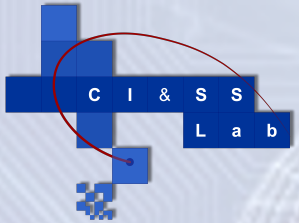


UNIVERSITÀ PARTHENOPE
DiST
DIPARTIMENTO DI SCIENZE E TECNOLOGIE

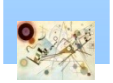
Intelligent Signal Processing

Fuzzy Systems

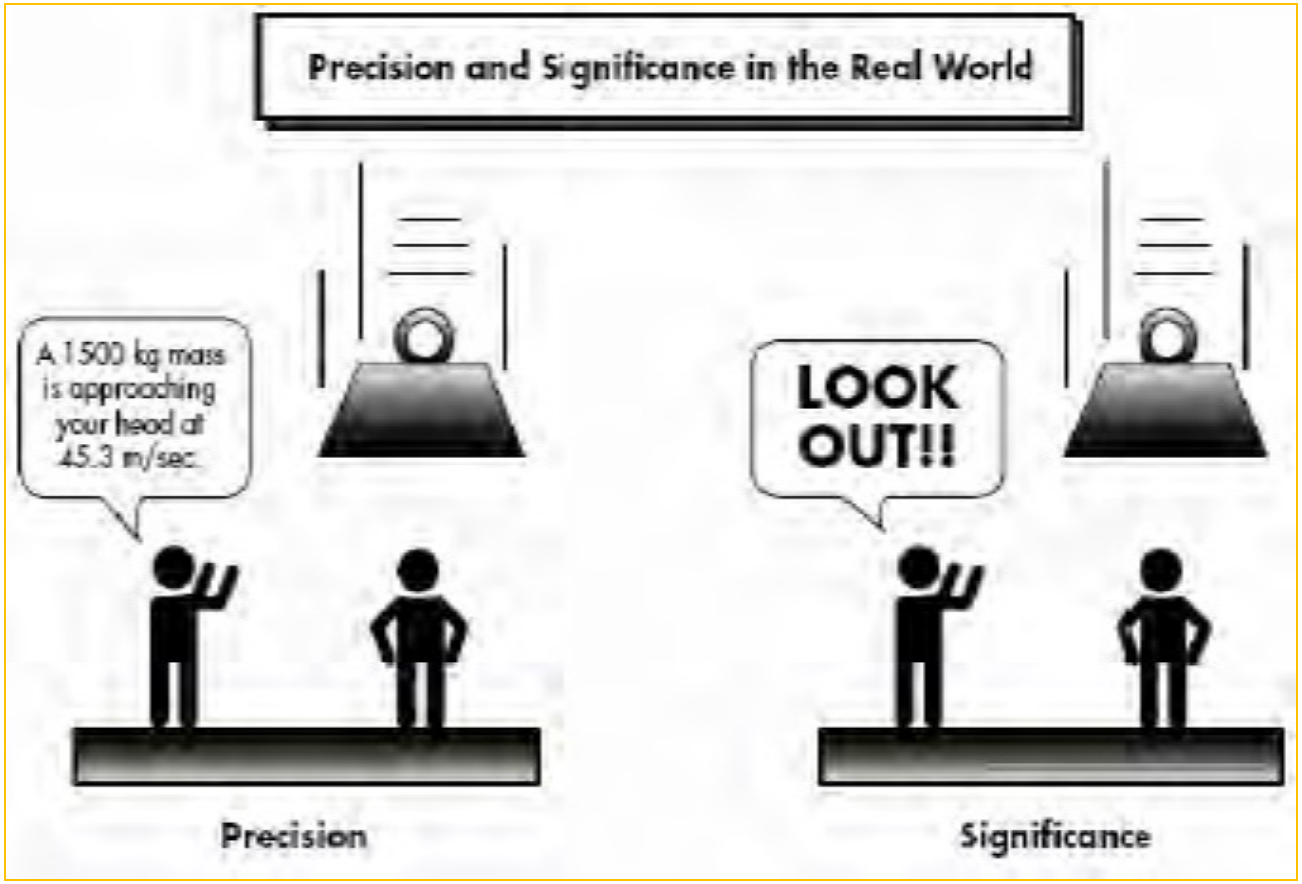
Angelo Ciaramella

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



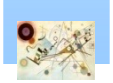
Meaning vs precision



Difference between meaning and precision

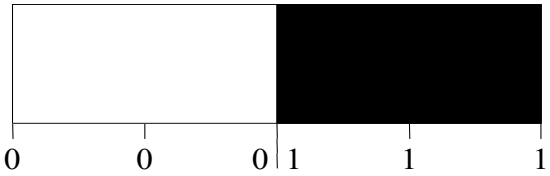
In brief …

- 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)

