Neural Networks : Introduction

Lecture 2

1

Characteristics of ANN

- ***Classification*** **:** They can extract classification (clustering) characteristics from a large number of input examples. e.g.
- ***Pattern Matching :*** They can produce the corresponding output patterns for given input patterns.
- ***Pattern Completion:*** For an incomplete pattern, networks can generate the missing portion of the input pattern.

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Characteristics of ANN

- ***Learning :*** Unlike expert systems, neural networks learn many example patterns and their associations i.e. desired outputs or conclusions.
- ***Generalization :*** The network responds in an interpolative way to noisy, incompetent, or previously unseen data. An associative network, where input is equal to desired output, can produce a full output if presented with a potential input. This property is called "generalization".

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Characteristics of ANN

- ***Fault Tolerance :*** In ANN, the memory is distributed and failure of some processing elements will slightly change overall behavior of the network.
- ***Optimization :*** For given initial values of a specific optimization problem, the networks help in arriving at a set of variables which represent a solution to the problem.

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Characteristics of ANN

- ***Control :*** Current state of a controller and the desired response for the controller as an input pattern, the networks generate proper command sequence to create the desired response.
- ***Distributed Memory :*** The connection weights are the memory units of the network. The value of weights represent the current state of knowledge of the network. A unit of knowledge, represented for example by an input/output pair is distributed across all the weighted connections of the network.

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Characteristics of ANN

- ***Storage Memory :*** There is one set of network weights capable of representing a large space of stored patterns. Thus it provides an advantage of lesser amount of storage memory.

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NN replaces the Mathematical Model .. How ?

- No need for a conventional equation
- Equations Maps or translates inputs onto outputs
- NN learns how to map based on input and output data
- It trains itself and learns to perform the task of prediction/forecasting

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What else NN can offer ?

- NN **learns** how to model a given site itself
- Scope for **performance improvement** over time
- **Easy** to maintain
- **Cheap** and automatic
- **Same software** can be applied to all sites
- Possibility of **real-time** retraining
- NN handles **imprecise data**
- Possibility of testing off-line to establish **confidence**

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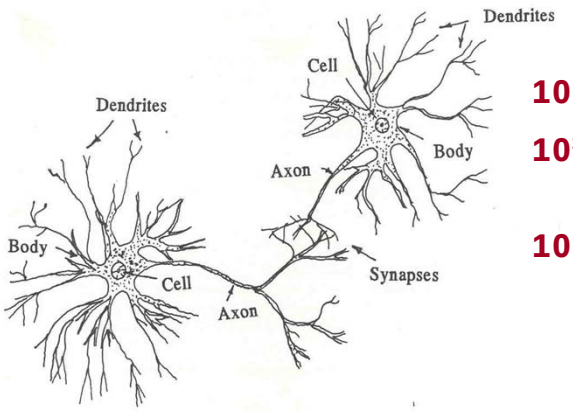
Biological Neuron



10^{10}-10^{11} Neurons

10^{3}-10^{4} Connections (synaptic)

10^{13}-10^{15} Connections

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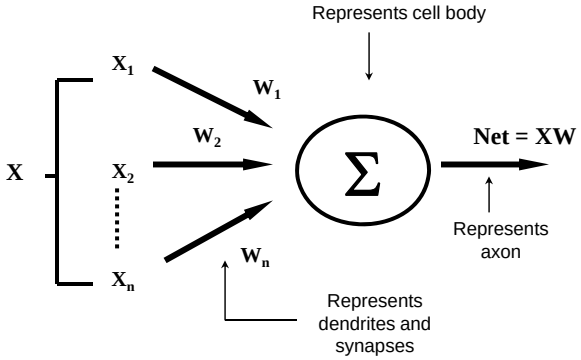
Artificial Neuron



$$Net = W_1X_1 + W_2X_2 + \ldots + W_nX_n$$

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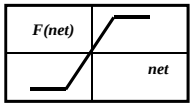
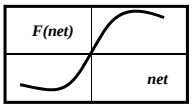
Activation Functions

