Kohonen Self Organising Maps

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Lecture Outline

- Vector Quantisation
- Unsupervised learning
- Kohonen Self Organising Topological Maps

Vector Quantisation

- represents a *n* dimensional space as a *m* dimensional one
- $m < n$
- Preserves similarity between examples
  - examples that are close in *n* dimensional space will be close in *m* dimensional space

Supervised vs Unsupervised Learning

- Supervised Learning
  - Network is taught by a teacher
  - Desired outputs play a strong role during training
  - Network cannot be trained without known output values

Supervised vs Unsupervised Learning

- Unsupervised Learning
  - Learning without a teacher
  - No desired outputs present
  - Network learns patterns in the data

Kohonen Self Organising Topological Maps

- Referred to as Kohonen SOMs or just SOMs
- Invented by Teuvo Kohonen around 1982
- Motivated by neurobiology
  - regions of the cortex specialise
  - similar items are stored nearby in biological brains

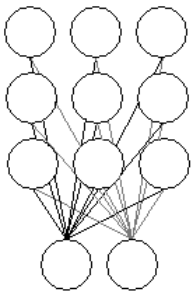
SOM Architecture

- Two layers of neurons
- Input layer
- Output map layer
- Each output neuron is connected to each input neuron
  - Fully connected network

SOM Architecture

- Output map usually has two dimensions
  - one and three dimensions also used
- Neurons in output map can be laid out in different patterns
  - rectangular
  - Hexagonal

SOM Architecture



SOM Architecture

- SOMs are competitive networks
- Neurons in the network compete with each other
- Other kinds of competitive network exist
  - e.g. ART

SOM Algorithm

- We are interested in finding the winning neuron in the output map layer
- The winning neuron is that neuron which is closest to the current input vector

SOM Algorithm

- Each output neuron is connected to each neuron in the input layer
- Therefore, each output neuron has an incoming connection weight vector
- Dimensionality of this vector is the same as the dimensionality of the input vector

SOM Algorithm

- Since the dimensionality of these vectors is the same, we can measure the Euclidean distance between them
- $D_j = \sqrt{\Sigma (x_i - w_{i,j})^2}$
- where:
  - D_j is the distance between the vectors
  - x_i is element *i* of the input vector
  - $w_{i,j}$ is element *i* of the weight vector of neuron *j*

SOM Algorithm

- Winning node is that with the least distance
  - i.e. the lowest value of *D*
- Outputs from a SOM are binary
- A node is either the winner, or it is not
- Only one node can win

SOM Training

- Based on rewarding the winning node
- This is a form of competitive learning
- Winners weights are adjusted to be closer to the input vector
- Why not equal?
  - We want the output map to learn regions, not examples

SOM Training

- SOM weight update rule

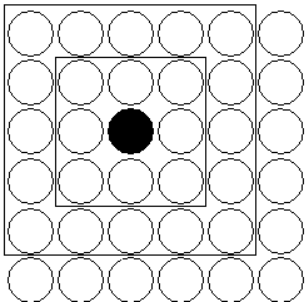
$$\Delta w_{i,j} = \alpha (x_i - w_{i,j})$$

- where:
  - $\Delta w_{i,j}$ is the weight change
  - α is the learning rate

SOM Training

- An important concept in SOM training is that of the "Neighbourhood"
- The output map neurons that adjoin the winner
- Neighbourhood size describes how far out from the winner the neighbours can be
- Neighbours weights are also modified

Neighbourhood



SOM Training

- Number of neighbours is effected by the shape of the map
  - rectangular grids
    - 4 neighbours
  - hexagonal grids
    - 6 neighbours
- Neighbourhood size and learning rate is reduced gradually during training

SOM Training

- Overall effect of training
  - groups, or "clusters" form in output map
  - clusters represent spatially nearby regions in input space
  - since dimensionality of the output map is less than the dimensionality of the input space
    - **vector quantisation**

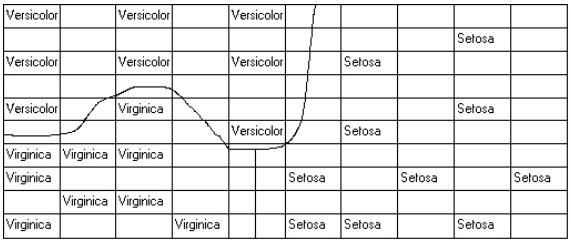
SOM Training

- It has been suggested that the total number of training cycles should be greater than 500 times the number of output neurons
- A training cycle is one presentation of one training example

SOM Mapping

- Labelled training data set fed through the trained SOM
- Finds winner for each training example
- Assigns label(s) for that example to that neuron
- Creates set of co-ordinates and labels
  - co-ordinates identify output neurons

SOM Mapping



SOM Recall

- Finds winner for each recall vector
- Co-ordinates of winner taken

Labelling

- Looks up map label using recall co-ordinates
- Results in a list of labels for each recall vector
- Allows you to identify the class each recall example belongs to

Conclusion

- Kohonen SOMs are competitive networks
- SOMs learn via an unsupervised algorithm
- SOM training is based on forming clusters
- SOMs perform vector quantisation