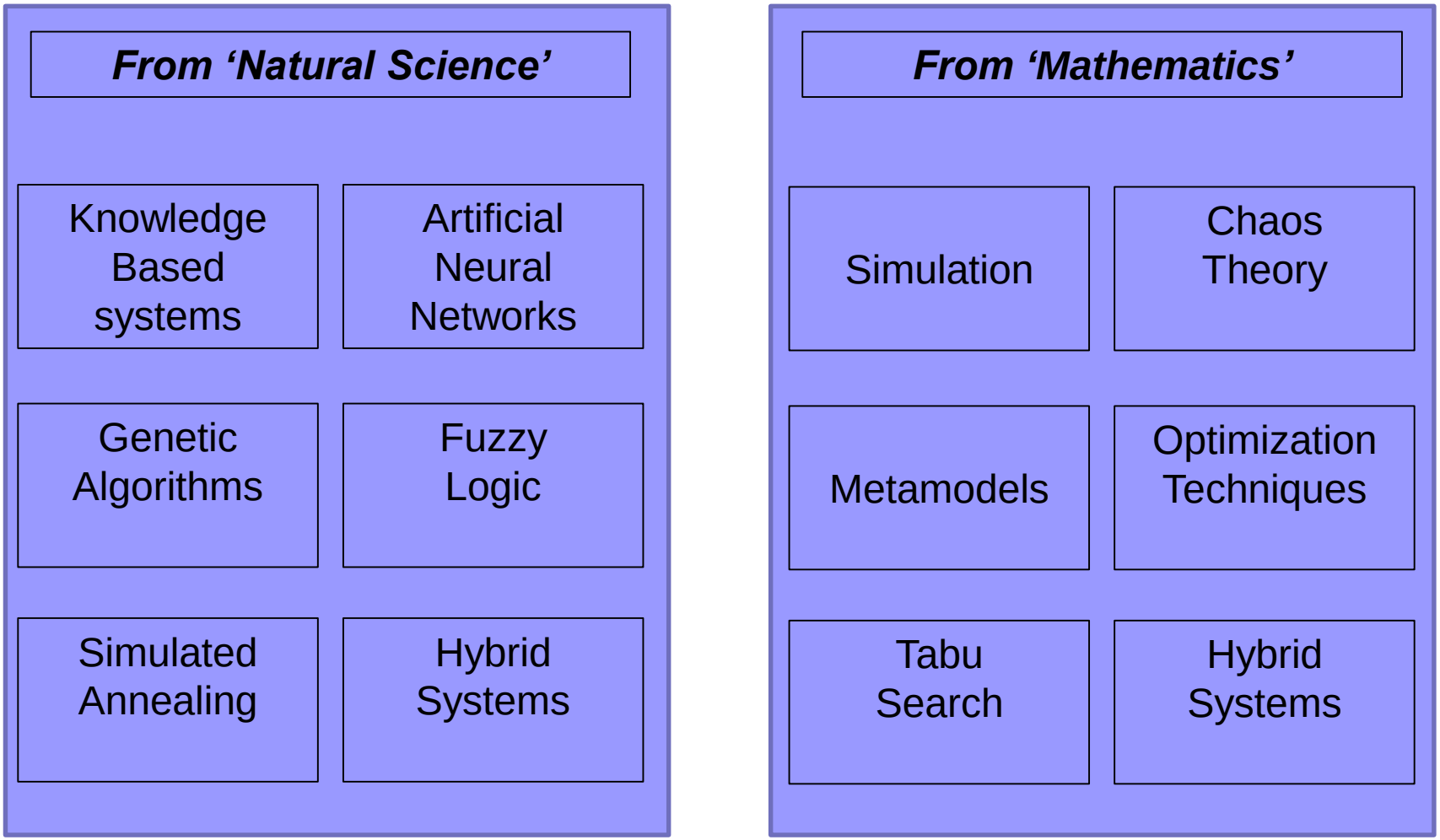
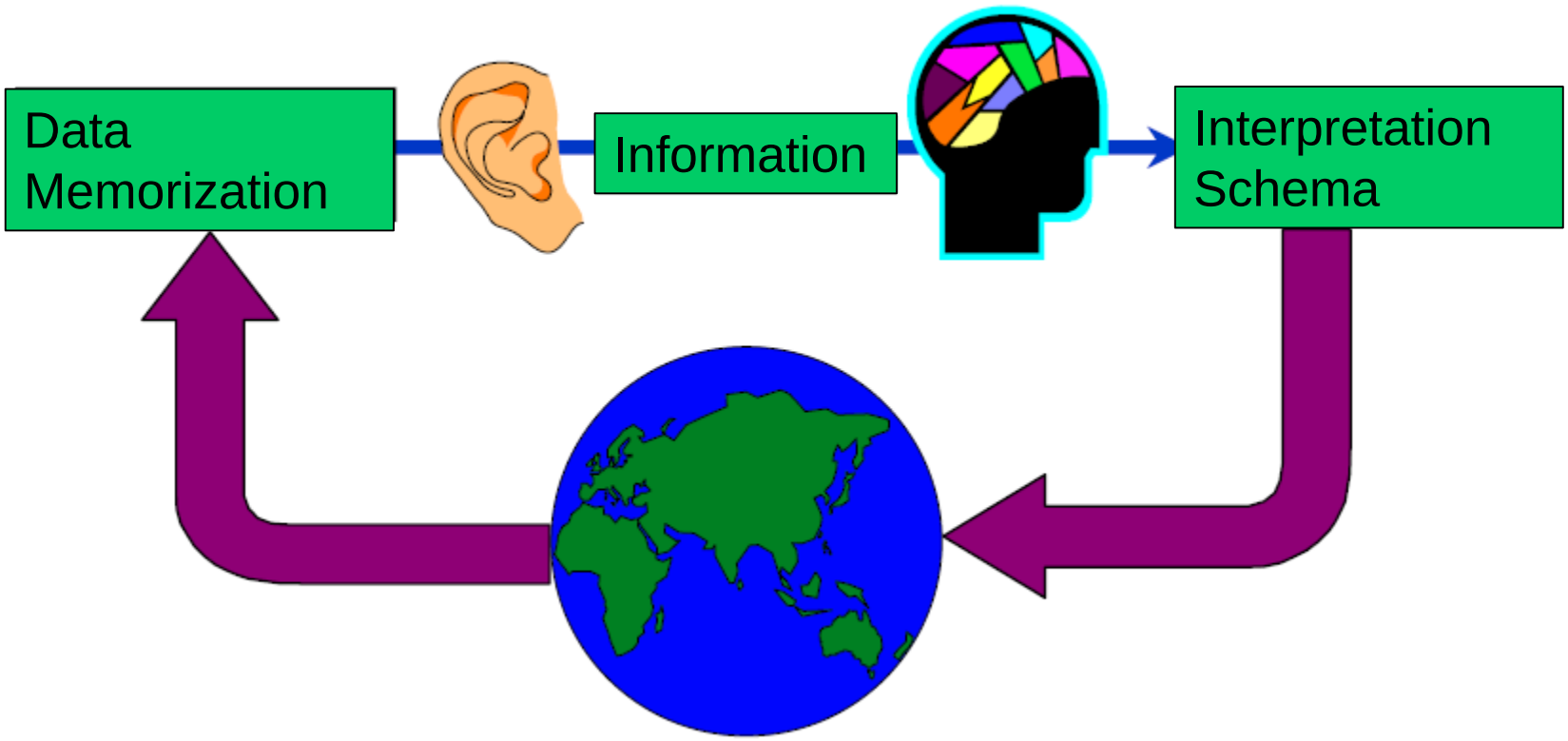
Advanced techniques for design and management of production systems