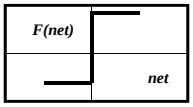
Linear Transfer Function



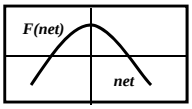
Sigmoid Function



Linear Step Function



Gaussian Function



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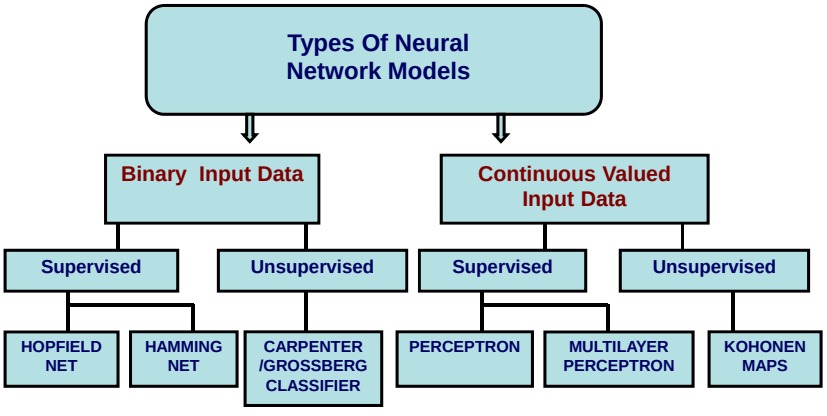
Existing Neural Models



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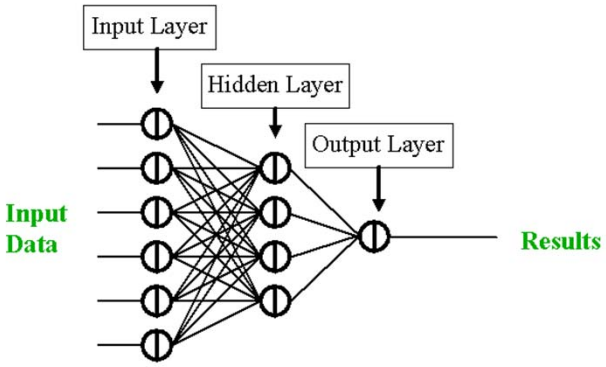
NN Architecture Representation



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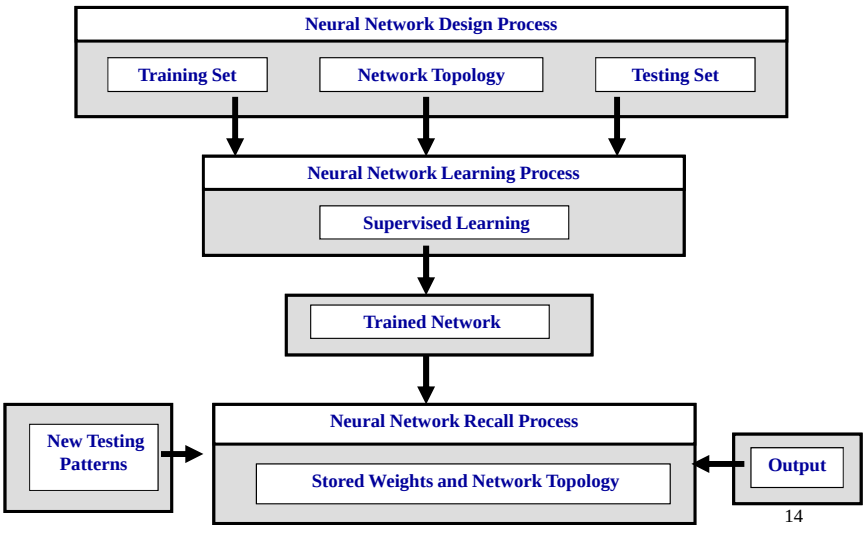
NN Modeling Phase



