Design & Training Issues

Design:

Architecture of network

Structure of artificial neurons

Learning rules

Training:

Ensuring optimum training

Learning parameters

Data preparation

Network Design

Architecture of the network: How many nodes?

Determines number of network weights

How many layers?

How many nodes per layer?

Input Layer	Hidden Layer	Output Layer
________	________	________

Some Automated methods:

- augmentation (cascade correlation)
- weight pruning and elimination

Network Design

Architecture of the network: Connectivity?

Concept of model or *hypothesis* space

Constraining the number of hypotheses:

selective connectivity

shared weights

recursive connections

Network Design

Structure of artificial neuron nodes

Choice of input integration:

summed, squared and summed

multiplied

Choice of activation (transfer) function:

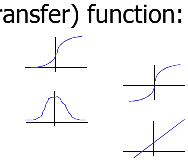
sigmoid (logistic)

hyperbolic tangent

Guassian

linear

soft-max



Network Design

Selecting a Learning Rule

Generalized delta rule (steepest descent)

Momentum descent

Advanced weight space search techniques

Global Error function can also vary

- normal - quadratic - cubic

Network Training

How do you ensure that a network has been well trained?

❖Objective: To achieve good generalization accuracy on new examples/cases

❖Establish a maximum acceptable error rate

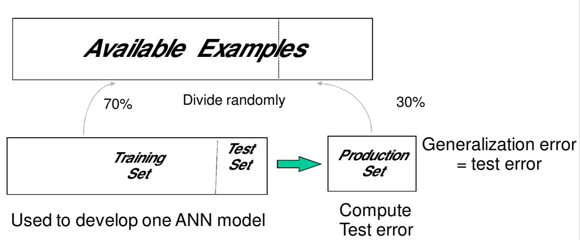
❖Train the network using a *validation test set* to tune it

❖Validate the trained network against a separate test set which is usually referred to as a *production test set*

Network Training

Approach #1: Large Sample

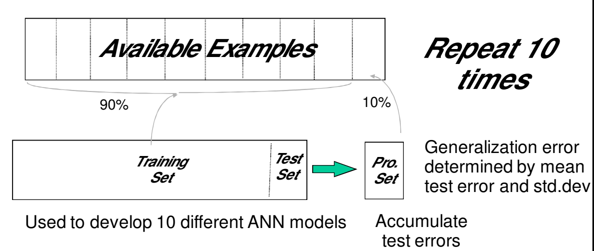
When the amount of available data is large ...



Network Training

Approach #2: Cross-validation

When the amount of available data is small ...



Network Training

How do you select between two ANN designs ?

A statistical test of hypothesis is required to ensure that a significant difference exists between the error rates of two ANN models

If Large Sample method has been used then apply McNemar's test*

If Cross-validation then use a paired *t* test for difference of two proportions

Network Training

Common ANN Parameters

		Typical	Range
learning rate -	η	0.1	0.01 - 0.99
momentum -	α	0.8	0.1 - 0.9
weight-cost -	λ	0.1	0.001 - 0.5

Fine tuning : adjust individual parameters at each node and/or connection weight

automatic adjustment during training

Network Training

Network weight initialization

Random initial values +/- some range

Smaller weight values for nodes with many incoming connections

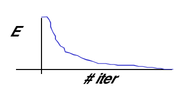
Rule of thumb: initial weight range should be approximately

$$\pm \frac{1}{\# weights}$$

coming into a node

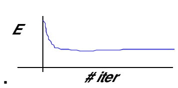
Typical Problems During Training

Would like:

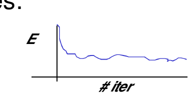


Steady, rapid decline in total error

But sometimes:



Seldom a local minimum - reduce learning or momentum parameter



Reduce learning parms.
- may indicate data is not learnable

Data Preparation

Garbage in ➡ Garbage out

The quality of results relates directly to quality of the data

50%-70% of ANN development time will be spent on data preparation

The three steps of data preparation:

- Consolidation and Cleaning
- Selection and Preprocessing
- Transformation and Encoding

Data Preparation

Data Types and ANNs

Four basic data types- may be more:

- *nominal* discrete symbolic (blue,red,green)
- *ordinal* discrete ranking (1^{st}, 2^{nd}, 3^{rd})
- *interval* measurable numeric (-5, 3, 24)
- *continuous* numeric (0.23, -45.2, 500.43)

bp ANNs accept only continuous numeric values (typically 0 - 1 range)

