

Machine Learning (Part II)

Soft Computing methodologies

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Introduction

■ Soft Computing

- as opposed to traditional computing, deals with **approximate models** and gives solutions to **complex real-life problems**
- principal constituents
 - Fuzzy Logic (FL)
 - Evolutionary Computation (EC)
 - Swarm Intelligence (SI)
 - Artificial Immune Systems (AIS)
 - Machine Learning (ML)
 - Probabilistic Reasoning (PR)
 - belief networks and parts of learning theory



Introduction

- Computational Intelligence
 - refers to the ability of a computer to learn a specific task from data or experimental observation
 - synonym of Soft Computing



AI Methodologies

- Machine Learning
 - Neural Networks
 - Shallow Neural Networks
 - Deep Neural Networks
 - Support Vector Machine
 - Bayesian Nets
 - Statistical learning

- Soft Computing
 - Fuzzy Logic
 - Neuro-Fuzzy
 - Evolutive Approaches
 - Genetic algorithms
 - Swarm optimization
 - Anton Colony
 - Bee Colony

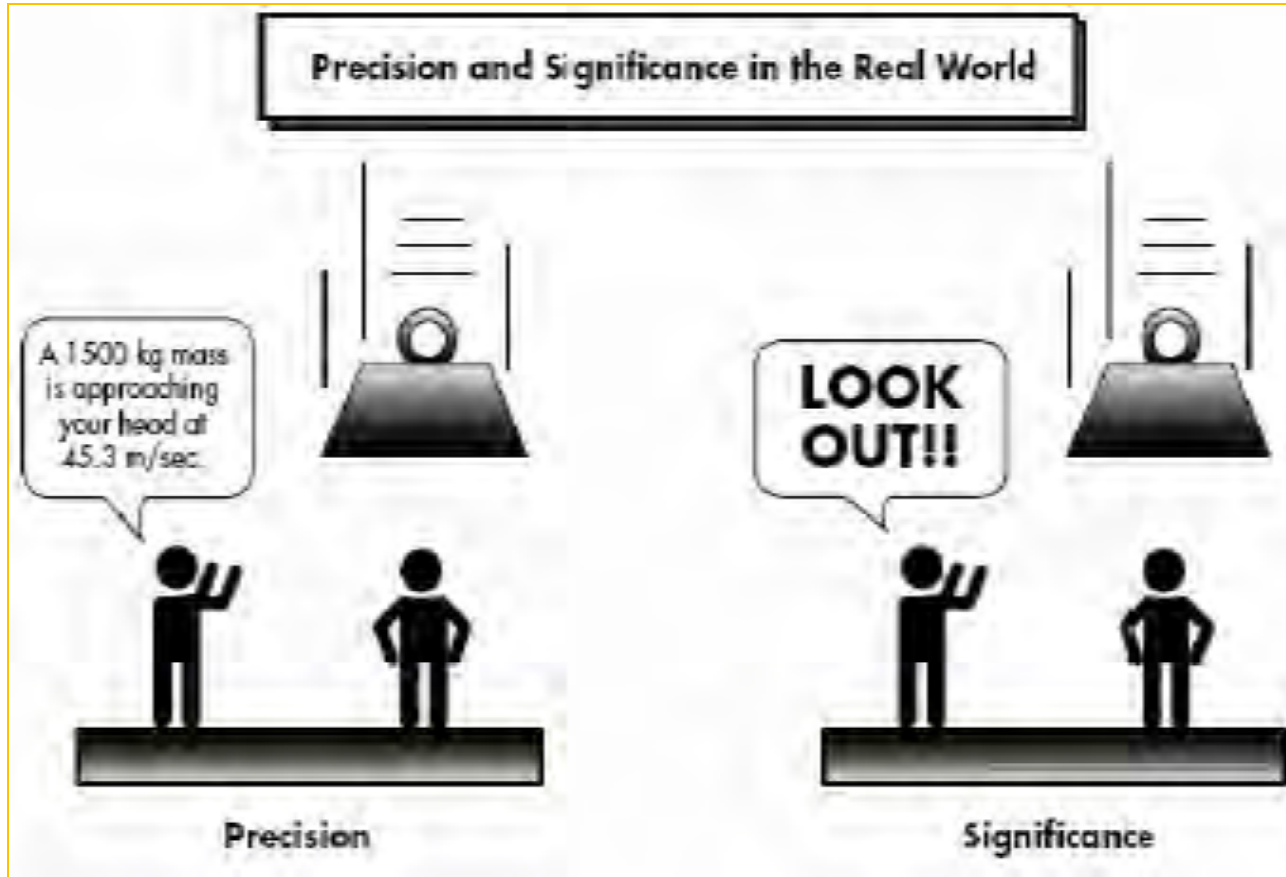


Fuzzy Logic

- **Fuzzy Logic** is used to describe and operate with **vague** definitions
 - Example (control of a cement plant)
 - if the temperature is high add a little cement and increase the water a lot
- **Fuzzy logic** is a form of **many-valued logic**
 - the truth values of variables may be any real number between 0 and 1 inclusive



Meaning vs precision



Difference between meaning and precision



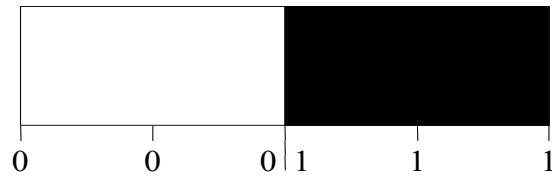
In brief ...

- **Boolean logic**
 - Boole (1854)
- **Classical set theory (1900)**
 - traditional sets (boolean belonging) and set operations
- **Multivariate logic**
 - Russell (1920)
 - Lukasiewicz (1930)
- **Fuzzy Logic theory**
 - Zadeh (1965)
 - extension of traditional sets (non boolean belonging) and operations on the elements
- **Neutrosophic logic**
 - Smarandache (1998)

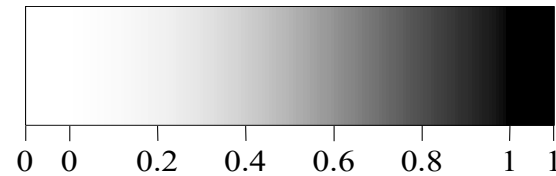


Crisp vs Fuzzy sets

- Fuzzy logic is a set of mathematical principles for representing knowledge based on the **degree** of belonging to a set



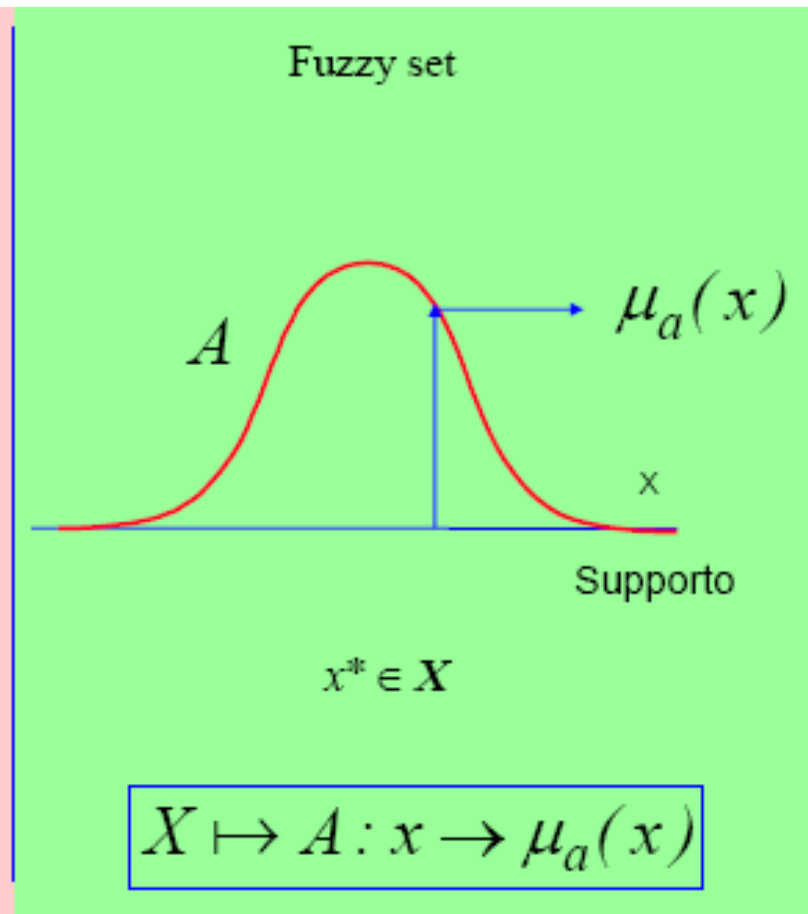
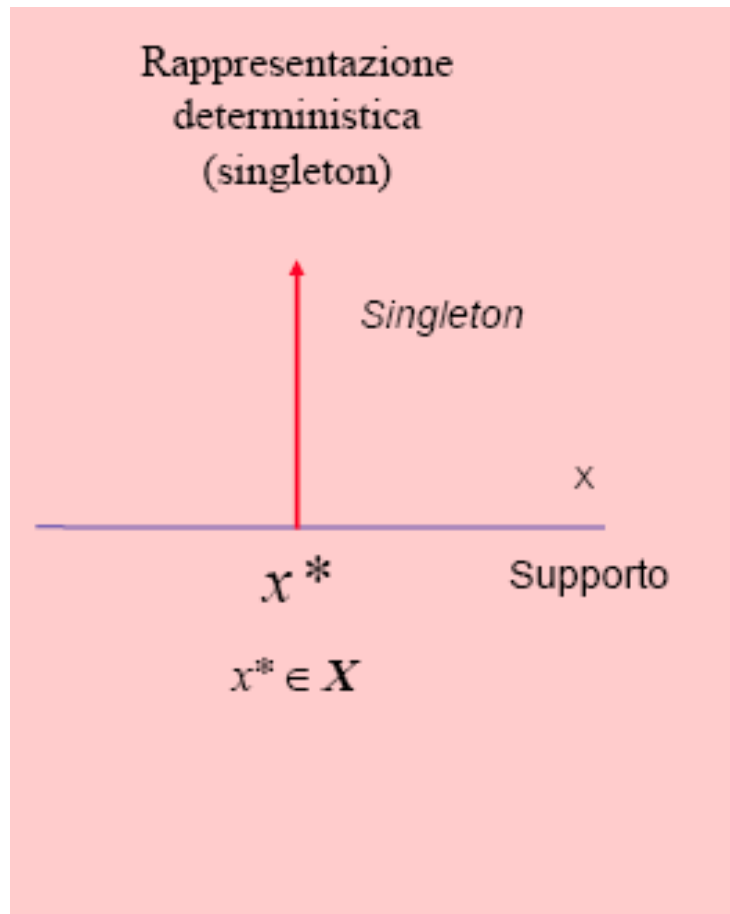
(a) Boolean Logic.



(b) Multi-valued Logic.