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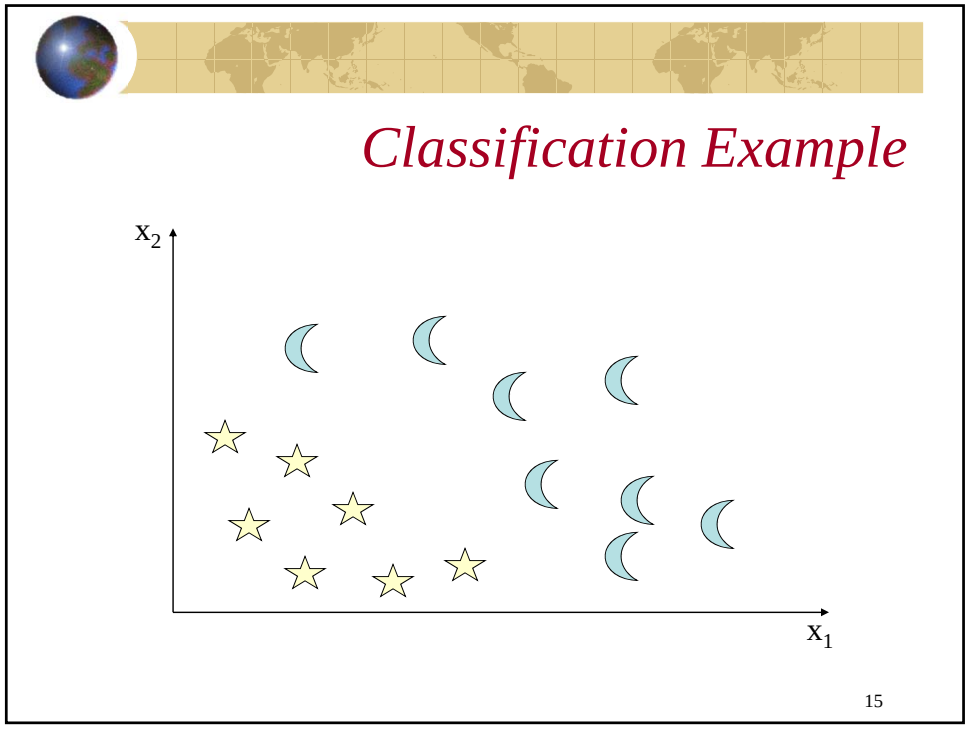
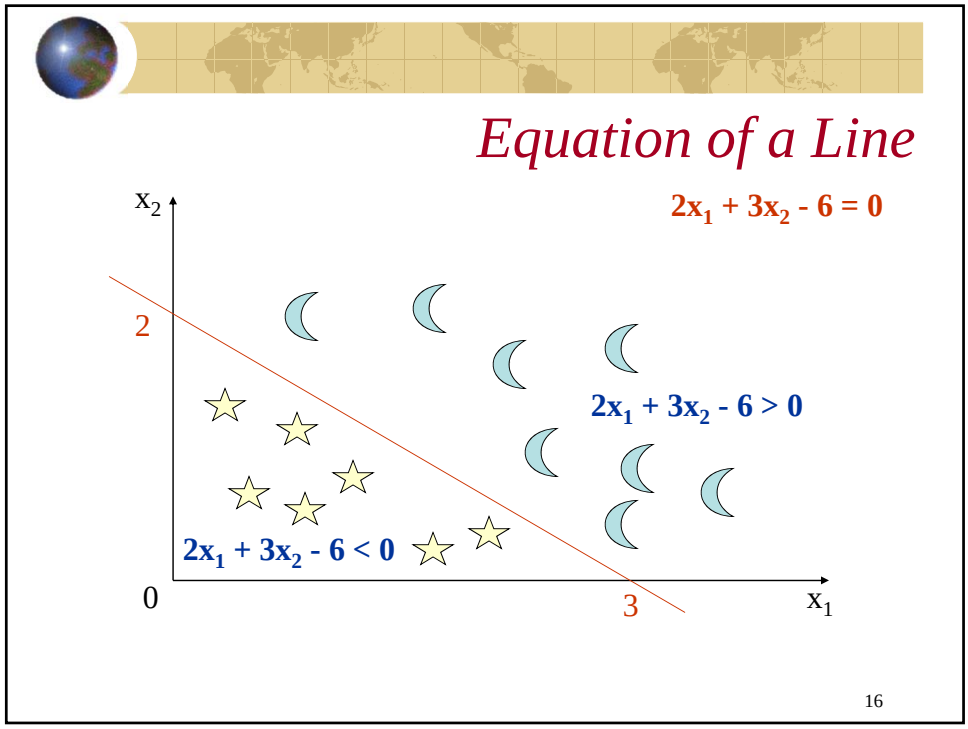