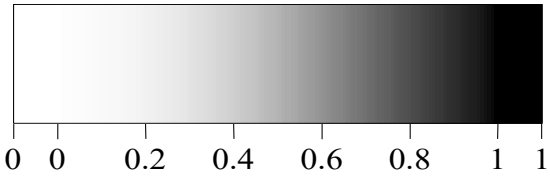


Crisp vs Fuzzy sets

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

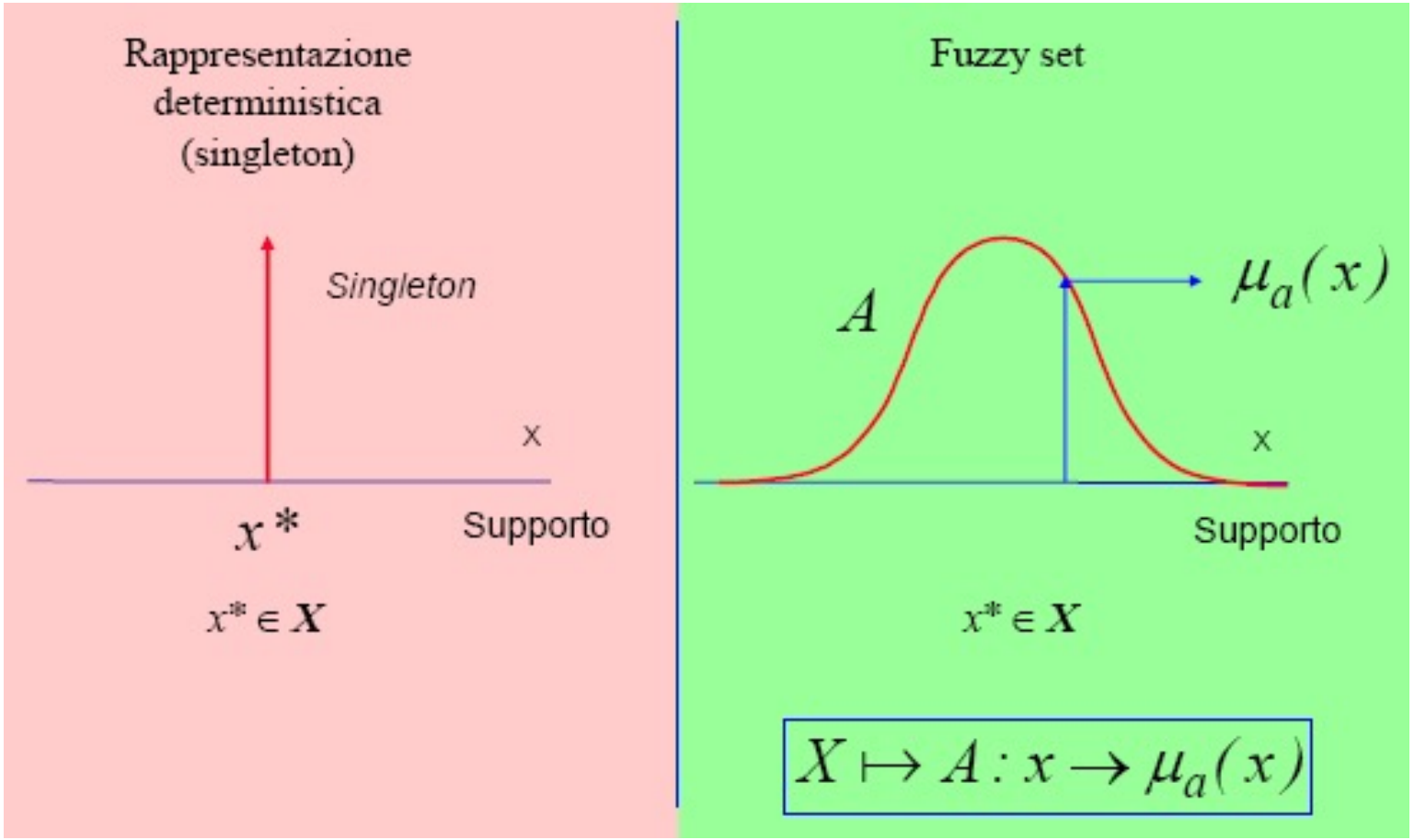


(*a*) Boolean Logic.