Crisp vs Fuzzy

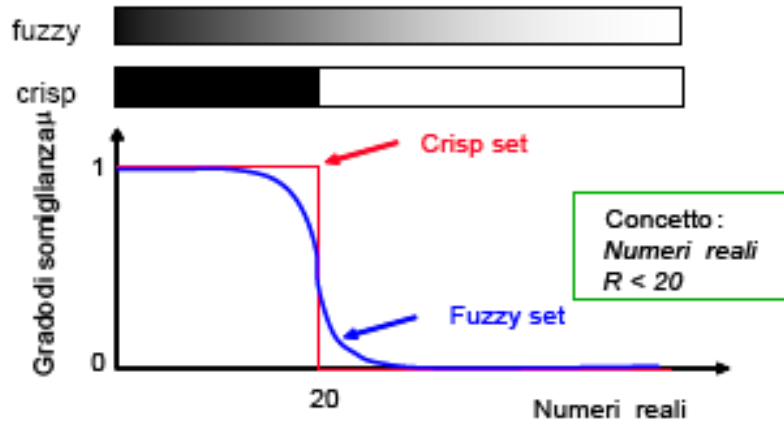


Linguistic variables

- A **linguistic variable** is a label that defines a concept
- This corresponds to a **membership function** (qualifier)
- It determines the **degree of truth** μ of any support value

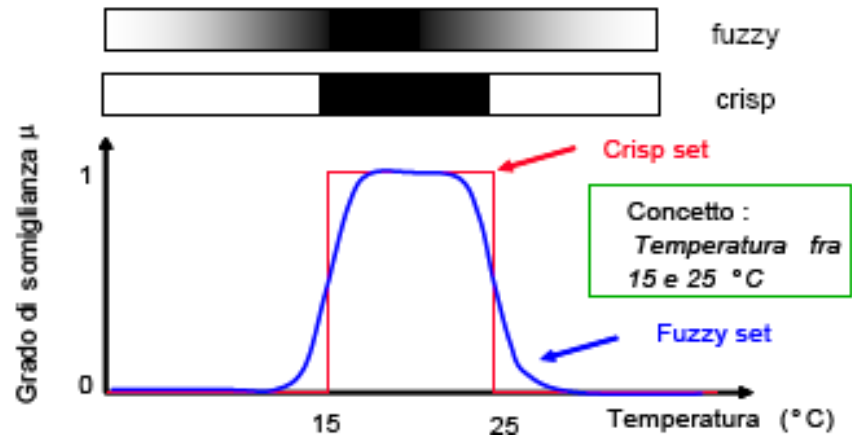


Linguistic variables

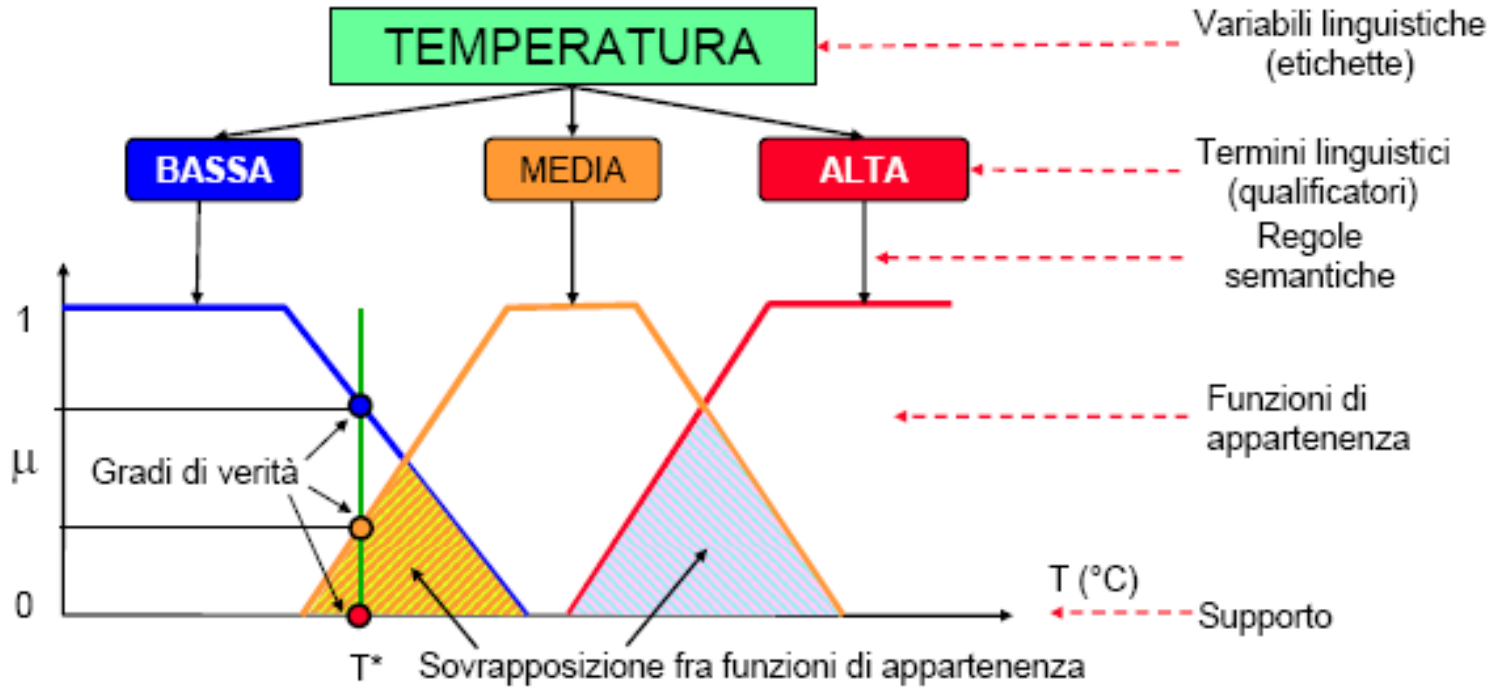


Numeri reali

Temperatura



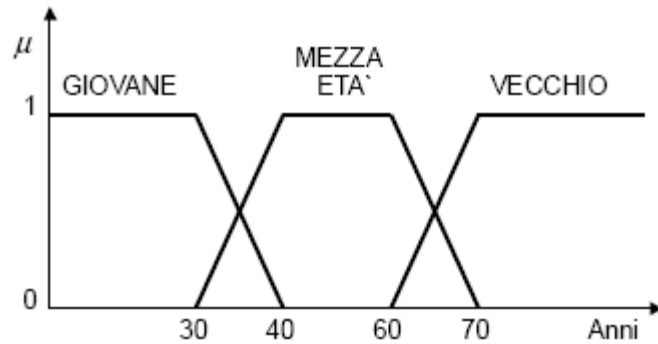
Linguistic variables



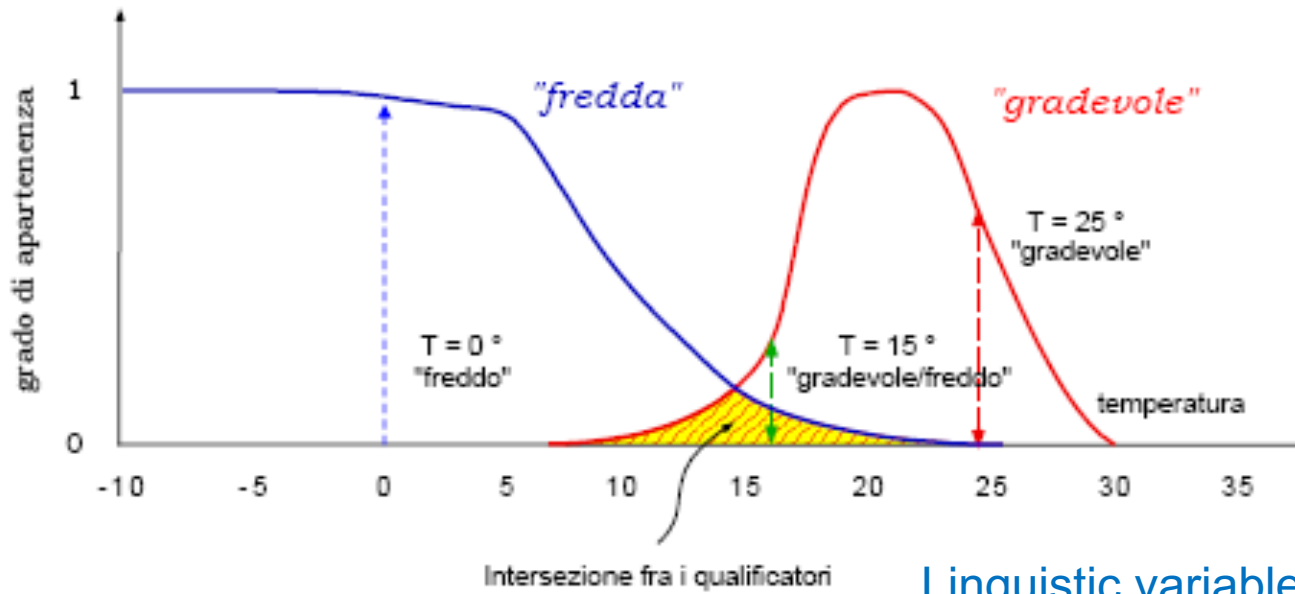
Esempio di fuzzificazione



Linguistic variables examples



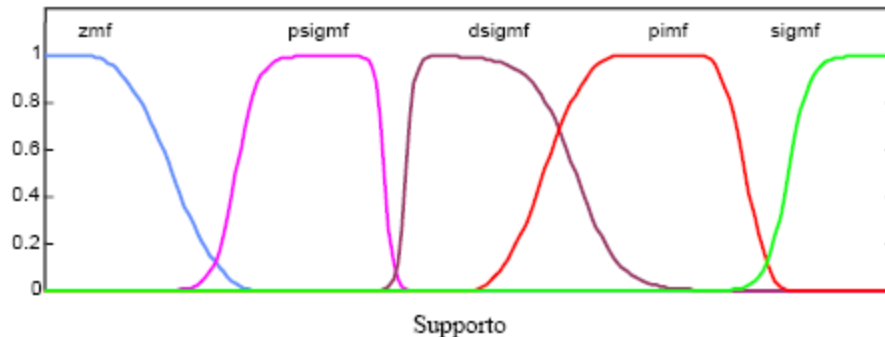
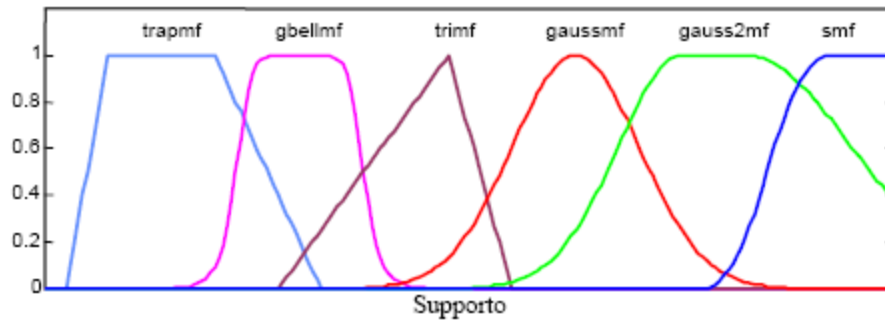
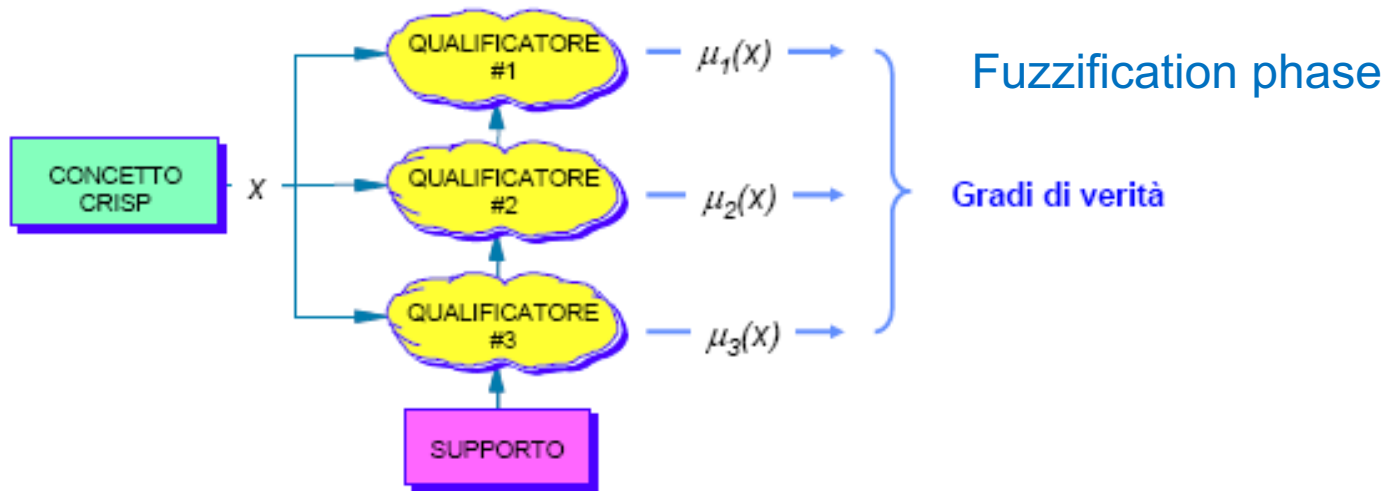
Linguistic variable "anni"



Linguistic variable "temperatura"