Classification Example
x2
x1
15


Equation of a Line
2x1 + 3x2 - 6 = 0
x2
2
2x1 + 3x2 - 6 > 0
2x1 + 3x2 - 6 < 0
0
3
x1
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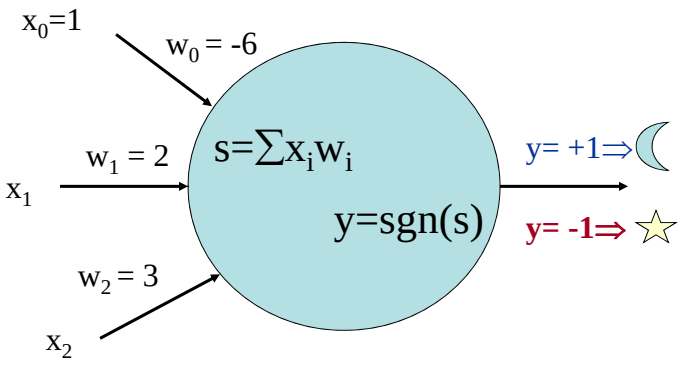
Neural Classifier



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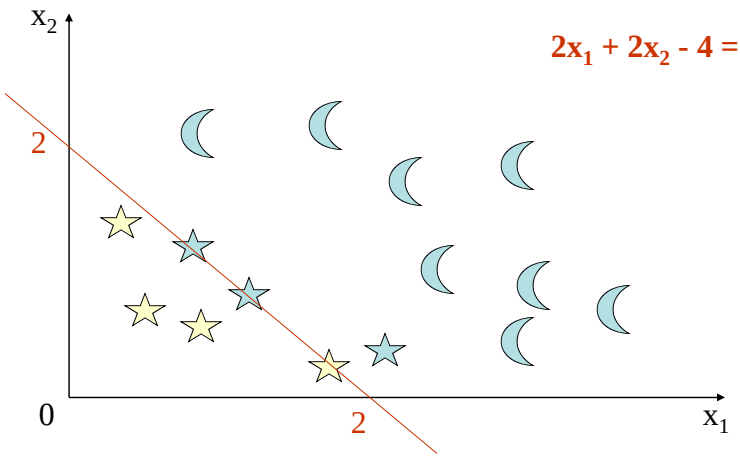
Equation of a Line is Wrong



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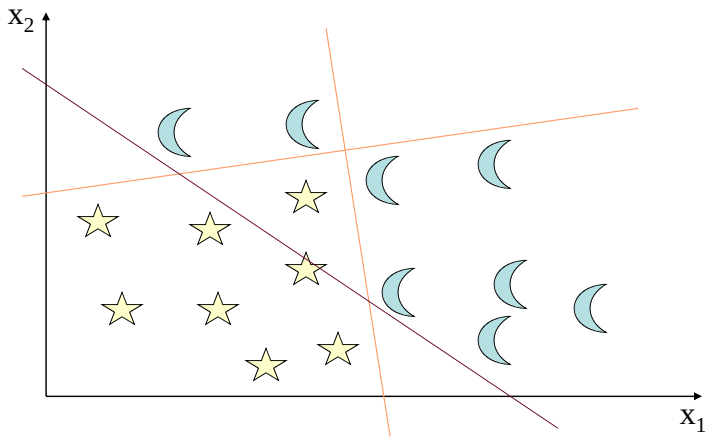
Linearly Separable -- Not