General overview

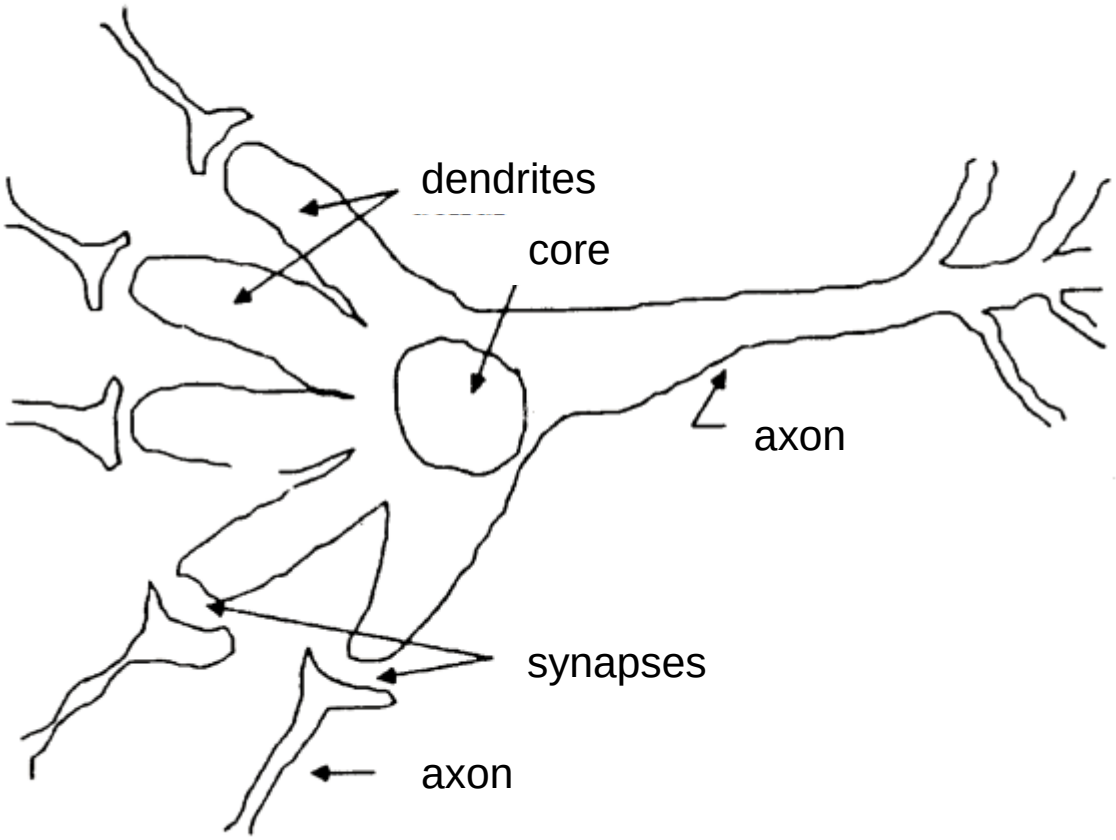


Artificial Neural Networks

Knowledge acquisition process

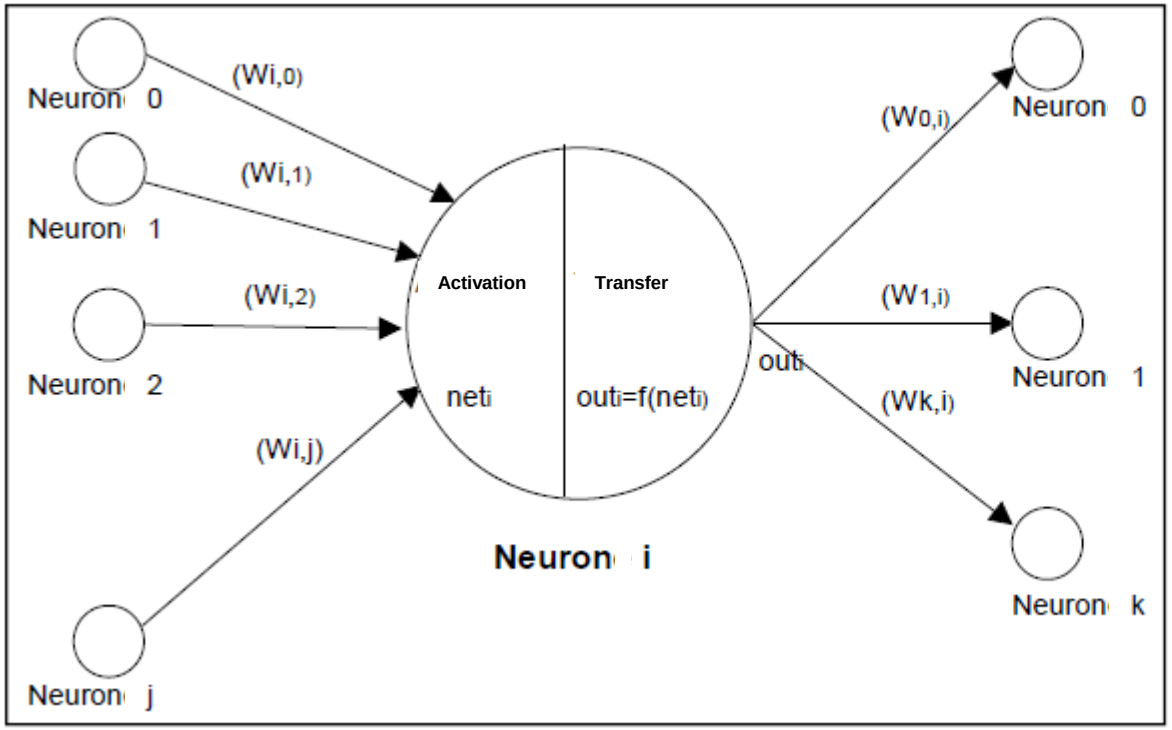


The bilogical neuron



- Human brain contains 10^{12} neurons
- Neuron dimensions from 0.01 mm to 1 m (depending on axon length)
- Connectivity of a single neuron from O(1) to O(10^5): the number of synapses is O(10^{15})

The artificial neuron

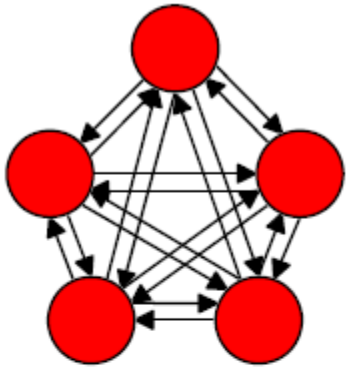


$$net_i = \sum_j w_{i,j}\, out_j + \vartheta_i$$

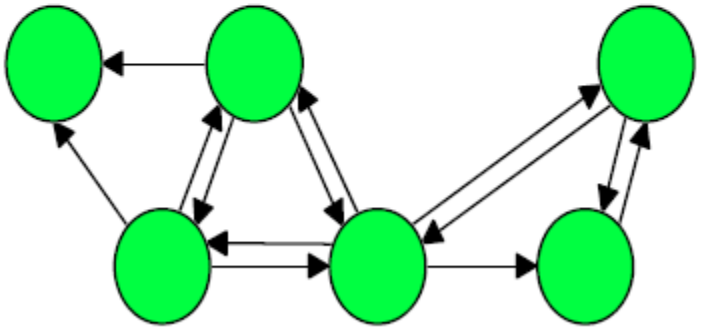
$$out_i = f(net_i)$$

i = index of generic neuron
j = index of generic neuron in input to neuron i
k = index of generic neuron in output from neuron i
j into S_{input} (set of input neurons to i)
k into S_{output} (set of output neurons from i)

