Image Sources

- http://www.image-restore.co.uk/blog/saving-your-images-correctly/
- http://www.codeproject.com/Articles/3907/Creating-Optical-Character-Recognition-OCR-applica
- http://www.pricepatternprediction.com/

Application Types

- Classification
  - Assigning objects to a predetermined group
  - Uses a training set to create classifiers
- Clustering
  - Grouping objects similar to each other
  - Like classification but without knowing the class
  - Commonly uses a distance relationship

Application Types

- Pattern Association
  - Can be used to reduce noise or corruption
  - Can be split into auto/hetero-association
- Vector Quantization
  - Associates each input with the nearest vector
  - Process is similar to clustering
  - Can compress large amounts of input data
  - Not lossless

Optical Character Recognition (OCR)

- Algorithms used to be processor intensive
  - Caused significant delay in recognition time
- Neural networks seen as efficient without extensive processing
  - Can be learnt with back propagation algorithm
  - Initial learning time is one time only

Image Compression

- Can decompose an image into a set of vectors
  - This can be based off brightness, colour etc.
- Vector quantisation can then be used in a neural network
  - Has several learning algorithms that can be used
- There are other ways of compressing images with neural networks

Stock Market Prediction

- Why use neural networks?
  - Good at finding patterns in data
  - Can find non-linear patterns with multiple layers
- The network
  - Have to decide how many inputs to use – complex
  - Which learning algorithm is most ideal?

Back Propagation

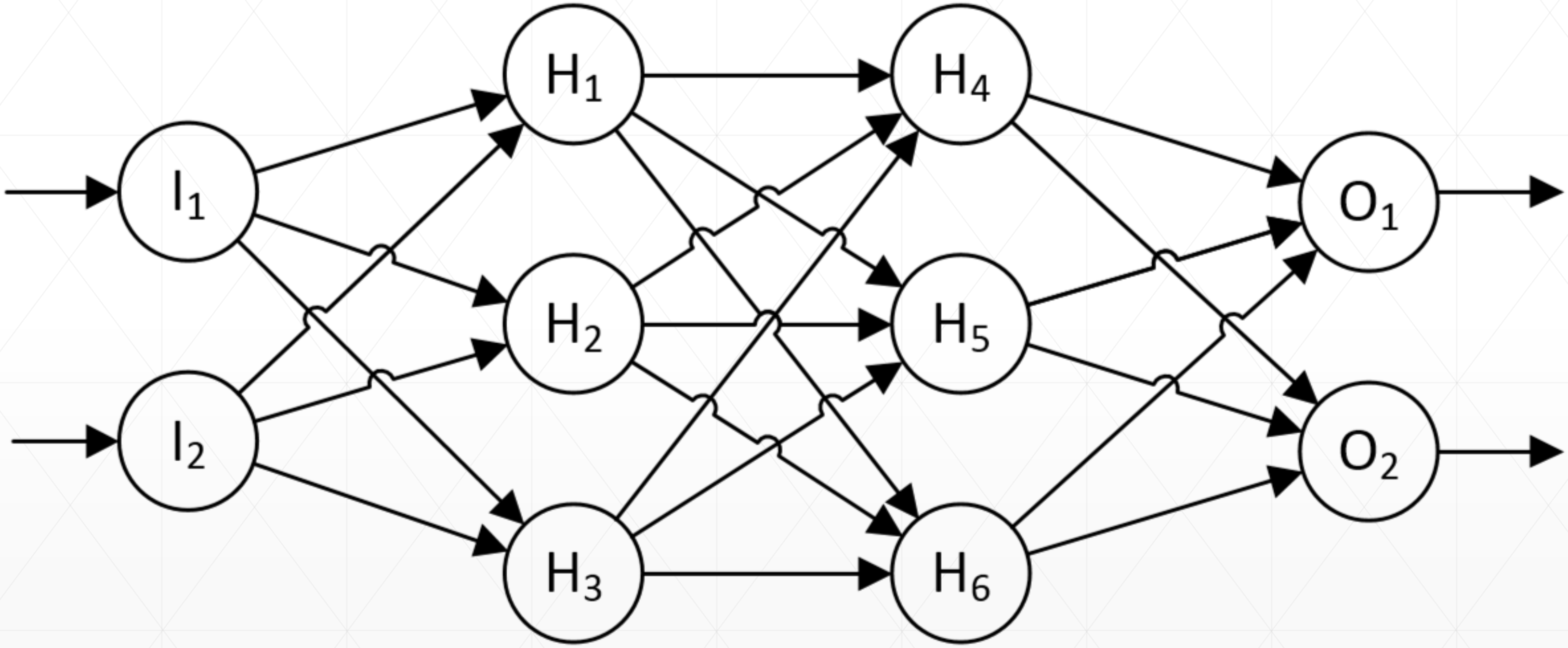
Only the weights of simple neural networks can be found without training, but complex networks must be trained