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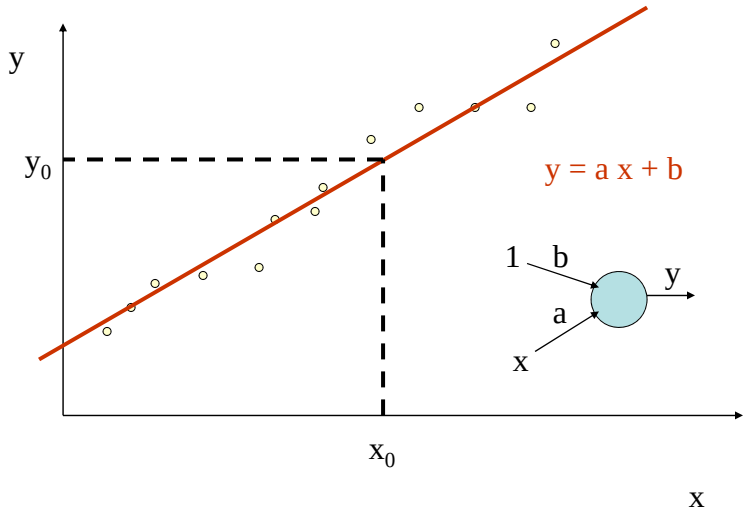
Linear Regression



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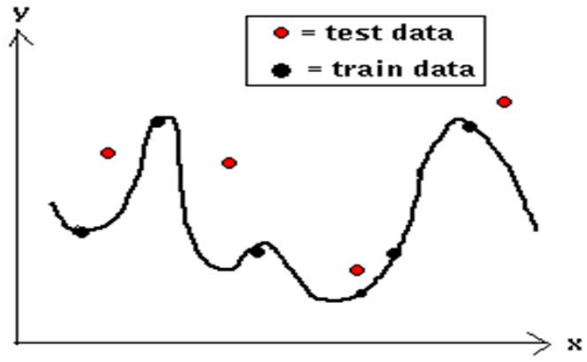
Over-fitting



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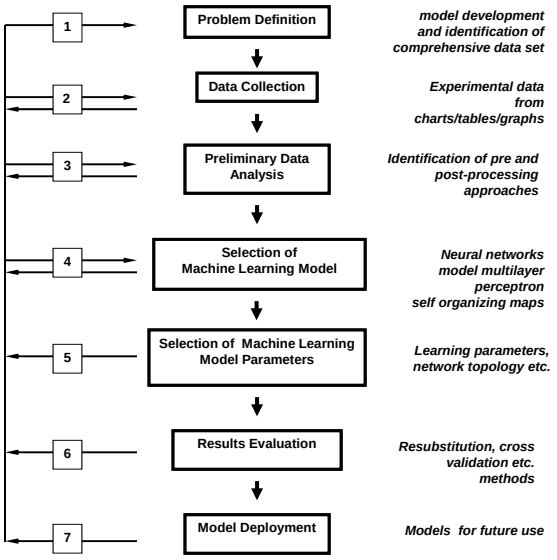
Scheme of Modelling



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1. Problem Definition

- Classification
- Pattern Matching
- Pattern Completion
- Learning
- Generalization
- Control
- Optimization
- Prediction
- Forecasting
- And so on.....

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2. Data Collection

Data is an extremely valuable asset,
but like a cash crop,
unless harvested, it is wasted.

-Sid Adelman

- Theoretical
- Experimental

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3. Preliminary Data Analysis

- Nature of Data : ***Source, Utility, Behaviour, Description***
- *Source:* Online/Offline, from Static/Dynamic Systems
- *Utility*: Analysis, Design, Diagnostics
- *Behaviour:* Discrete/Continuous
- *Description:* Quantitative/Qualitative

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3. Preliminary Data Analysis

- Are they sparse or dense?
- Are they in raw or clean form?
- Are they representative of the application domain?
- Are they noisy?
- Do they contain missing data?
- Scientific data :

  Insight (novelty detection, anomalies etc.)