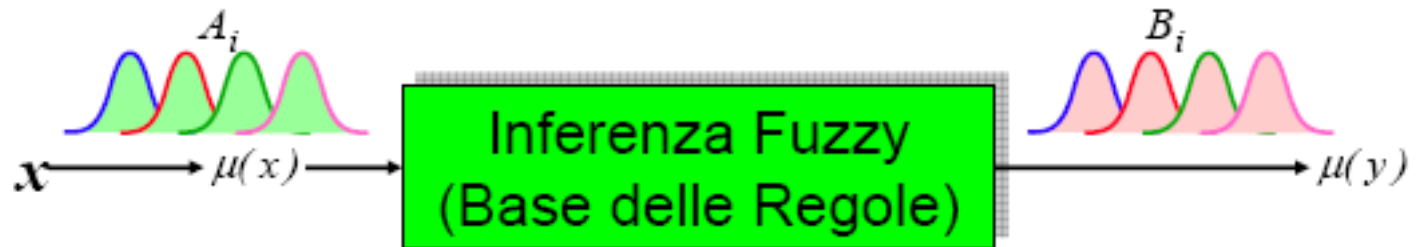
Fuzzification



Kinds of memberships



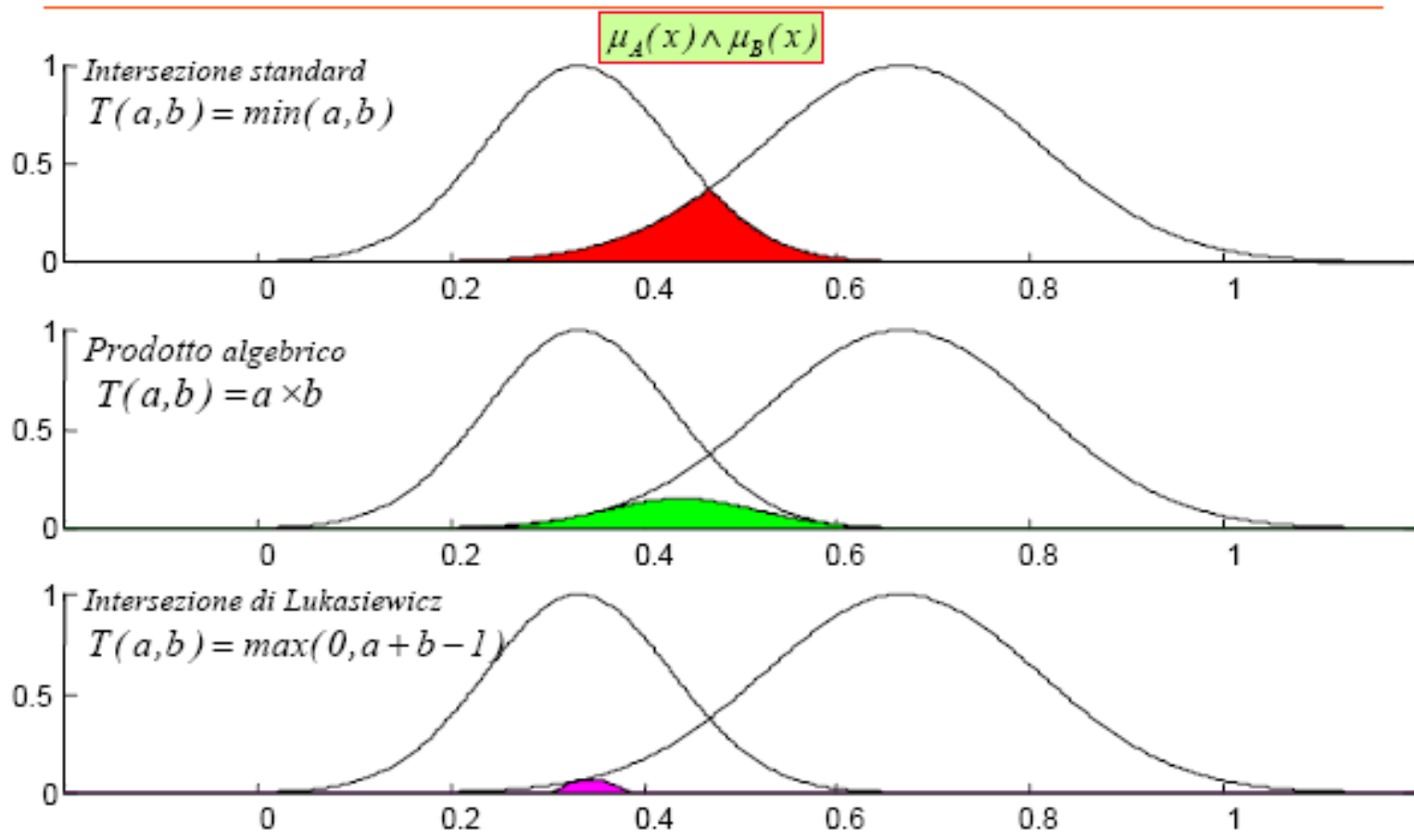
Inference system



$R_i : IF \underbrace{x_1 \text{ is } A_1 \text{ AND } x_2 \text{ is } A_2}_{\text{antecedente}} THEN \underbrace{y \text{ is } B}_{\text{conseguente}}$