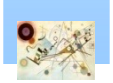
(*b*) Multi-valued Logic.

Crisp vs Fuzzy

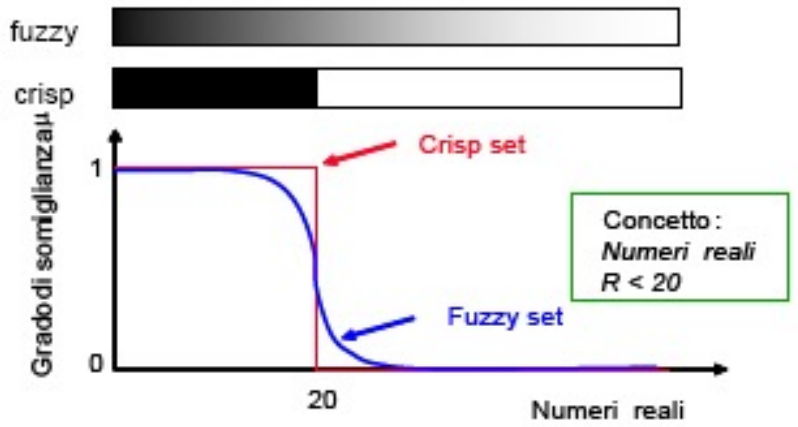


Linguistic variables

- 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