  Predictive Model (Neural networks)

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3. Preliminary Data Analysis

- Pre-processing and Post-processing of data

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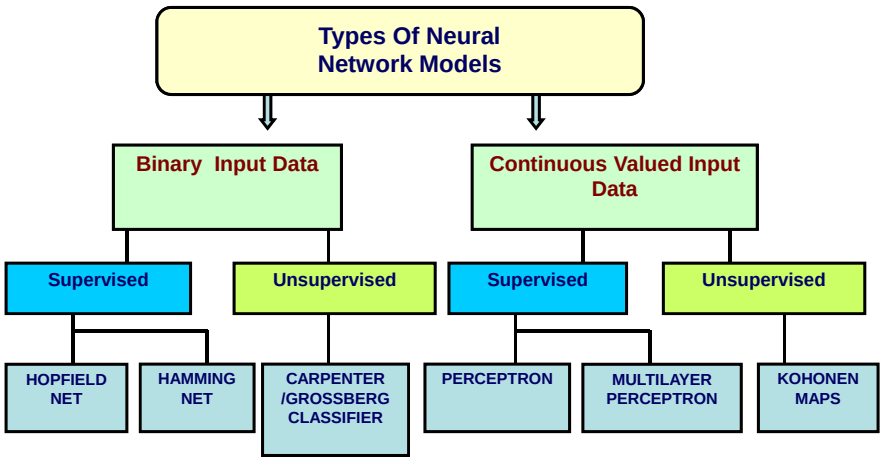
4. Selection of Neural Models



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5. Selection Model Parameters

- Number of input units
- Number of output units
- Number of hidden units and layers
- Activation functions
- Learning parameters etc.

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6. Model Performance Evaluation

- **R** - Resubstitution
- **B** - Bootstrap
- Cross-validation
  - **L** - Leave-one-out and
  - **K**- 10-fold
- **H** - Hold-out
- **TTV**- Training-Testing-Validation

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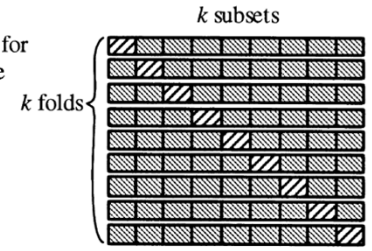
6. Cross-Validation Test

Procedure

1. Subdivide the data into k subsets.
2. Perform k folds such that for each fold j:
   a. Learn a model from the (k- 1) training subsets (all but the jth subset).
   b. Test the model performance on the jth subset and record the accuracy.
3. Calculate the average accuracy over the k folds.

Legend

- k- 1 subsets for learning the model
- 1 subset for testing the model



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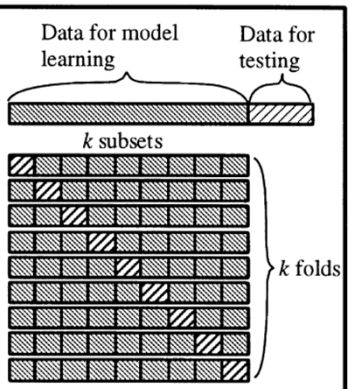
6. Training-Testing-Validation Test

Procedure

1. Divide the data into training and testing subsets.
2. Select the best learner and its parameters:
   a. Test each combination of learner and/or parameters with a k- fold CV test.
   b. Select the combination that leads to the best CV performance.
3. Assessment of best learner:
   a. Creat a model from all training data using the best learner and parameters.
   b. Test the model on the testing set.



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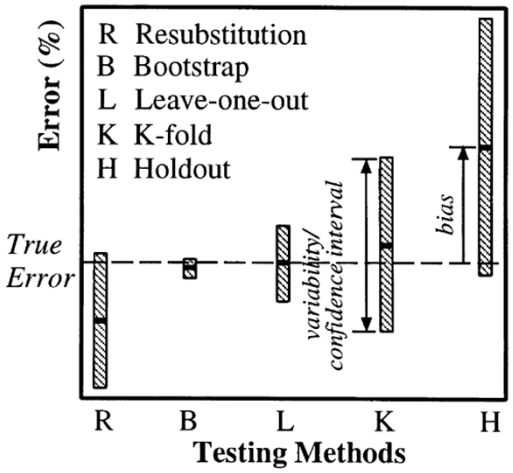
6. Relative Performance