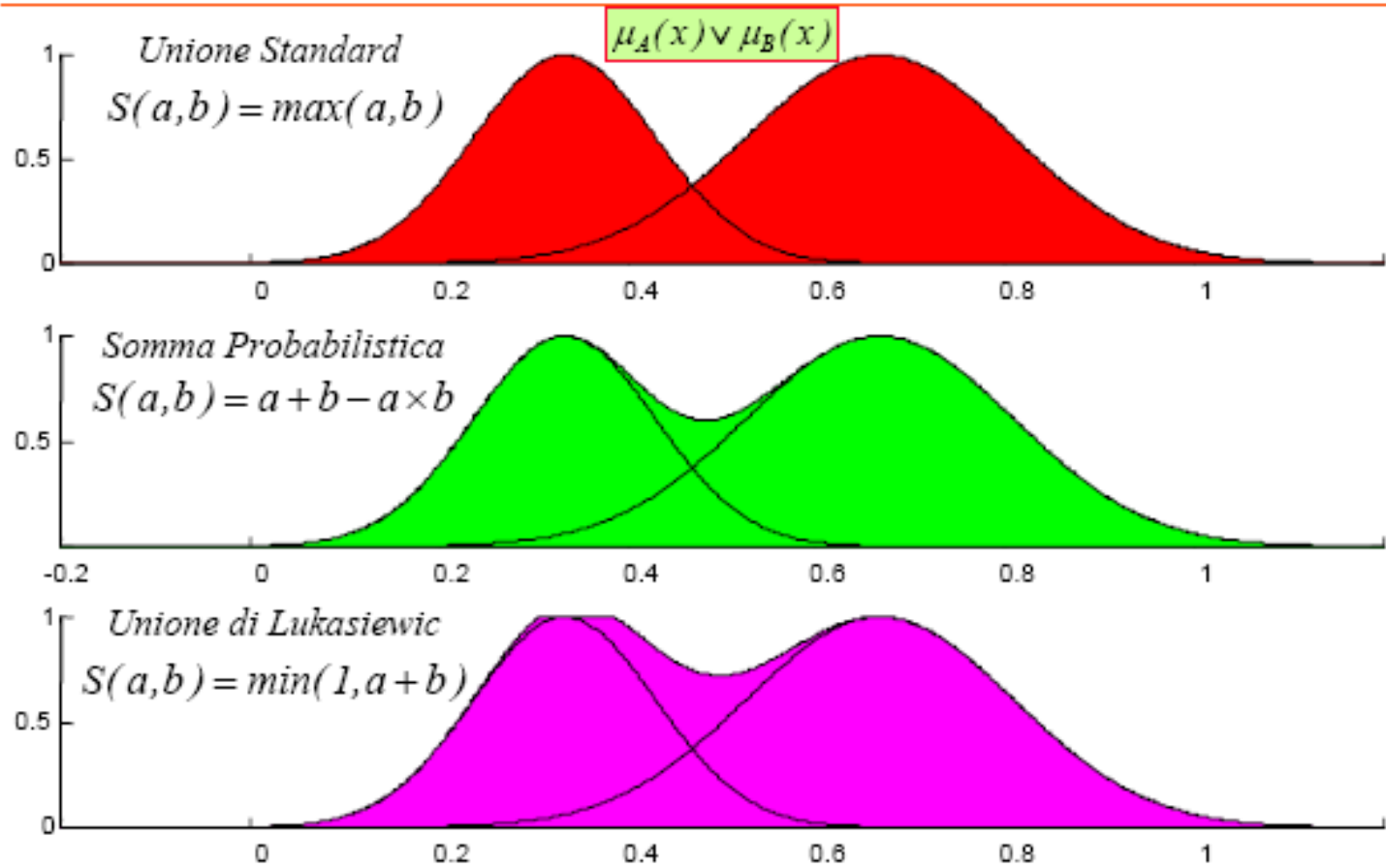
Operators



Intersection operators



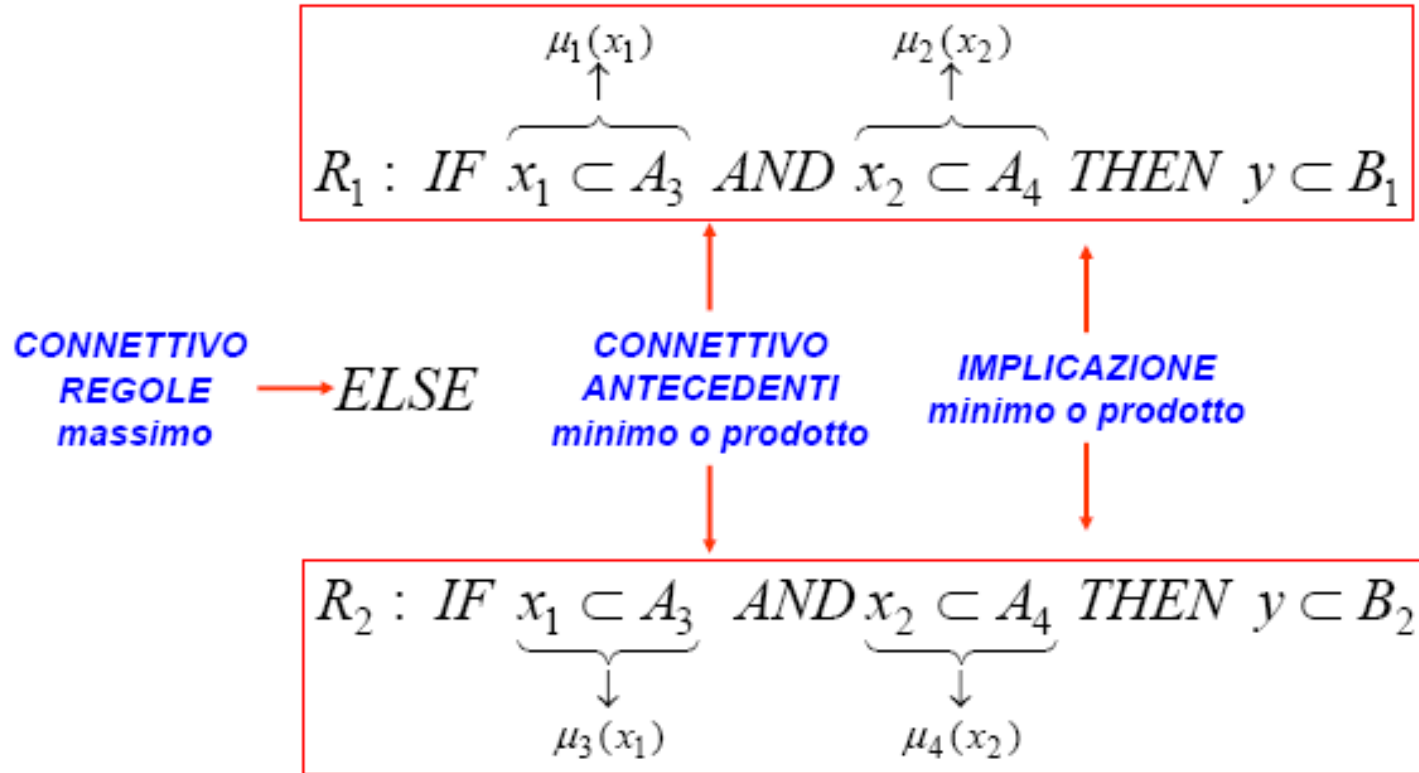
Operators



Union operators



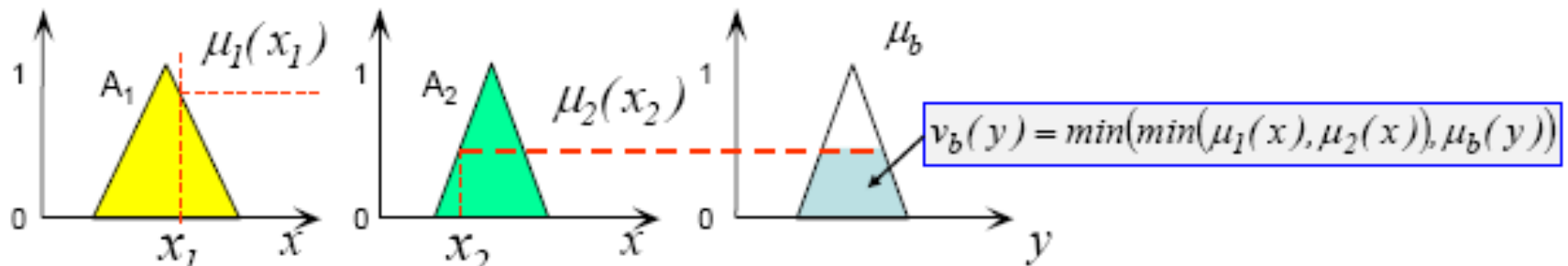
Inference rules



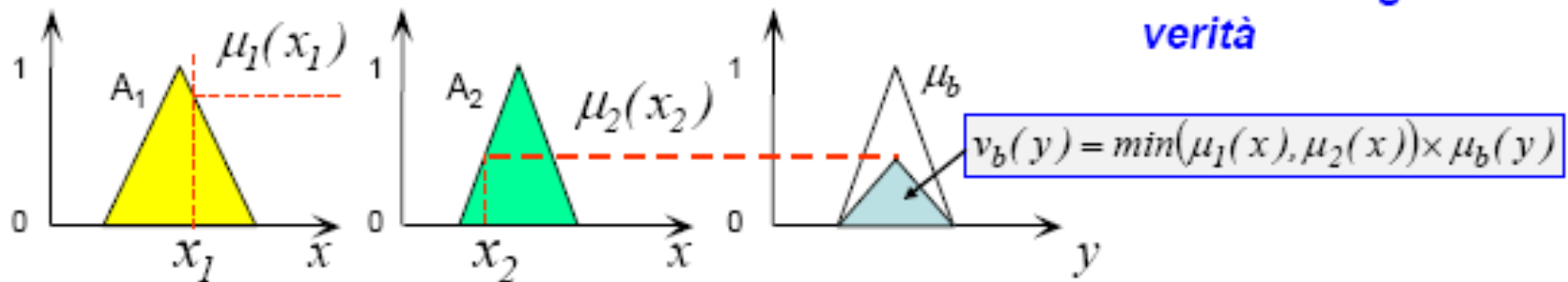
Inference (Mamdani)