Back propagation is a common supervised learning algorithm for training neural networks

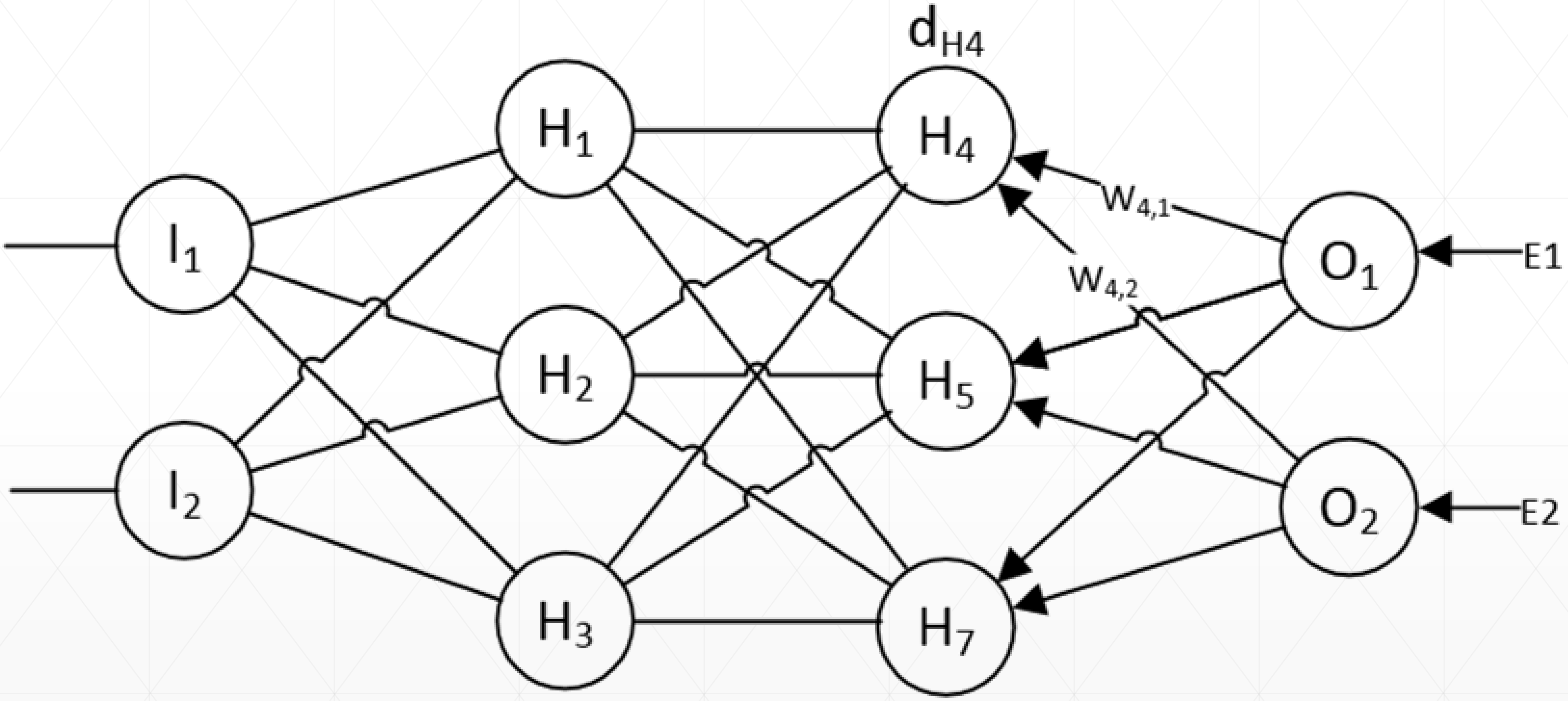
Algorithm Outline

1. Randomise all synaptic weights
2. Create a training set
   i. Choose a input – expected output pair from the set
   ii. Run the network with the input and measure the error of each output
   iii. Adjust each weight in the network using these errors
   iv. Repeat 2i - iii until the training set is empty