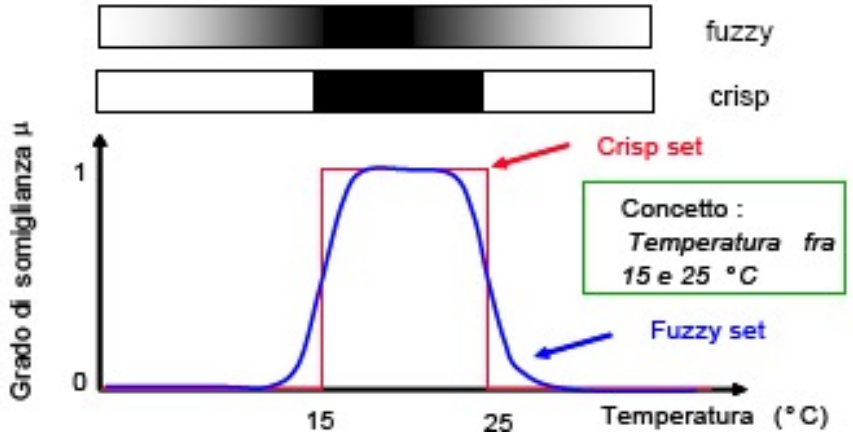


Linguistic variables

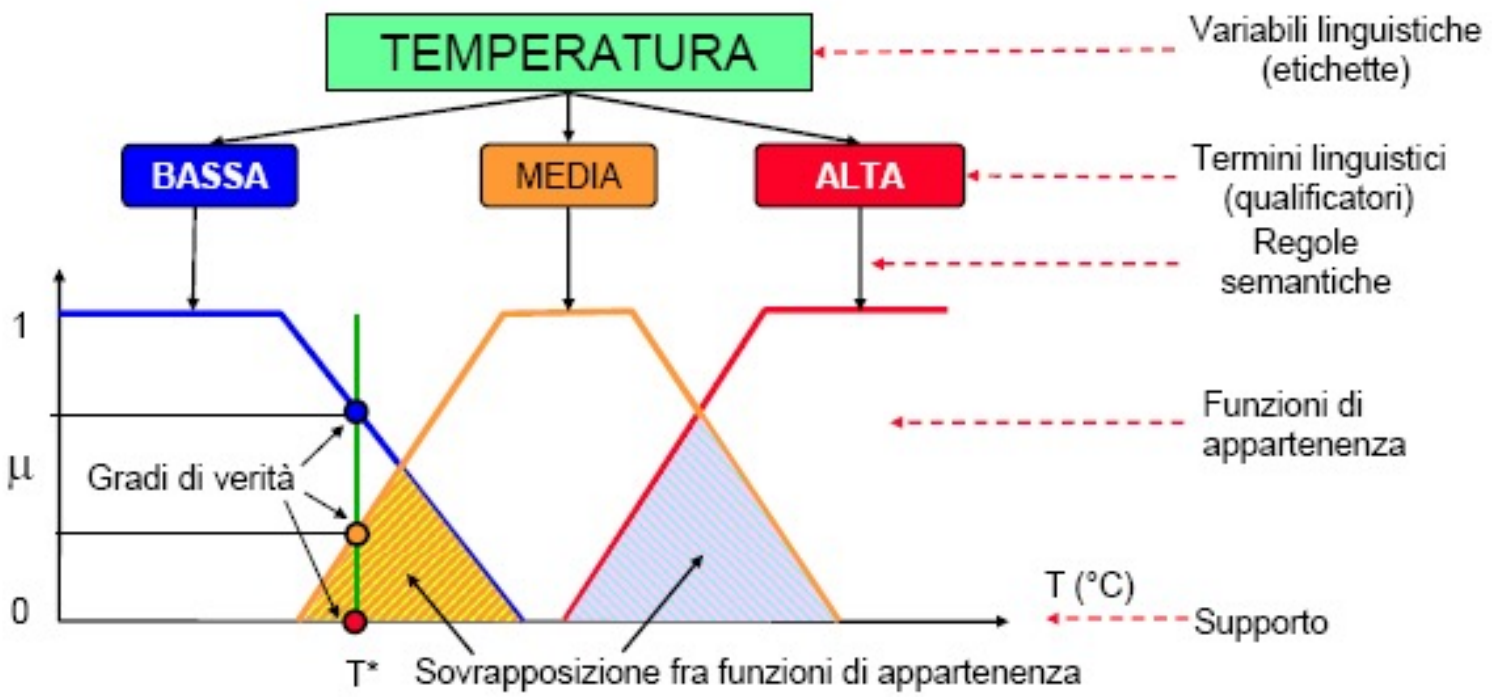


Numeri reali

Temperatura

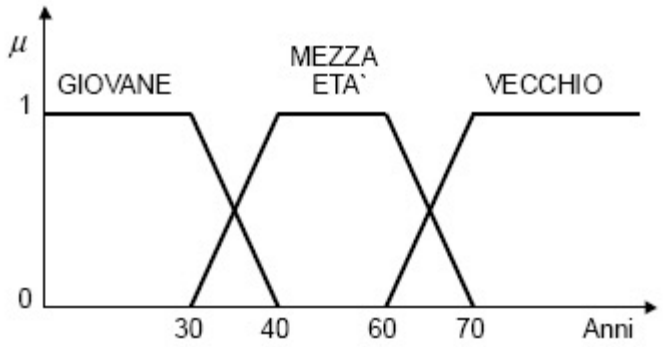


Linguistic variables

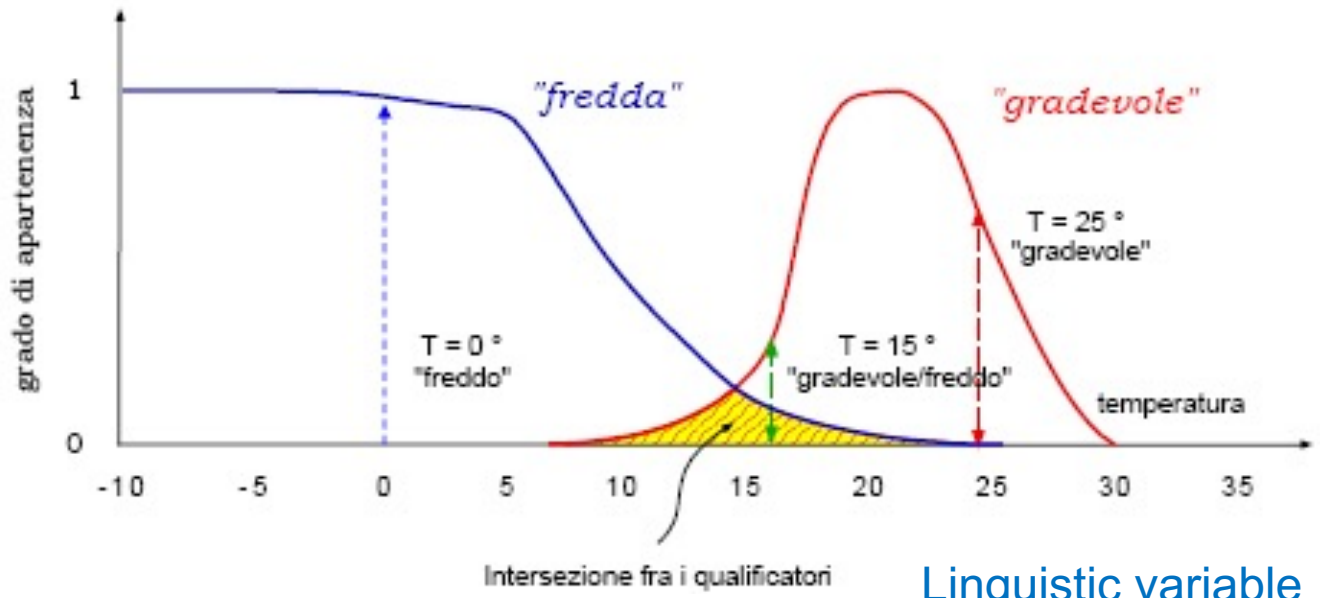