Topologies of ANN



A)

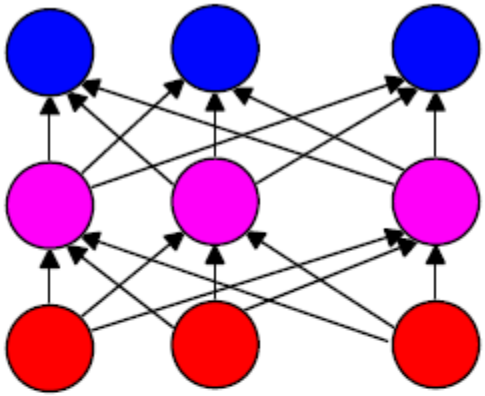


B)

Output layer

Hidden layer

Input layer

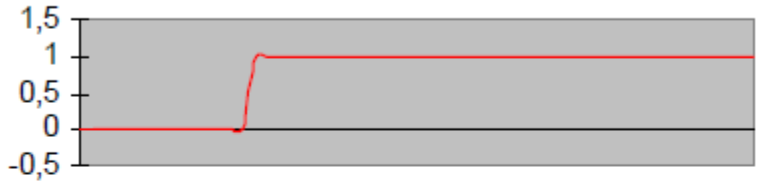


C)

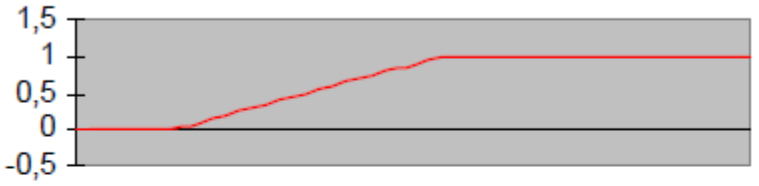
A) Completely interconnected
B) Partially connected
C) In layers