IF (x_1 is A_1) *AND* (x_2 is A_2) *THEN* y is B

$$\mu_b(y) = (\mu_1(x^*) \wedge \mu_2(x^*)) \wedge \mu_b(y)$$



**Nell'implicazione prevale
l'antecedente con minore grado di
verità**



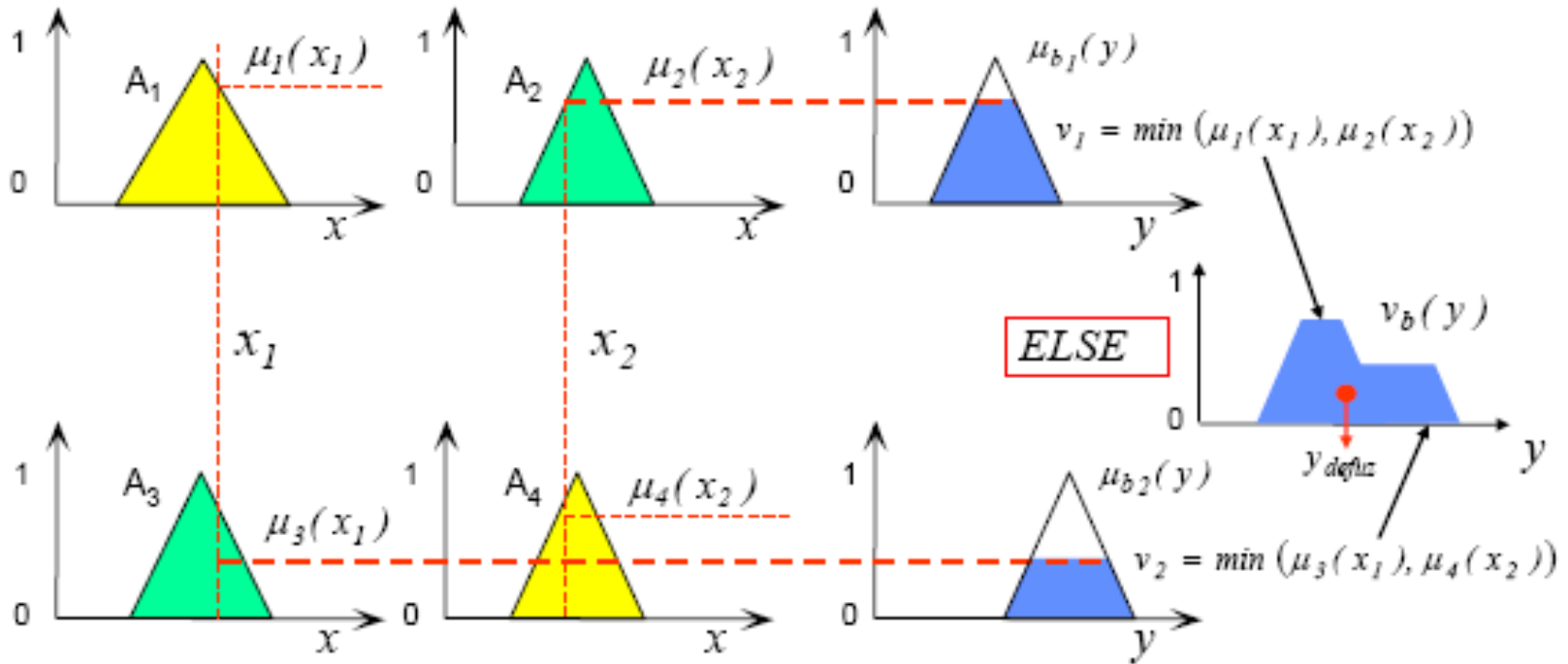
Mamdani based inference



Defuzzification

Prima regola

IF $x_1 \in A_1$ AND $x_2 \in A_2$ THEN $y \in B_1$



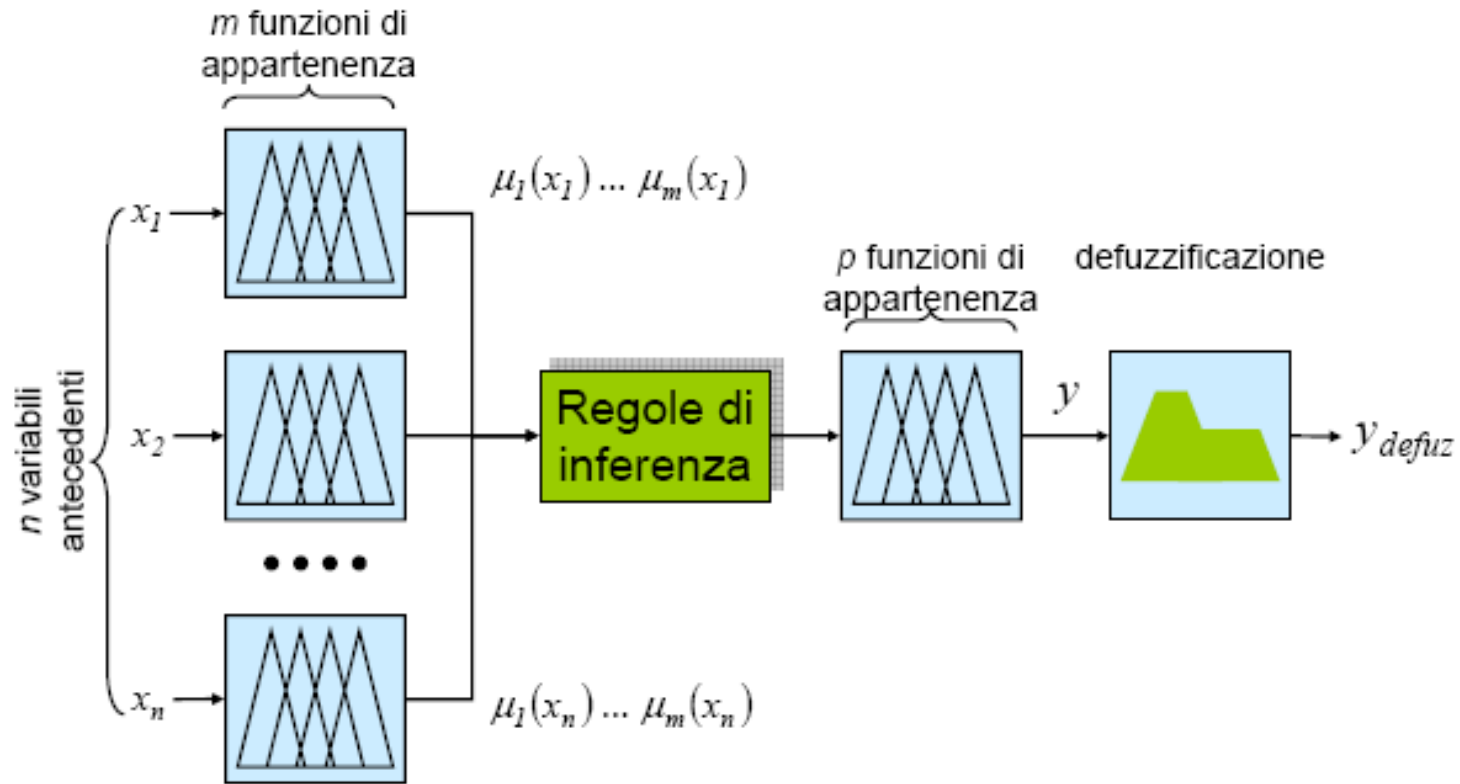
Seconda regola

IF $x_1 \in A_3$ AND $x_2 \in A_4$ THEN $y \in B_2$

Inference and defuzzification



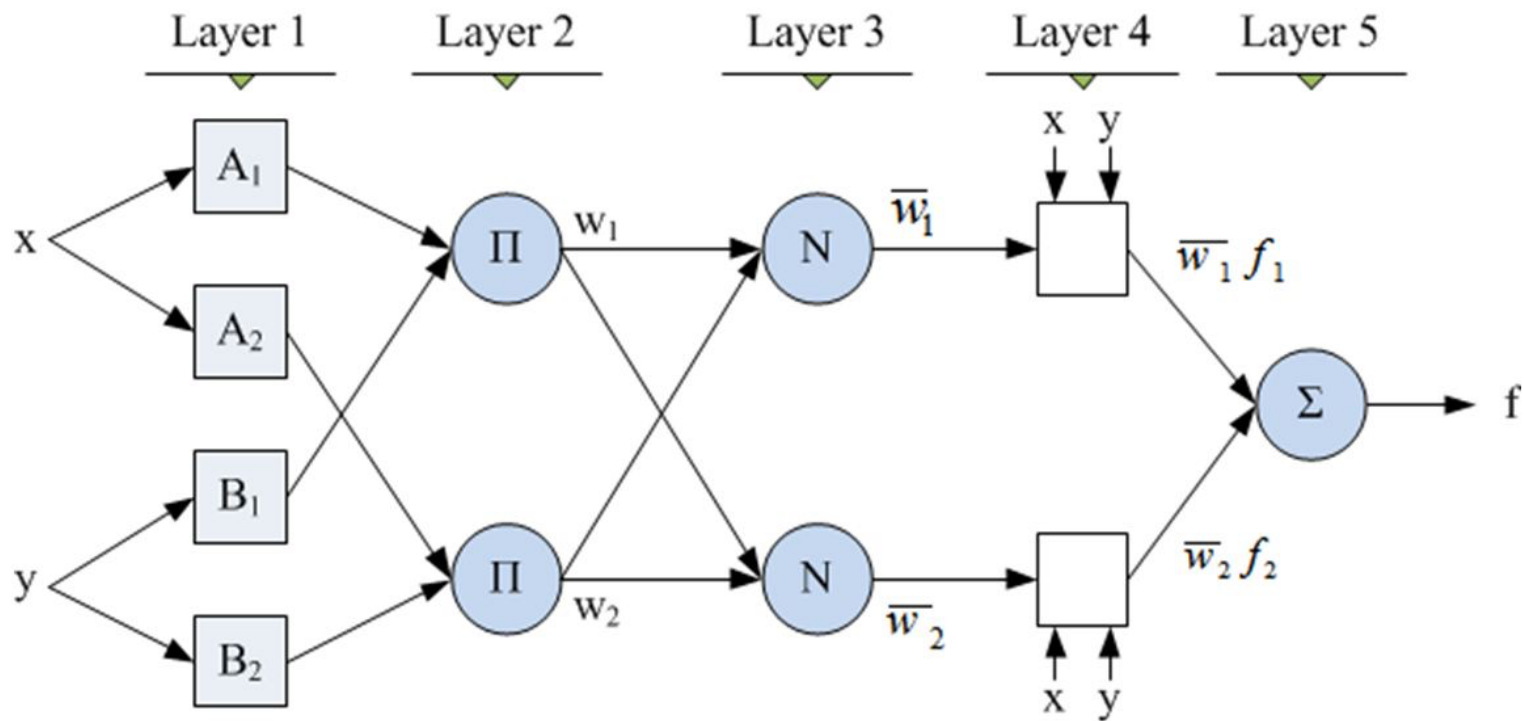
Fuzzy systems



... neuro-fuzzy systems



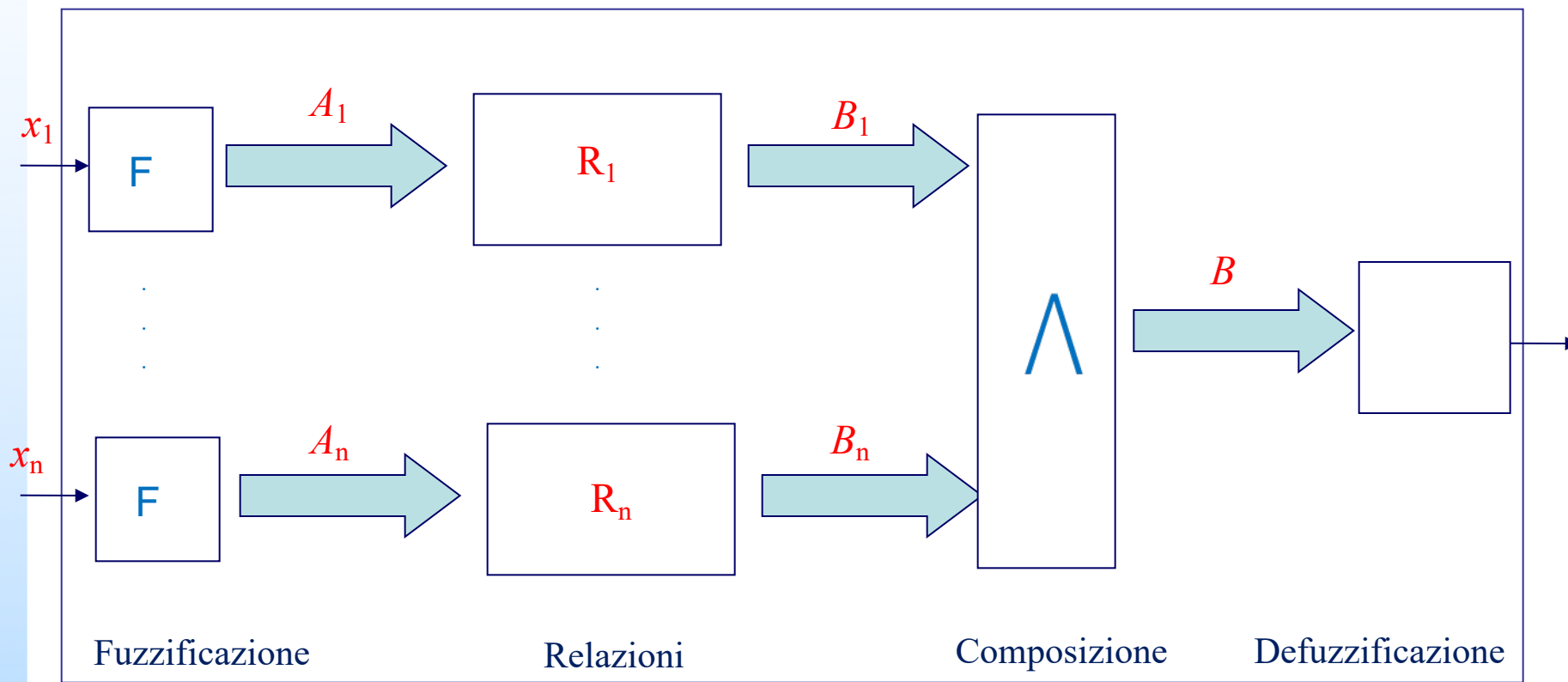
ANFIS



ANFIS model



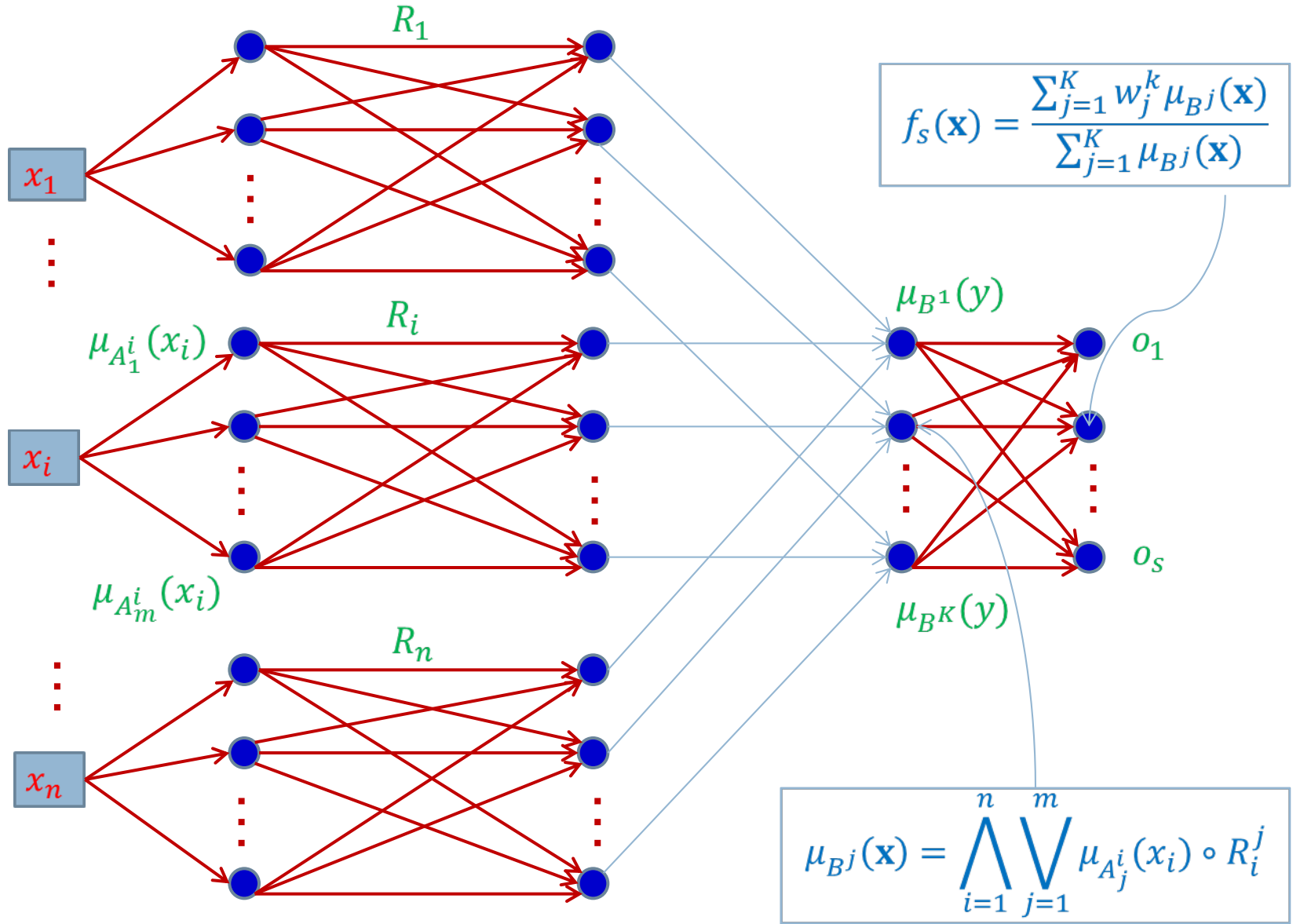
FRNN



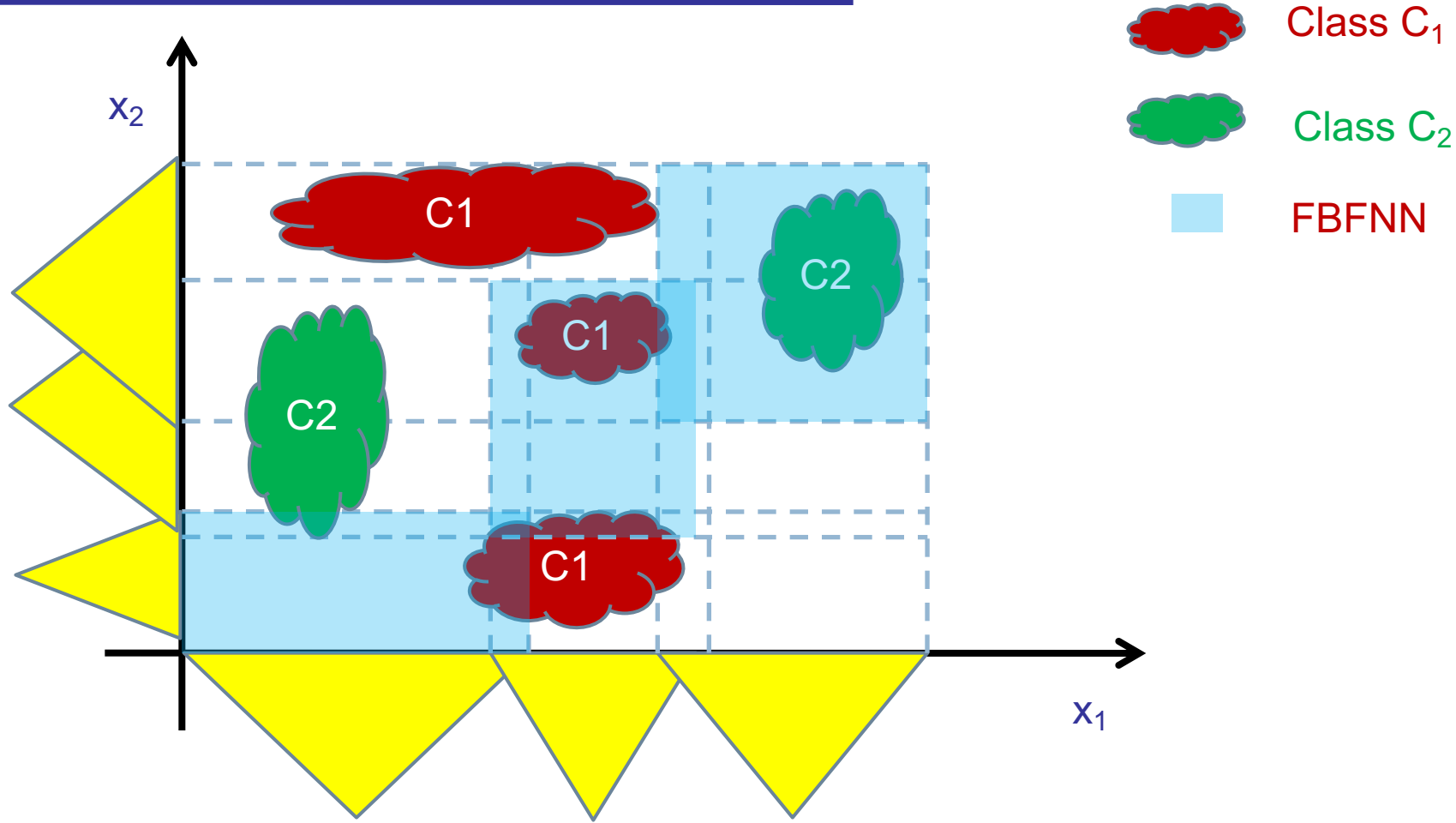
Fuzzy Relation Neural Network Model