Esempio di fuzzificazione

Linguistic variables examples

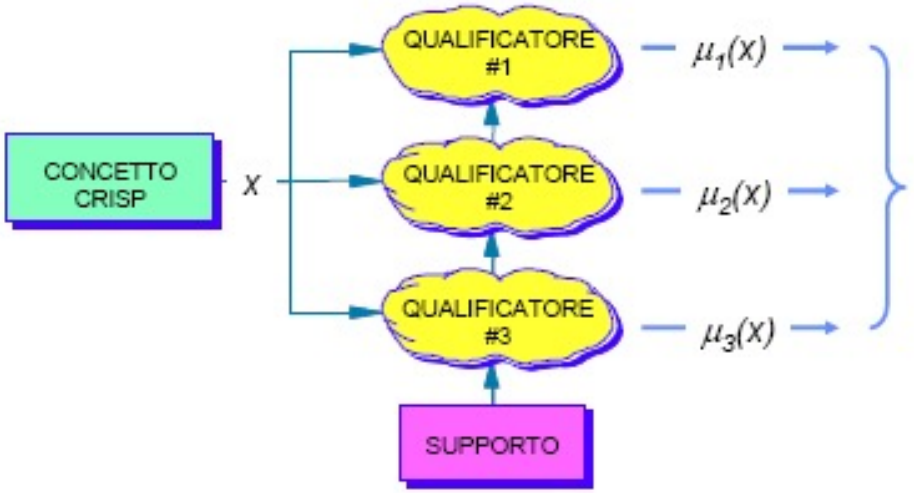


Linguistic variable “anni”

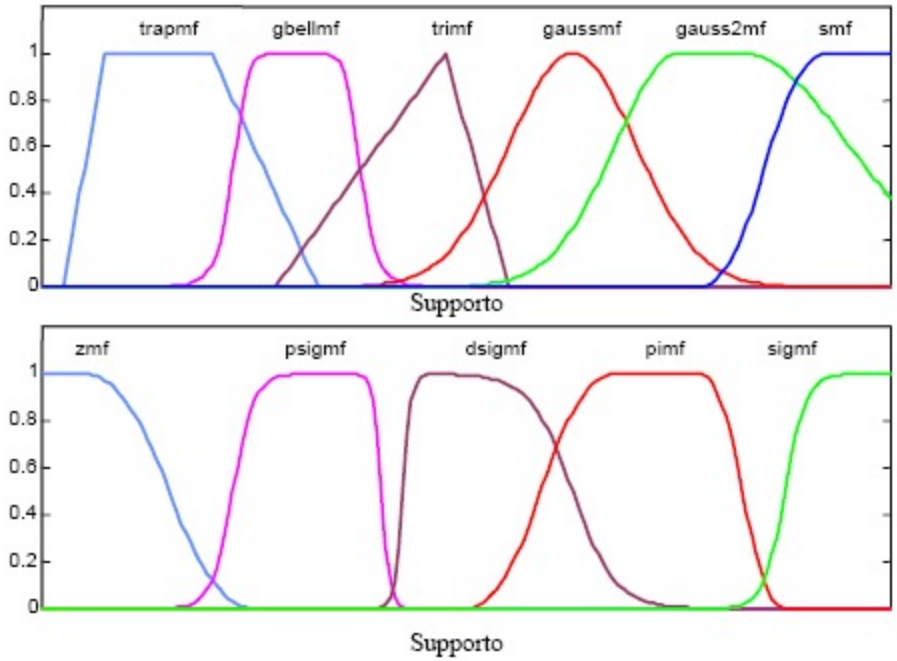


Linguistic variable “temperatura”