Transfer functions

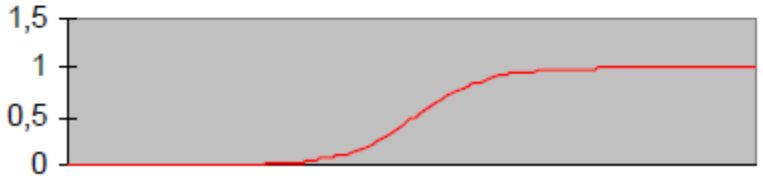
Step



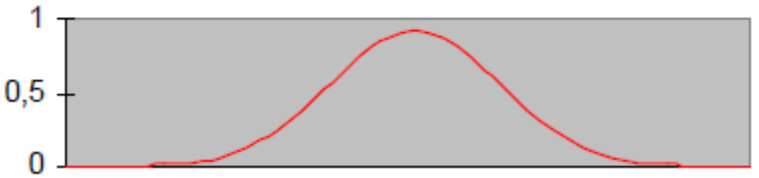
Ramp



Sigmoidal



Gaussian

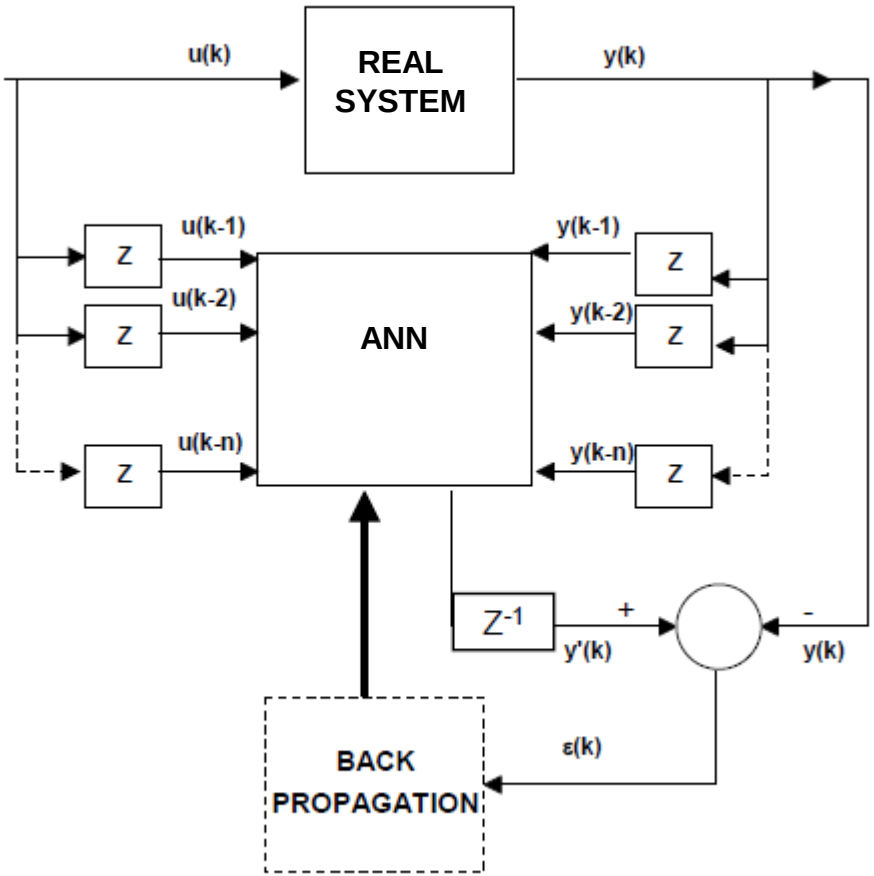


Knowledge and learning

- Knowledge is not defined by rules (like Knowledge-based Systems), but is distributed into values of connection weights.
- Learning processes:
  - Supervised
  - Not supervised
  - Fixed weights
- Learning occurs on the basis of specific algorithms which update the weights of connections.
- Hebb law:

$$W_{i,j}(t+1) = W_{i,j}(t) + \Delta W_{i,j}$$

Supervised learning



The goal is the minimization of the following cost function:

$$E = \frac{1}{2}\sum_{n=1}^{N}\left(y'_n(t) - y_n(t)\right)^2$$

where $y'_n(t)$ is the value of output n computed by ANN, with an input u(t)

At each iteration the connection weight is changed by using the following law:

$$\Delta w_{ij}(t) = -\eta \cdot \frac{\partial E(t)}{\partial w_{ij}(t)} + \alpha \cdot \Delta w_{ij}(t-1)$$

Where:

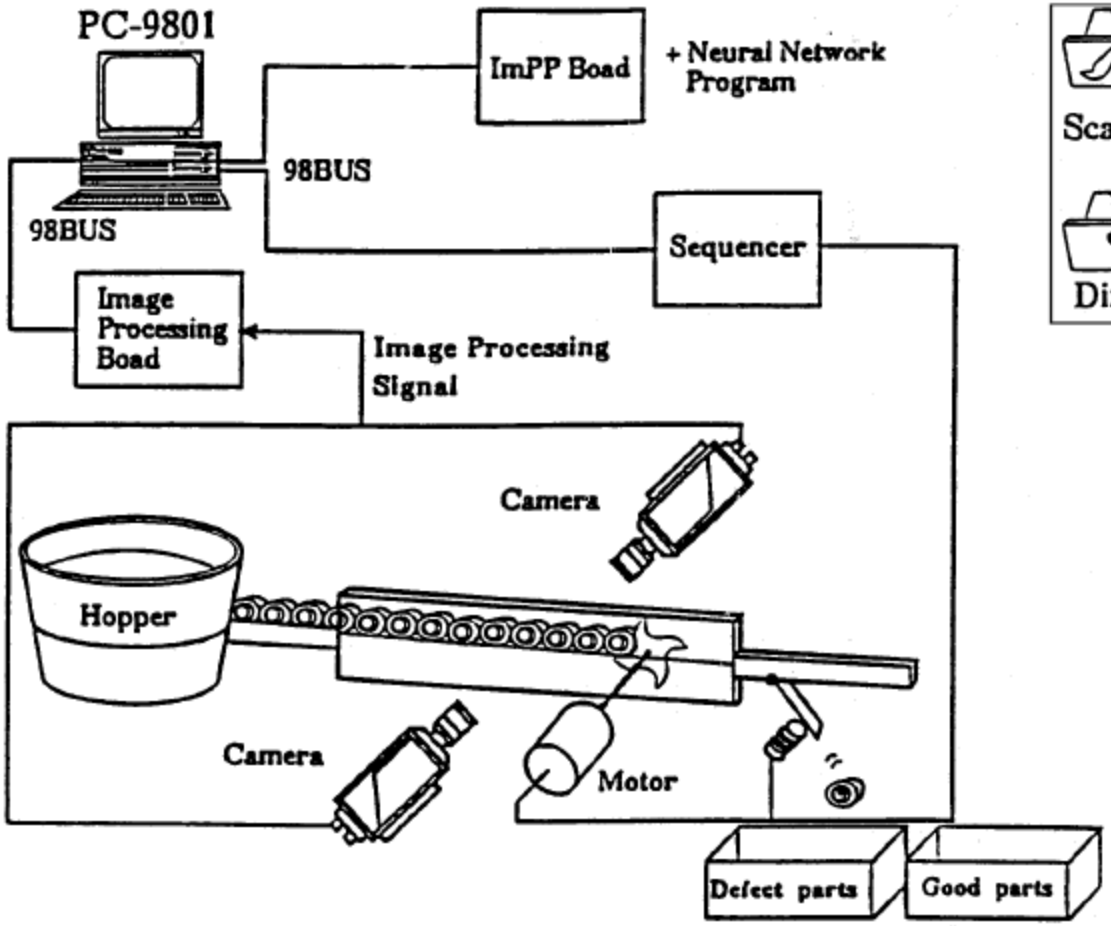
– η is the learning coefficient

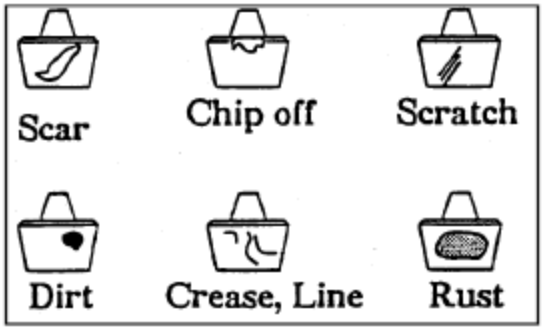
– α is the inertia coefficient

Applications

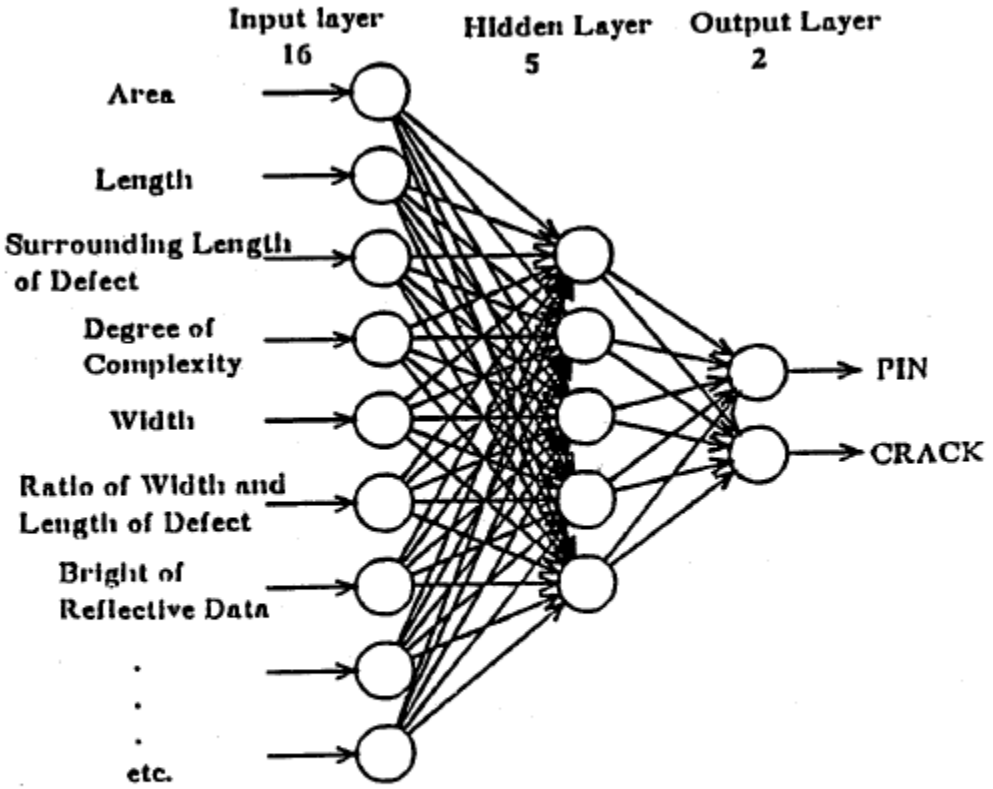
- Classification and recognition: e.g. OCR, quality control in production, medical analysis, …
- Forecast: loan approval, financial market, …
- Optimization: delivery path, production management, ...
- Control: robot movement, industrial process control, veichle control

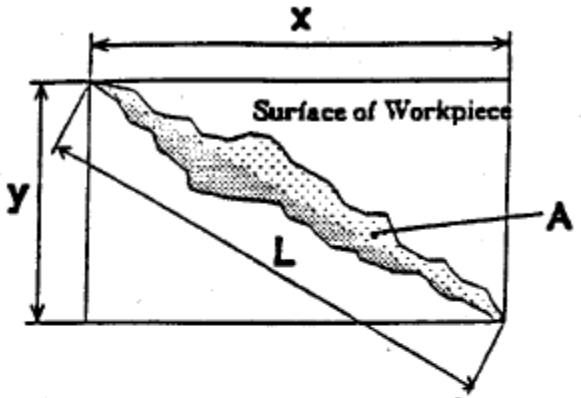
An example


PC-9801
ImPP Boad
+ Neural Network Program
98BUS
98BUS
Sequencer
Image Processing Boad
Image Processing Signal
Camera
Hopper
Camera
Motor
Defect parts
Good parts


Scar
Chip off
Scratch
Dirt
Crease, Line
Rust

An example





An Example of Crack

Features

1. Area of Defect :A
2. Length of Defect :L
3. Surrounding Length of Defect :Ls
4. Degree of Complexity :$\theta = L^2/A$
5. Ratio of Width and Length of Defect :S/L
6. Brightness of Reflective Data
7. Color of Defect
8. Feature of Surrounding Line of Defects

ANN advantages

- Data-driven and not model-driven
- Easy to use
- Lower costs than other techniques
- It is possible to solve problem currenlty not solveable automatically