Algorithm
2ii: Forward pass

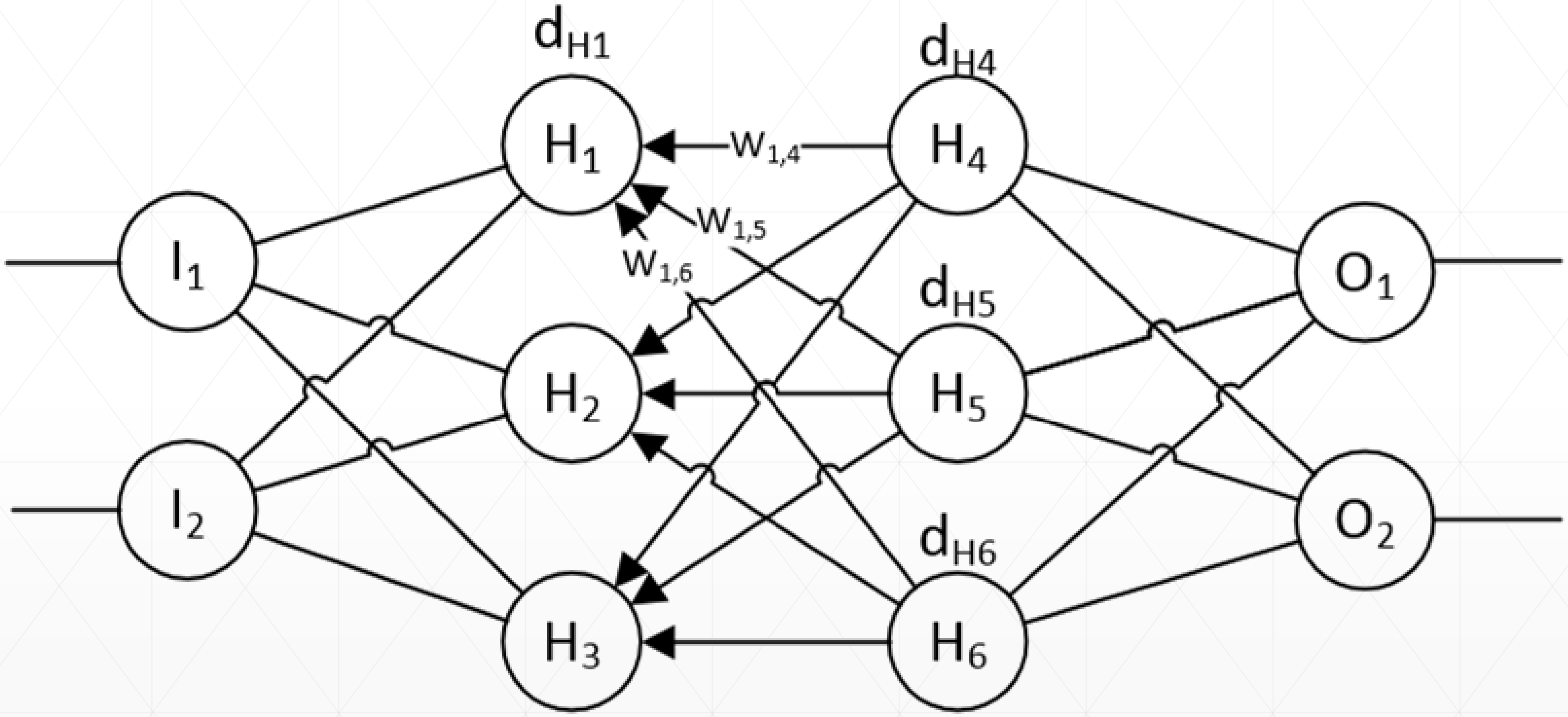


Algorithm
Step 2iii: Backward pass



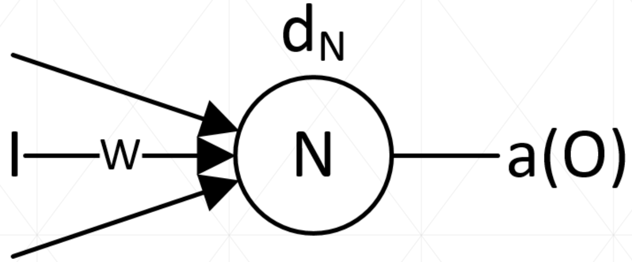
$$d_{H4} = E_1 * W_{4,1} + E_2 * W_{4,2}$$