Fuzzification

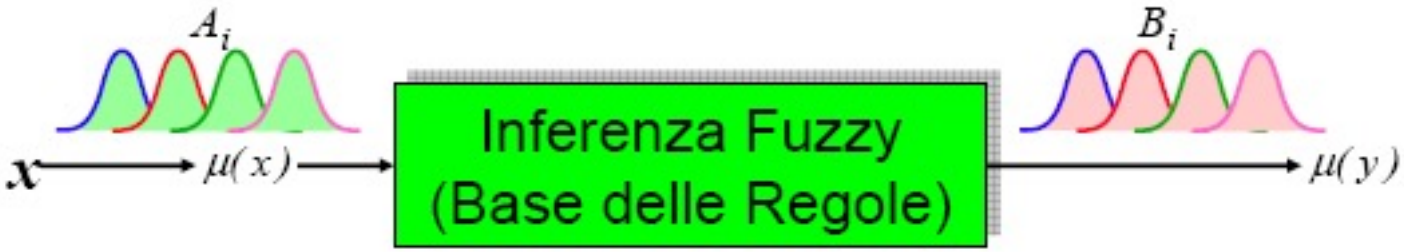


Fuzzification phase

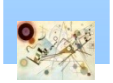


Kinds of memberships

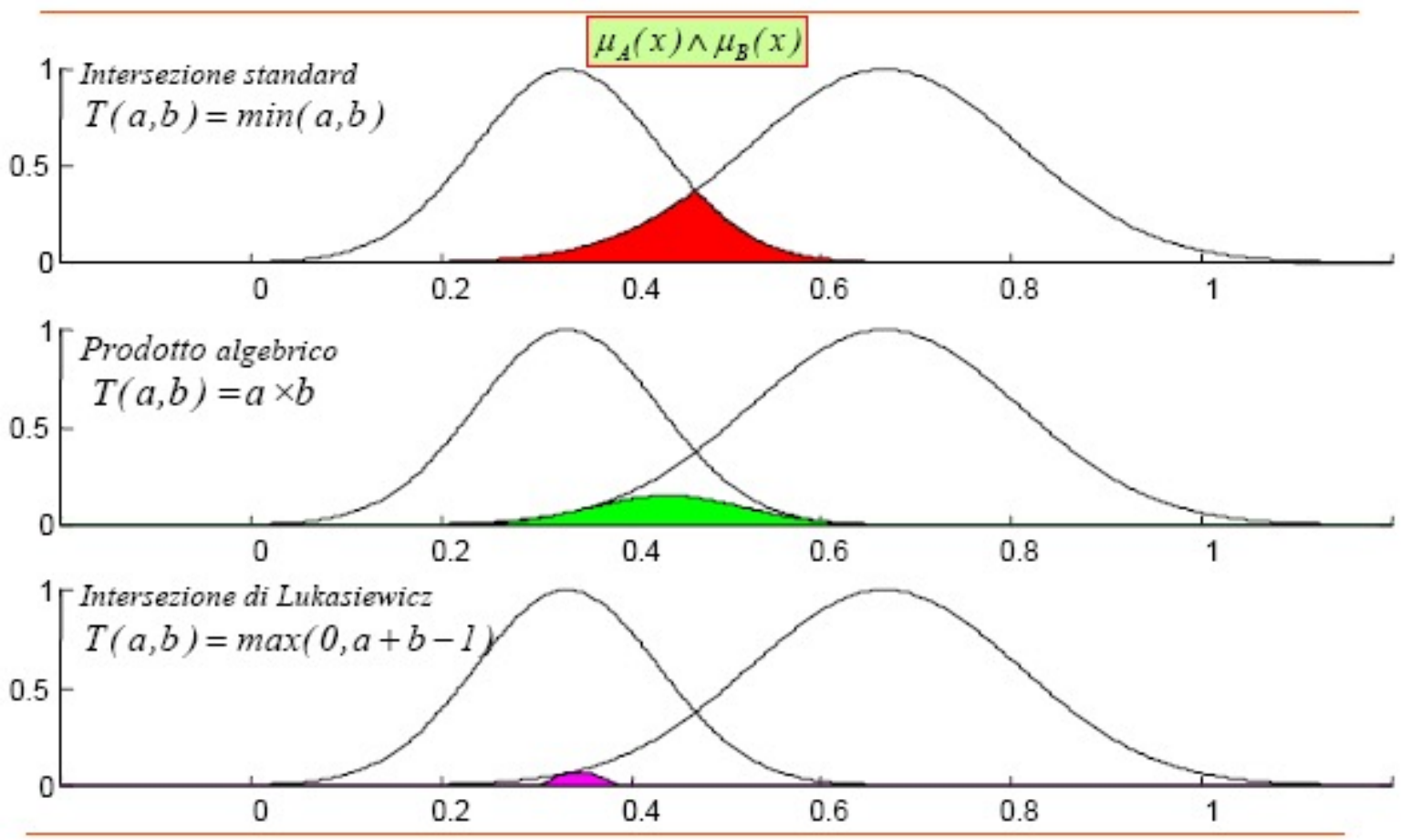
Inference system



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

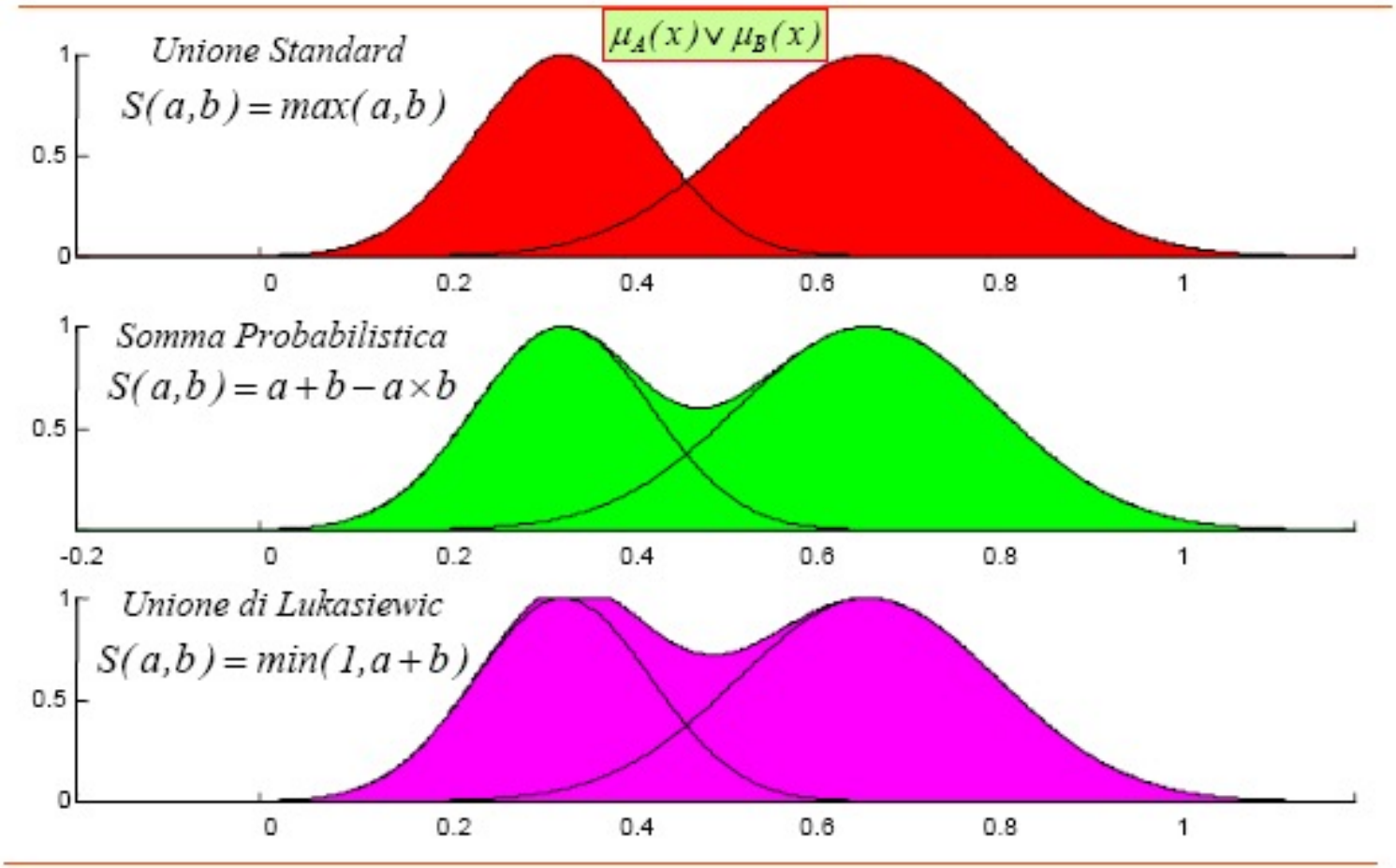