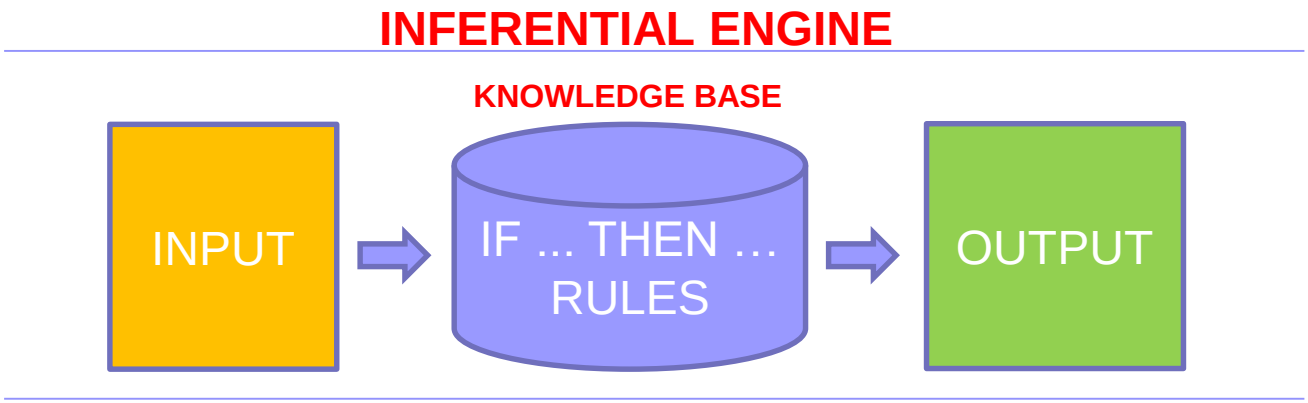
Knowledge-based systems

Knowlegde-based systems

- Software programs that are able to deduce informations from a set of starting input data
- They are based on human competence, registered into a so called ‘knowledge base’
- It is possible to operate on incomplete and qualitative data (e.g. "fuzzy logic“)
- It is always possible to explain the decisions of the knowledge-based system (Glass Box)

Knowledge-based systems

- It is composed of two elements:
  - KNOWLEDGE BASE: facts that happen in real life; it represents the knowledge of an operator
  - INFERENTIAL ENGINE: a mechanism that analyze the data in input to the system, in order obtain conclusions from the observed facts.

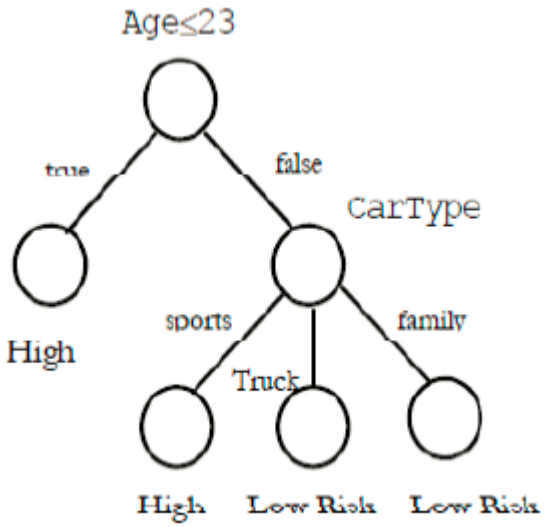


Knowledge-based systems types

- Based on rules
  - They are programs composed of ‘IF condition THEN action’ rules. Given a set of facts, knowledge-based systems, due to rules application, can deduce new facts.
- Based on trees:
  - From a set of data and some deductions, a decision tree is defined in order to classify the input data. New informations are analyzed by the tree and the arrival node represents the decision.

Examples

- Example of tree:



- Example of rule:
  - Input data set:
    - Headache
    - Cold
    - Temperature 38° C
  - Rule:

IF *headache* AND *cold* AND *temperature>37°C* AND *temperature<38.5°C* THEN *flu*

Knowledge-based systems design

- The knowledge-based system use the defined rules, but cannot create them. Hence during design phase it is necessary to define:
  - The logical structure
  - The data types
  - The sets and the classes
  - The limits
  - The IF…THEN… rules

An example

IF (vel IS 120) AND (limit is 50) AND (autovelox IS present) THEN (reaction IS slowdown)

- The logical structure: triple IF
- The data types:
  - Vel: float
  - Limit: integer
  - Autovelox: boolean (present/not present)
  - Reaction: 3 state (slowdown, mantain, accelerate)
- The sets/classes and limits:
  - Vel: from 0 to 220
  - Limit: 30, 50, 70, 90, 110, 130

Advantages vs problems

- Same responses in case of repeated decisions
- Glass box
- Contains several data and informations
- The decision can always be clearly explained
- Every aspects included are analyzed: nothing is forgotted or leaved out

- Important data can be leaved out from design
- Not useful in case of unexpected facts
- Cost to exctract knowledge from operators.
- Bad design = bad decisions
- Cannot be adapted in case of environment changes