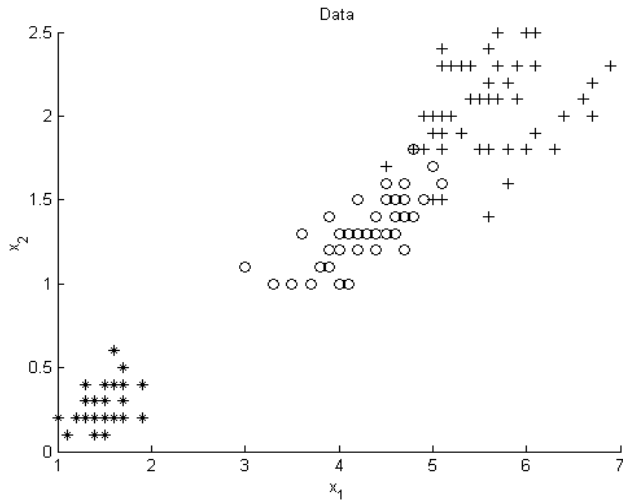
FRNN



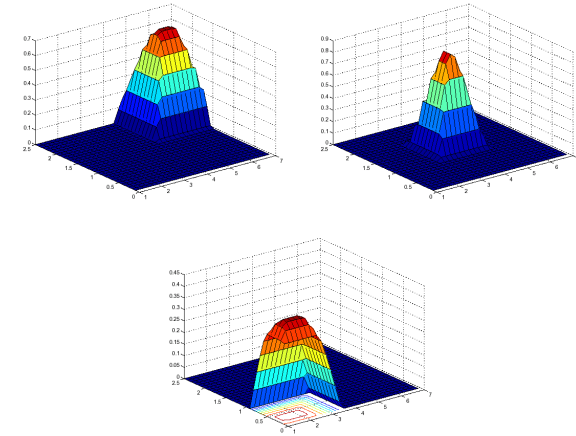
Granulation



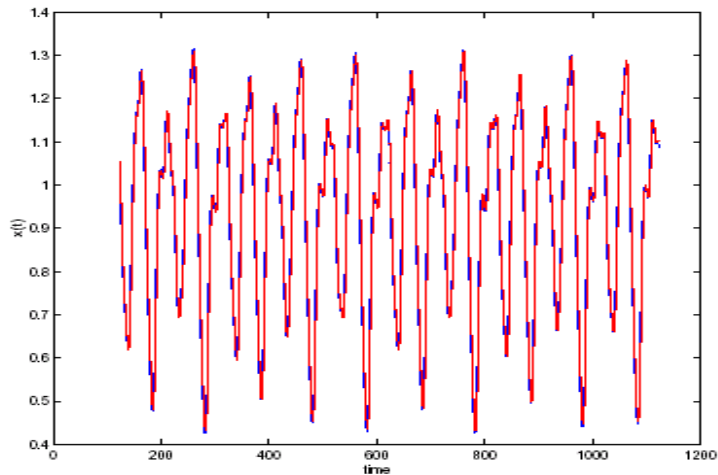
Some results



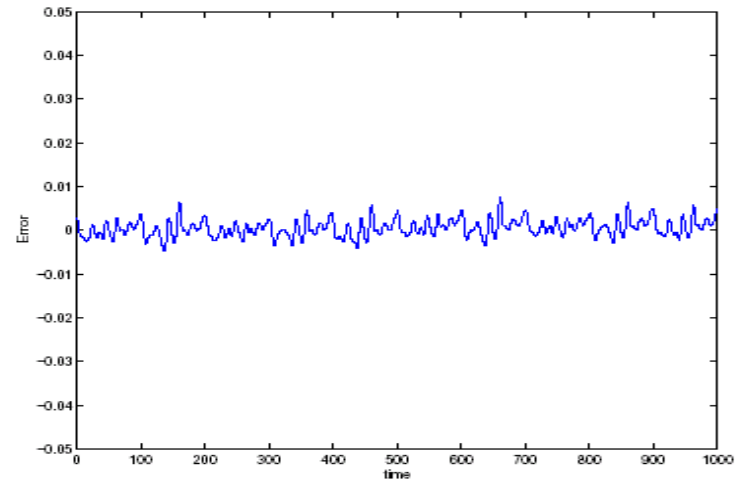
IRIS data set



Memberships



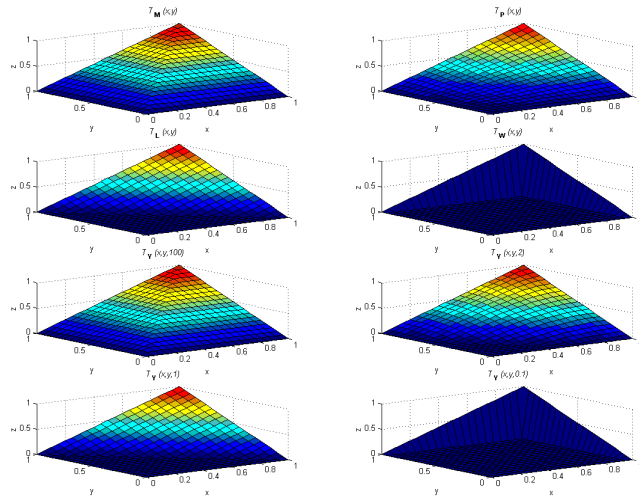
Mackey-Glass chaotic time series



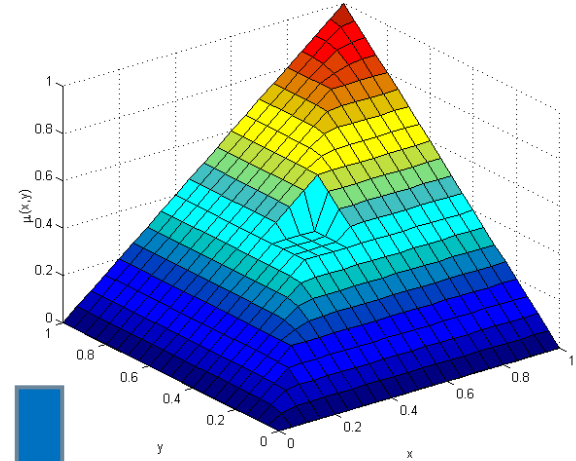
Residum



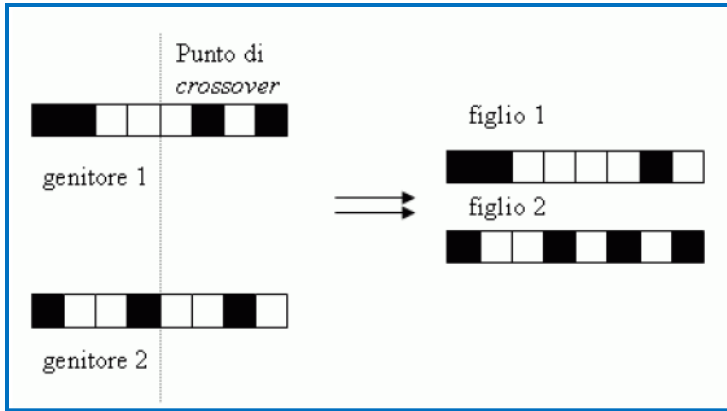
Norm generalization



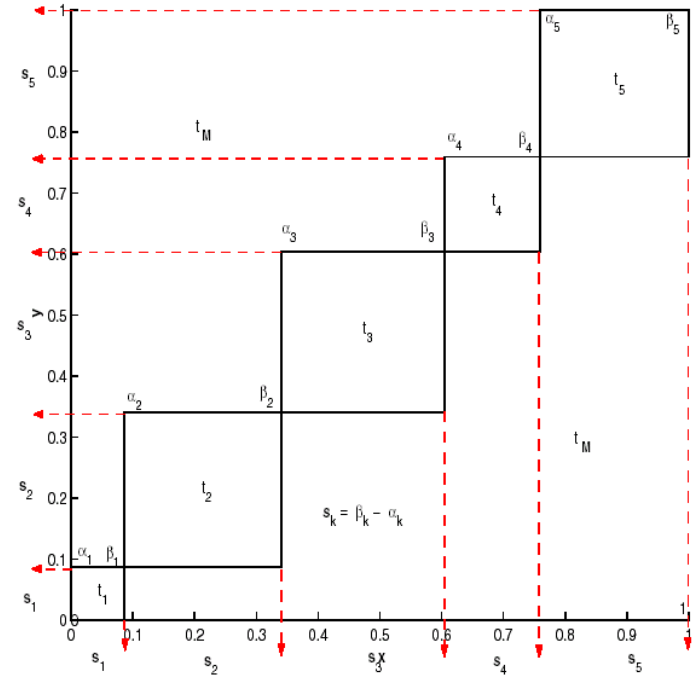
Ordinal sums



t-norms and t-conorms



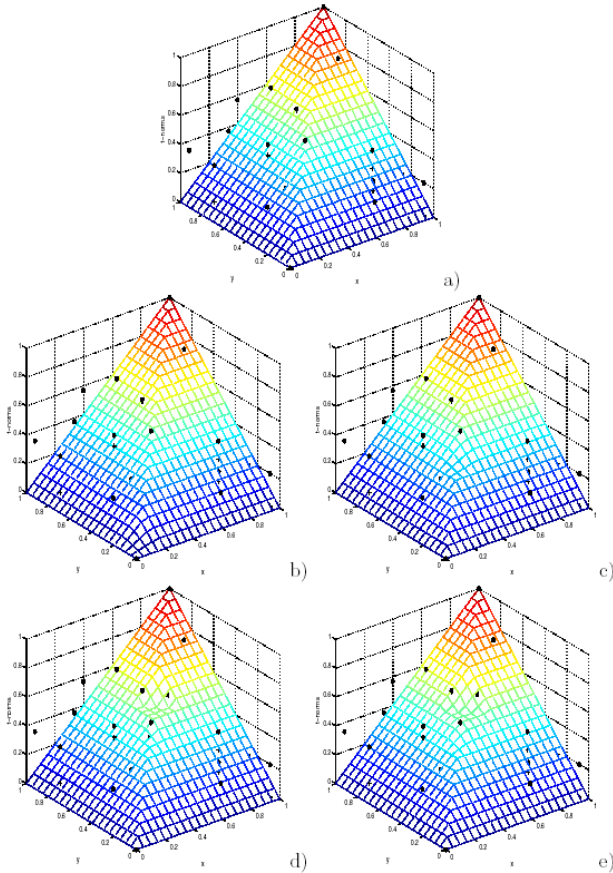
Chromosome



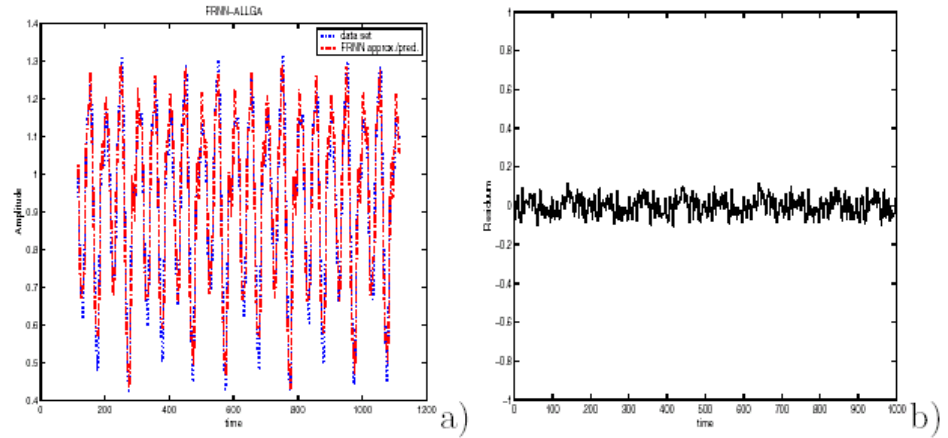
Parameters of Ordinal Sums



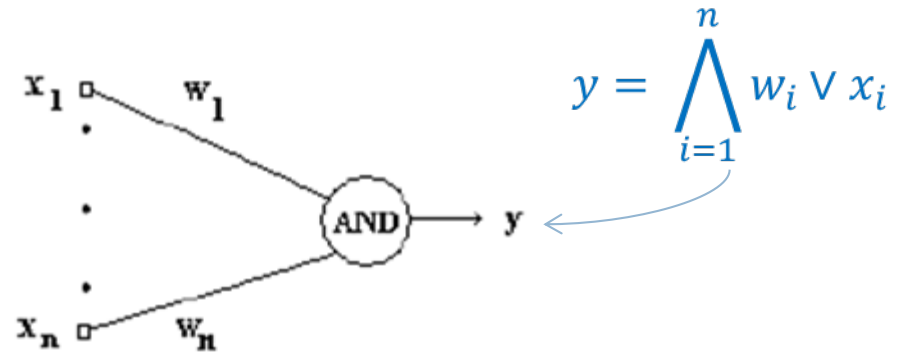
Neuron generalization



Zimmermann and Zysno data set



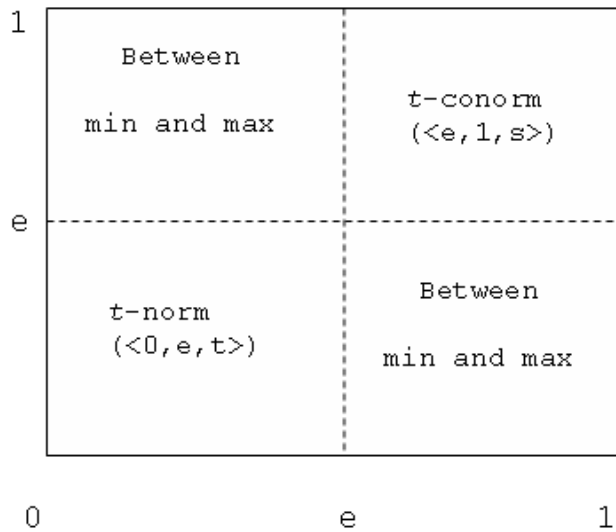