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7. Model Deployment

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Neural Networks Applications

- **Aerospace**
  - High performance aircraft autopilot
  - Flight path simulation
  - Aircraft control systems
  - Autopilot enhancements
  - Aircraft component simulation
  - Aircraft component fault detection

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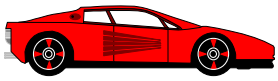
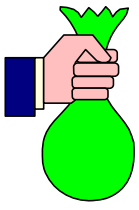
Neural Networks Applications

- **Automotive**
  - Automobile automatic guidance system
  - Warranty activity analysis



- **Banking**
  - Cheques and other document reading
  - Credit application evaluation



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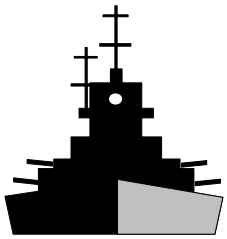
Neural Networks Applications

- **Defense**



- Weapon steering, target tracking
- Object discrimination
- Facial recognition
- New kinds of sensors
- Sonar, radar and image signal processing including data compression
- Feature extraction and noise suppression,
- Signal/image identification

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Neural Networks Applications

- **Electronics**
- Code sequence prediction
- Integrated circuit chip layout
- Process control,
- Chip failure analysis,
- Machine vision
- Voice synthesis
- Nonlinear modeling

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Neural Networks Applications

- **Entertainment**
  - Animation
  - Special effects
  - Market forecasting

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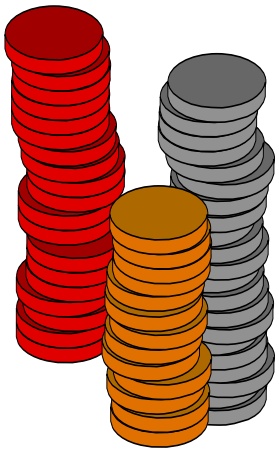
Neural Networks Applications

- **Financial**
  - Real estate appraisal
  - Loan advisor
  - Mortgage screening
  - Corporate bond rating
  - Credit line use analysis
  - Portfolio trading program
  - Corporate financial analysis
  - Currency price prediction



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Neural Networks Applications

- **Insurance**
  - Policy application evaluation
  - Product optimization

- **Manufacturing**
  - Manufacturing process control
  - product design and analysis
  - process and machine diagnosis
  - real-time particle identification

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Neural Networks Applications

- **Manufacturing**
  - Beer testing
  - Welding quality analysis
  - Paper quality prediction
  - Computer chip quality analysis
  - Visual quality inspection systems
  - Analysis of grinding operations
  - Chemical product design analysis

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Neural Networks Applications

- **Manufacturing**
  - Machine maintenance analysis, project
  - Bidding, planning and management
  - Dynamic modeling of chemical process system

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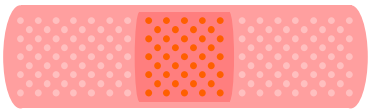
Neural Networks Applications

- **Medical**
  - Breast cancer cell analysis
  - EEG and ECG analysis
  - Prosthesis design,
  - Optimization of transplant times
  - Hospital expense reduction
  - Hospital quality improvement
  - Emergency room test advisement



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Neural Networks Applications

- **Oil and Gas**
  - Exploration
- **Robotics**
  - Trajectory control
  - Forklift robot
  - Manipulator controllers
  - Vision systems

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Neural Networks Applications

- **Speech**
  - Speech recognition
  - Speech compression
  - Vowel classification
  - Text to speech
  - Synthesis

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Neural Networks Applications

- **Securities**
  - Market analysis
  - Automatic bond rating
  - Stock trading advisory systems

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Neural Networks Applications

- **Telecommunications**
  - Image and data compression
  - Automated information services
  - Real-time translation of spoken language
  - Customer payment processing systems

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Neural Networks Applications

- **Transportation**
  - Truck brake diagnosis systems
  - Vehicle scheduling
  - Routing systems

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Text Book Reference

- **Simon Haykin** – Neural Networks – A Comprehensive Foundation, Pearson Education Asia, Low Price Edition

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