Data Preparation

Consolidation and Cleaning

- Determine appropriate input attributes
- Consolidate (merge) data into working database
- Eliminate or estimate missing values
- Remove *outliers* (obvious exceptions)
- Determine prior probabilities of categories and deal with *volume bias*

Data Preparation

Selection and Preprocessing

- Select examples ➡ random sampling
  - Consider number of training examples?
- Reduce attribute dimensionality
  - remove redundant and/or correlating attributes
  - combine attributes (sum, multiply, difference)
- Reduce attribute value ranges
  - group symbolic discrete values
  - quantize continuous numeric values

Data Preparation

Transformation and Encoding

Nominal or Ordinal values

Transform to discrete numeric values

Encode the value 4 as follows:

- one-of-N code (0 1 0 0 0) - five inputs
- thermometer code (1 1 1 1 0) - five inputs
- real value (0.4)* - one input if ordinal

Consider relationship between values

(*single, married*) *vs.* (*youth, adult*)

* Target values should be 0.1 - 0.9 , not 0.0 - 1.0 range

Data Preparation

Transformation and Encoding

Interval or continuous numeric values

De-correlate example attributes via normalization of values:

- Euclidean: *n = x/sqrt(sum of all x^2)*
- Percentage: *n = x/(sum of all x)*
- Variance based: *n = (x - (mean of all x))/variance*

Scale values using a linear transform if data is uniformly distributed or use non-linear (log, power) if skewed distribution

Data Preparation

Transformation and Encoding

Interval or continuous numeric values

Encode the value 1.6 as:

- Single real-valued number (0.16)* - OK!
- Bits of a binary number (010000) - BAD!
- one-of-N quantized intervals (0 1 0 0 0)
  - NOT GREAT! - discontinuities
- distributed (fuzzy) overlapping intervals
  (0.3 0.8 0.1 0.0 0.0) - BEST!

** Target values should be 0.1 - 0.9 , not 0.0 - 1.0 range*

After-Training Analysis

Examining the neural net model:

Visualizing the constructed model

Detailed network analysis

Sensitivity analysis of input attributes:

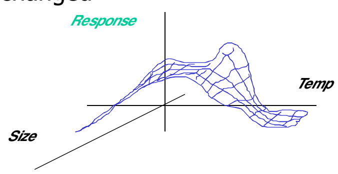
Analytical techniques

Attribute elimination

After-Training Analysis

Visualizing the Constructed Model

Graphical tools can be used to display output response as selected input variables are changed



After-Training Analysis

Detailed network analysis

- Hidden nodes form internal representation
- Manual analysis of weight values often difficult - graphics very helpful
- Conversion to equation, executable code
- Automated ANN (computational models) to symbolic logic conversion is a hot (new/ hard) area of research

After-Training Analysis

Sensitivity analysis of input attributes

- Analytical techniques
  - factor analysis
  - network weight analysis
- Feature (attribute) elimination
  - forward feature elimination
  - backward feature elimination

The ANN Application Development Process

Guidelines for using neural networks

1. Try the best existing method first
2. Get a **big** training set
3. Try a NN without hidden units
4. Use a sensible coding for input variables
5. Consider methods of constraining network
6. Use a test set to prevent over-training
7. Determine confidence in generalization through cross-validation

Applications

- Pattern Recognition *(reading zip codes)*
- Signal Filtering *(reduction of radio noise)*
- Data Segmentation *(detection of seismic onsets)*
- Data Compression *(TV image transmission)*
- Database Mining *(marketing, finance analysis)*
- Adaptive Control *(vehicle guidance)*
- Handwriting recognition
- Face recognition
- Optical character recognition (OCR)

Applications

- Text to Speech (NetTalk)
- Fraud detection

  9 of top 10 US credit card companies use Falcon uses neural nets to model customer behavior, identify fraud claims
- Prediction & Financial Analysis

  In Banks: financial forecasting, investing, marketing analysis
- control & optimization
  - Intel – computer chip manufacturing quality control
  - AT&T (cell phones) – echo & noise control in phone lines (filters and compensates)
  - Ford engines utilize neural net chip to diagnose misfirings, reduce emissions