FRNN inference system



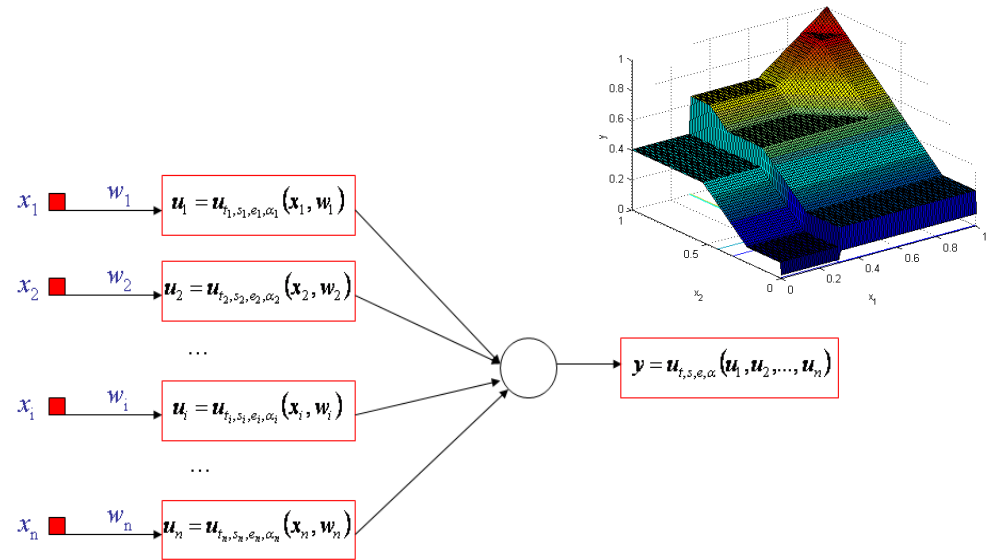
AND/OR neuron based on OS



Uninorm



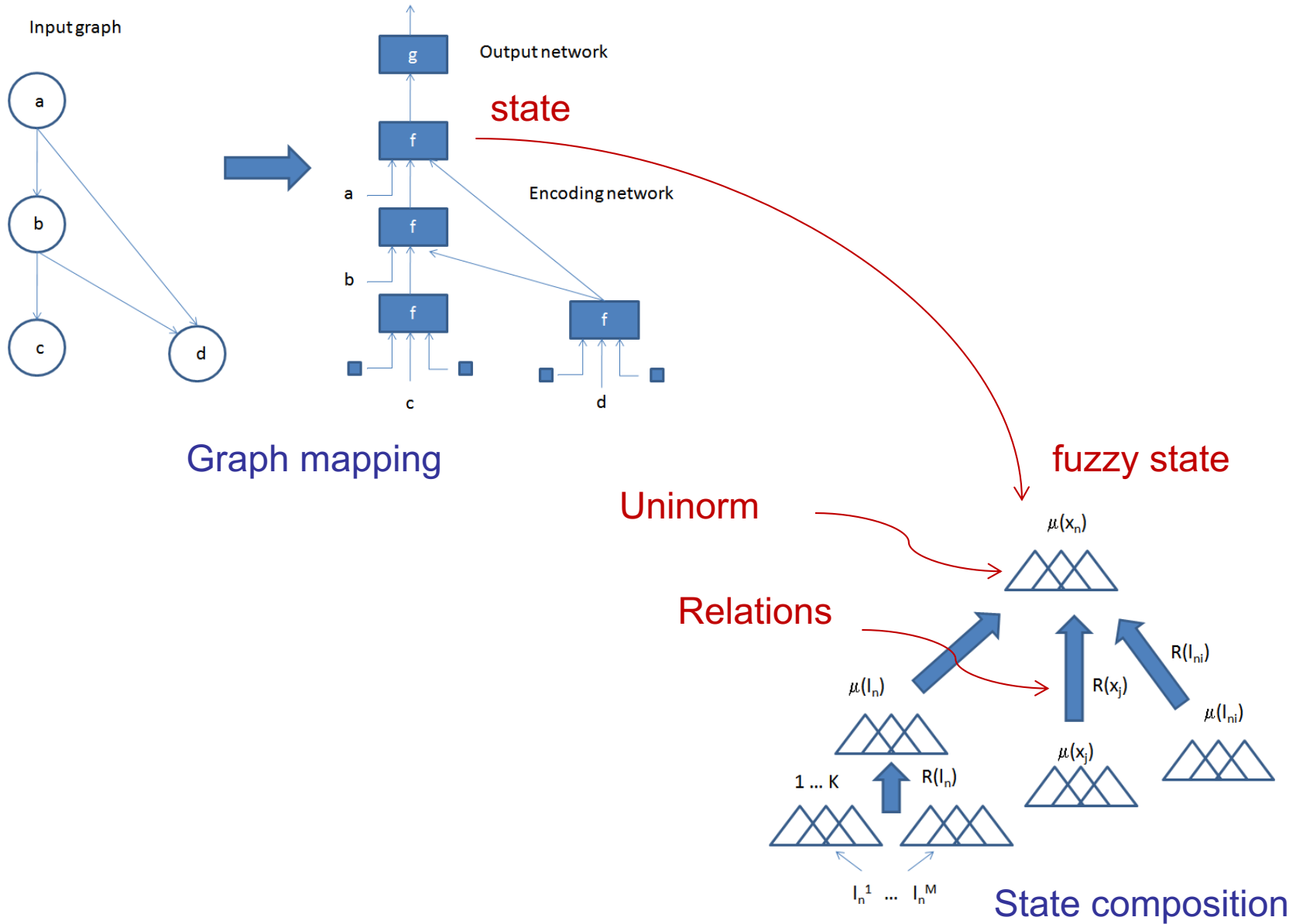
Uninorm representation



Uninorm based neuron



Structured data



Multimedia Event Database

- Materials
 - Newscast
 - Commercials
 - Cartoons
 - Football
 - Musics
 - Weather Forecasts
 - Talk Shows



Fuzzy c-means

- **Fuzzy C-Means (FCM)**
 - unsupervised clustering
 - labeling of the classes



Music Emotion Recognition

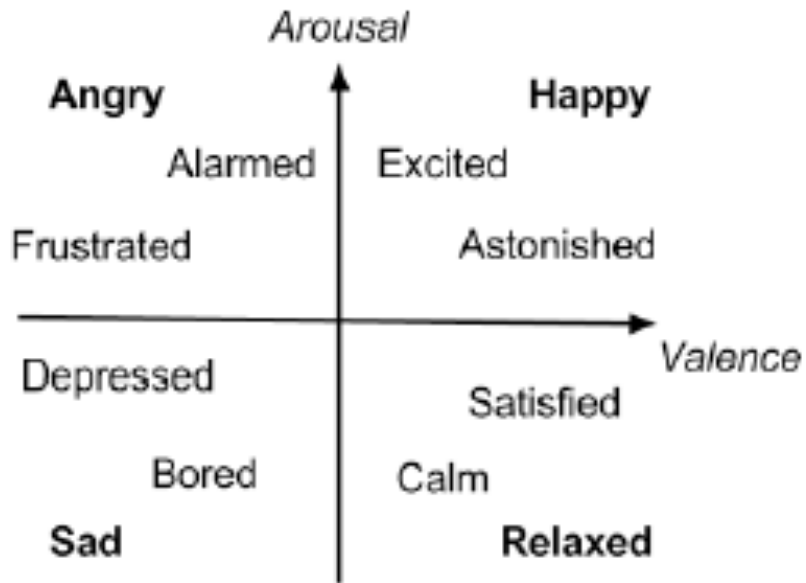


Fig. 1 Two-dimensional emotion representation in Thayer's model.



Features

- Used features
 - Intensity
 - Rhythm
 - Key
 - Harmony
 - Spectral centroid



System architecture

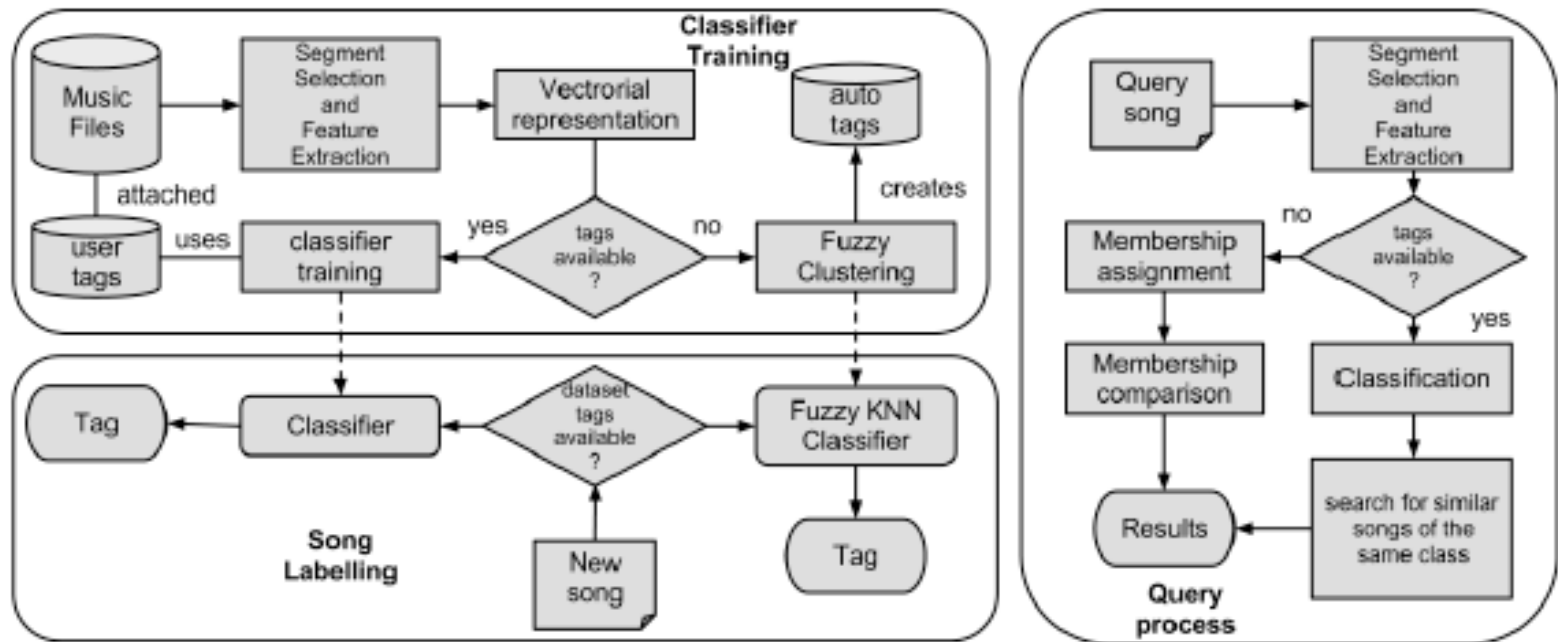


Fig. 2 System architecture.