Fuzzy logic

Fuzzy logic

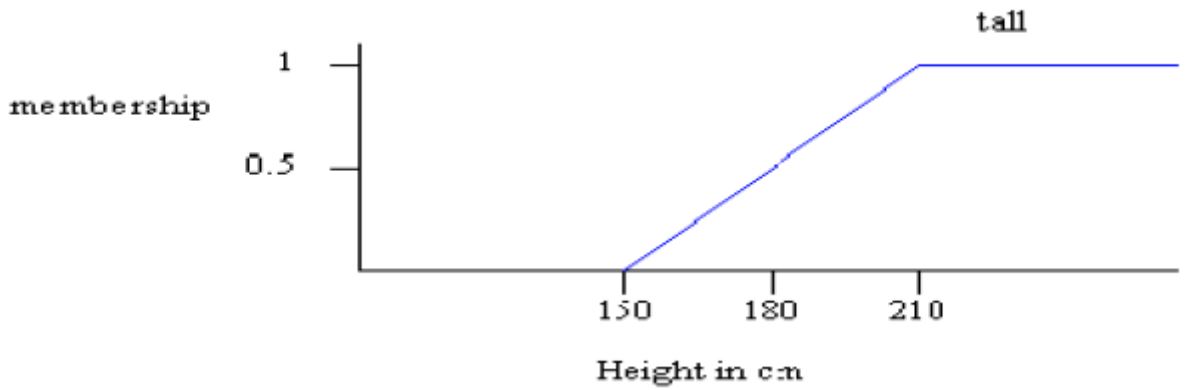
- L.A. Zadeh
- It is a mathematical theory introduced in order to model uncertainty
- It is an extension of Aristotelian logic (a.k.a. crisp logic)

Aristotelian logic

- Principle of excluded middle (third excluded): an element cannot belong at the same time to a set and its complement.
- Principle of non-contradiction: a statement can be only true or false

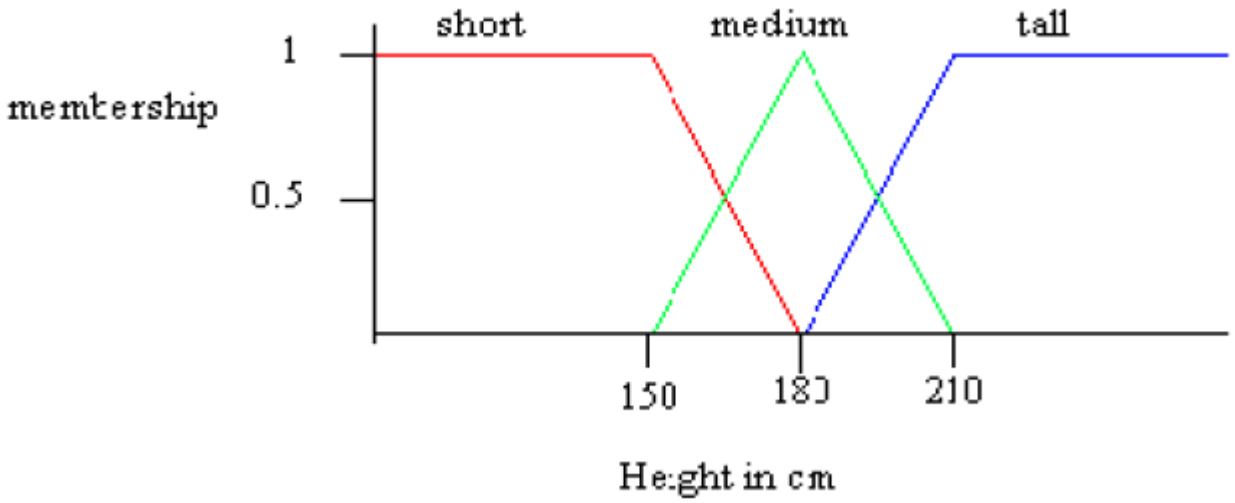
Fuzzy logic

- In real life (natural language) it is difficult to have statement that can be only true or false. E.g. Am I old? Am I tall?
- The truth level (membership) can be represented with a value from 0 to 1 (with 0 and 1 the logic is the same as Aristotelian)



Uncertainty representation

- If an element belongs to a set, this does not mean that it cannot belong to its complement.



Real life and uncertainty

- Height, wealth, heat, speed, difficulty: they are all vague concepts.
- The semantics of the natural language can represent this aspect:
  - The soaked road
  - The wet road
  - The dry road

Fuzzy logic and knowledge-based system

- Fuzzy logic is able to represent the typical situations of a human being.
- It is very useful in order to create knowledge-based Systems, that have to respond like a human being
- The IF … THEN … rules can be defined by using fuzzy logic
  - IF soaked road THEN go slowly
  - IF wet road THEN go a little bit slowly
  - IF awash road THE go very slowly

Fuzzy logic advantages

- It operates with the same logic as humans, with vague concepts and with uncertainty
- It allows to code the technical knowledge without defining with precision the limits of rules.
- It allows to represent rules by using common language and not numerical sets (aligned with expert knowledge).
- Soft transition to one rule to another one (more than one rule can be applied, with different levels of truth).

Fuzzy logic disadvantages

- Identification of the complete set of rules
- Risk to create an inaccurate and incomplete knowledge base
- Long time in order to obtain a good knowledge base