Algorithm
Step 2iii: Backward pass



$$d_{H1} = d_{H4} * W_{1,4} + d_{H5} * W_{1,5} + d_{H6} * W_{1,6}$$

Algorithm
Step 2iii: Weight adjustment



$$d_W = LR * I * dN * da/dx(O)$$

d_W is the weight adjustment

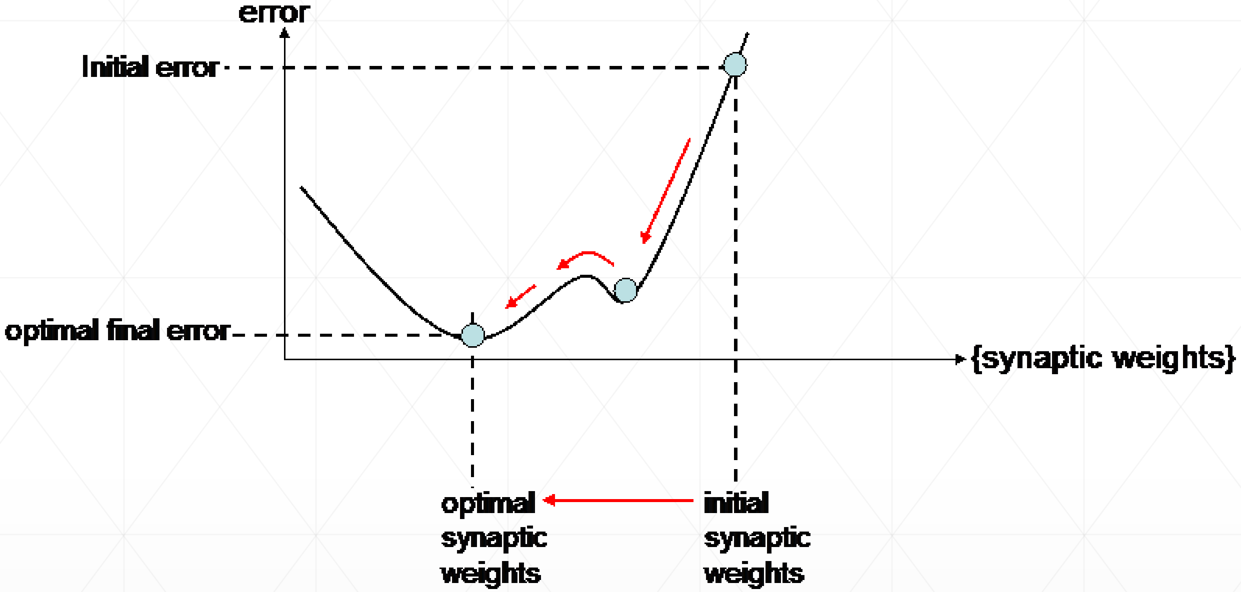
LR is the learning rate

I is the input to the synapse

d_N is the delta (or error) value of the neuron which the synapse connects to

da(O)/dx is the gradient of the activation function at output of the neuron

Momentum



$$d_W(t + 1) = LR * I * dN * da/dx(O) + M * d_W(t)$$

Image source: http://www.nexyad.net/HTML/e-book-Tutorial-Neural-Networks.html

The Healthcare prize

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Heritage Health

Improve Healthcare, Win $3,000,000.

Identify patients who will be admitted to a hospital within the next year using historical claims data. (Enter by 06:59:59 UTC Oct 4 2012)

- **Description**
- Evaluation
- Rules
- Dos and Don'ts
- FAQ
- Milestone Winners
- Timeline

Please note: Deadline is 06:59:59 UTC on October 4, 2012 for new registrations and team mergers.

This means that the only people can download the data or make submissions are people who accepted the competition rules prior to 06:59:59 UTC on October 4, 2012. Individuals who had accepted to rules but not yet formed a team at that date may join a team or create their own team (consisting of them only). No teams may merge at this point.

More than 71 million individuals in the United States are admitted to hospitals each year, according to the latest survey from the American Hospital Association. Studies have concluded that in 2006 well over $30 billion was spent on unnecessary hospital admissions. Is there a better way? Can we identify earlier those most at risk and ensure they get the treatment they need? The Heritage Provider Network (HPN) believes that the answer is "yes".

To achieve its goal of developing a breakthrough algorithm that uses available patient data to predict and prevent unnecessary hospitalizations, HPN is sponsoring the Heritage Health Prize Competition (the "Competition"). HPN believes that incentivized competition is the best way to achieve the radical breakthroughs necessary to begin fixing America's health care system.

The winning team will create an algorithm that predicts how many days a patient will spend in a hospital in the next year. Once known, health care providers can develop new care plans and strategies to reach patients before emergencies occur, thereby reducing the number of unnecessary hospitalizations. This will result in increasing the health of patients while decreasing the cost of care. In short, a winning solution will change health care delivery as we know it – from an emphasis on caring for the individual after they get sick to a true health care system.

The Competition runs for two years and offers a US $3 million Grand Prize, as well as six Milestone Prizes totaling $230,000, which are awarded in varying amounts at three designated intervals during the Competition.

Started: 5:03 pm, Monday 4 April 2011 UTC
Ends: 6:59 am, Wednesday 3 April 2013 UTC (729 total days)