Fuzzy c-means

- Objective function

$$J_{\text{FCM}} = \sum_{k=1}^N \sum_{i=1}^c (\mu_{ik})^m \|\mathbf{x}_k - \mathbf{v}_i\|^2$$

- centroids and memberships

$$\mathbf{v}_i = \frac{\sum_{k=1}^N (\mu_{ik})^m \mathbf{x}_k}{\sum_{k=1}^N (\mu_{ik})^m}$$

$$\mu_{ik} = \frac{1}{\sum_{j=1}^c \left(\frac{d_{ik}}{d_{jk}}\right)^{\frac{2}{m-1}}}$$

- where

$$d_{ik} = \|\mathbf{x}_k - \mathbf{v}_i\|^2$$

$$\sum_{i=1}^c \mu_{ik} = 1$$

- Update: rough fuzzy c-means



Classification

Table 1 Results for 10-fold cross-validation with three different machine learning approaches considered for the automatic song labeling task.

Classifier	TP Rate	FP Rate	Precision	Recall
Bayes	0.659	0.114	0.66	0.659
SVM	0.727	0.091	0.73	0.727
MLP	0.705	0.099	0.705	0.705



Results examples

- Target: “La domenica delle salme” – De Andrè
 - Classified as **Sad**
 - The first 4 similar songs
 - “Il suonatore Jones” – De Andrè (**Sad**)
 - “Comptine d’un autre été” – Yann Tiersen (**Relax**)
 - “Vespertine” – Bjork (**Relax**)
 - “Un blasfemo” – De Andrè (**Sad**)



Example of results

- Target: “Musclemuseum” – Muse
 - Classified as **Angry**
 - The first 4 similar songs
 - “My life for one more day” – Helloween (**Angry**)
 - “Mentre tutto scorre” – Negramaro (**Angry**)
 - “Space Dementia” – Muse (**Angry**)
 - “Hysteria” – Muse (**Angry**)

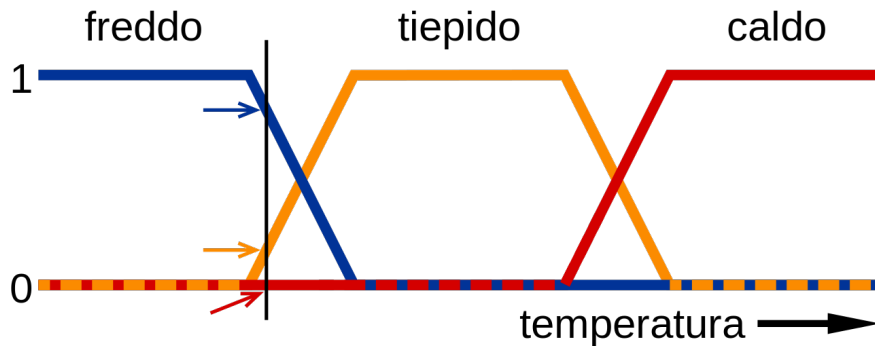


Example of results

- Target: “L’angioletto in blue jeans” – Zecchino d’oro
 - Classified as **Happy**
 - The first 4 similar songs
 - “La sveglia biricchina” – Zecchino d’oro (**Happy**)
 - “Non capirò mai” – Per Cortese (**Happy**)
 - “La Valse Des Vieux Os” – Yann Tiersen (**Relax**)
 - “Il topo zorro” – Zecchino d’oro (**Happy**)



Fuzzy Logic

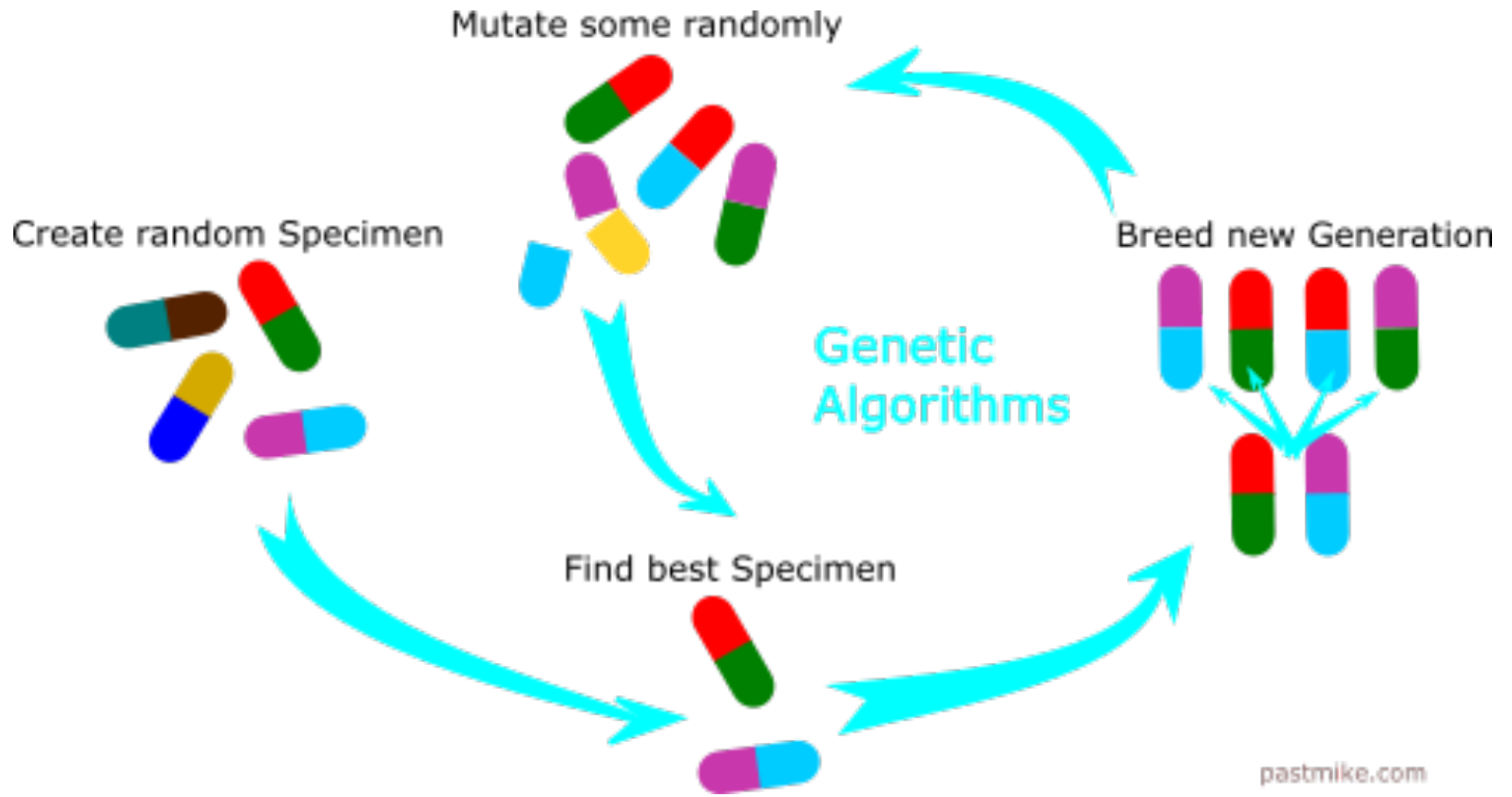


Linguistic variables

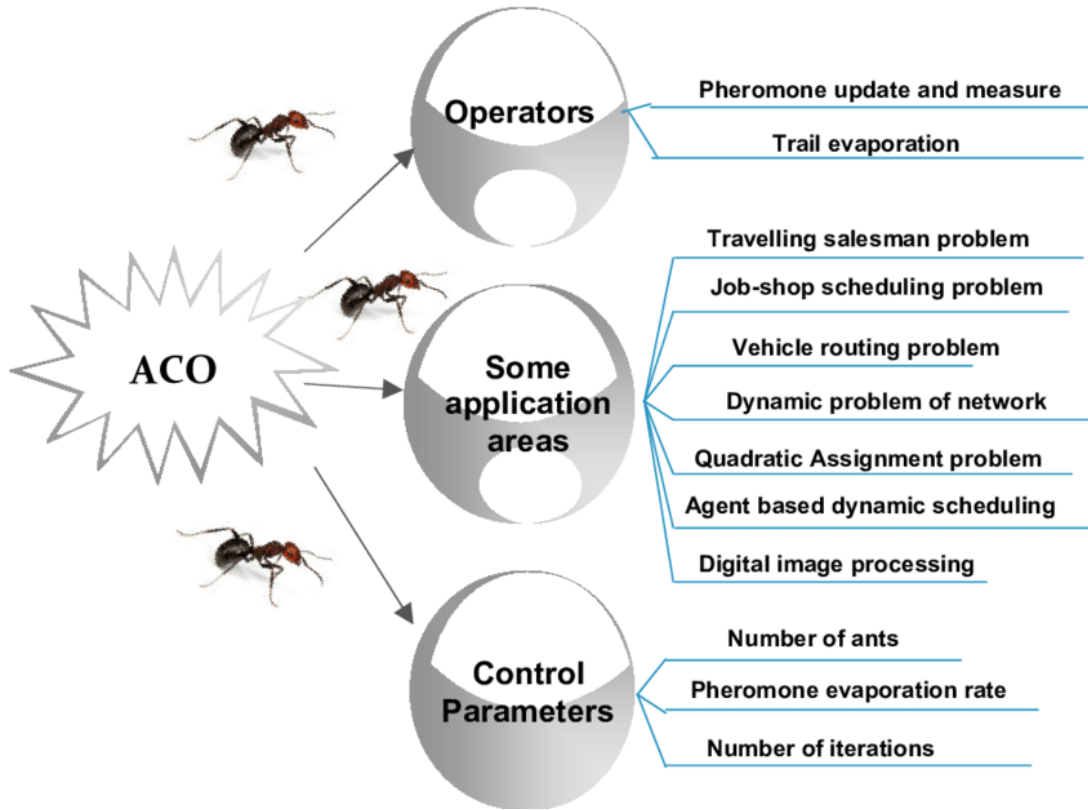
The screenshot shows the FIS Editor interface for a fuzzy inference system named 'mancia'. The main workspace displays a diagram with two input fuzzy variables, 'servizio' and 'cibo', each with a bell-shaped membership function. These are connected to a central box labeled 'mancia (mamdani)'. The output is another fuzzy variable 'mancia' with three triangular membership functions. Below the workspace, the FIS Name is 'mancia' and the FIS Type is 'mamdani'. A configuration panel includes dropdown menus for 'And method' (min), 'Or method' (max), 'Implication' (min), 'Aggregation' (max), and 'Defuzzification' (centroid). The 'Current Variable' section has fields for Name and Type, and a Range field. 'Help' and 'Close' buttons are at the bottom right. A status bar at the bottom indicates 'System "mancia": 2 inputs, 1 output, and 3 rules'.

Fuzzy inferrece

Genetic Algorithms



Ant Colony Optimization



ACO scheme