Operators

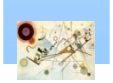


Intersection operators

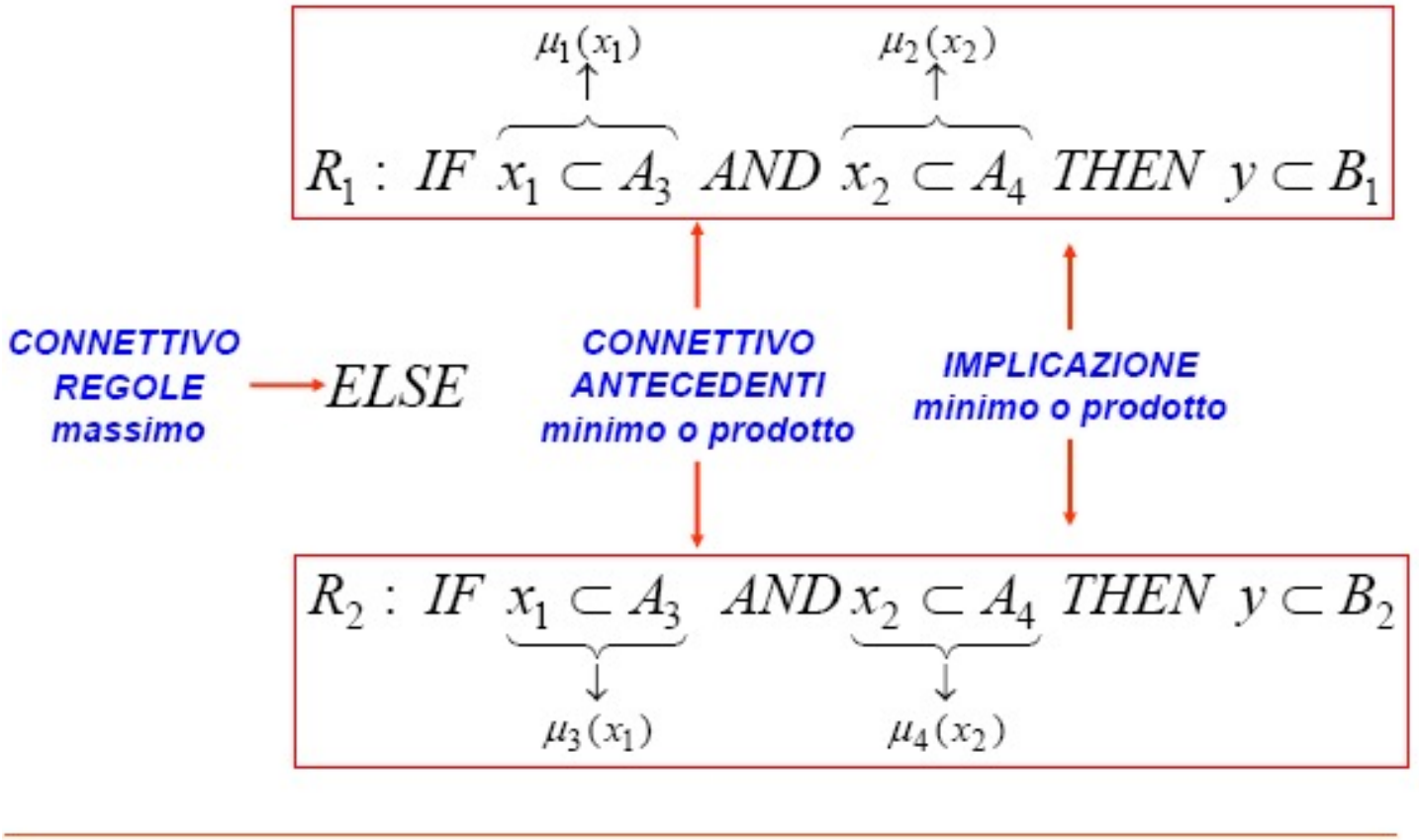
Operators



Union operators



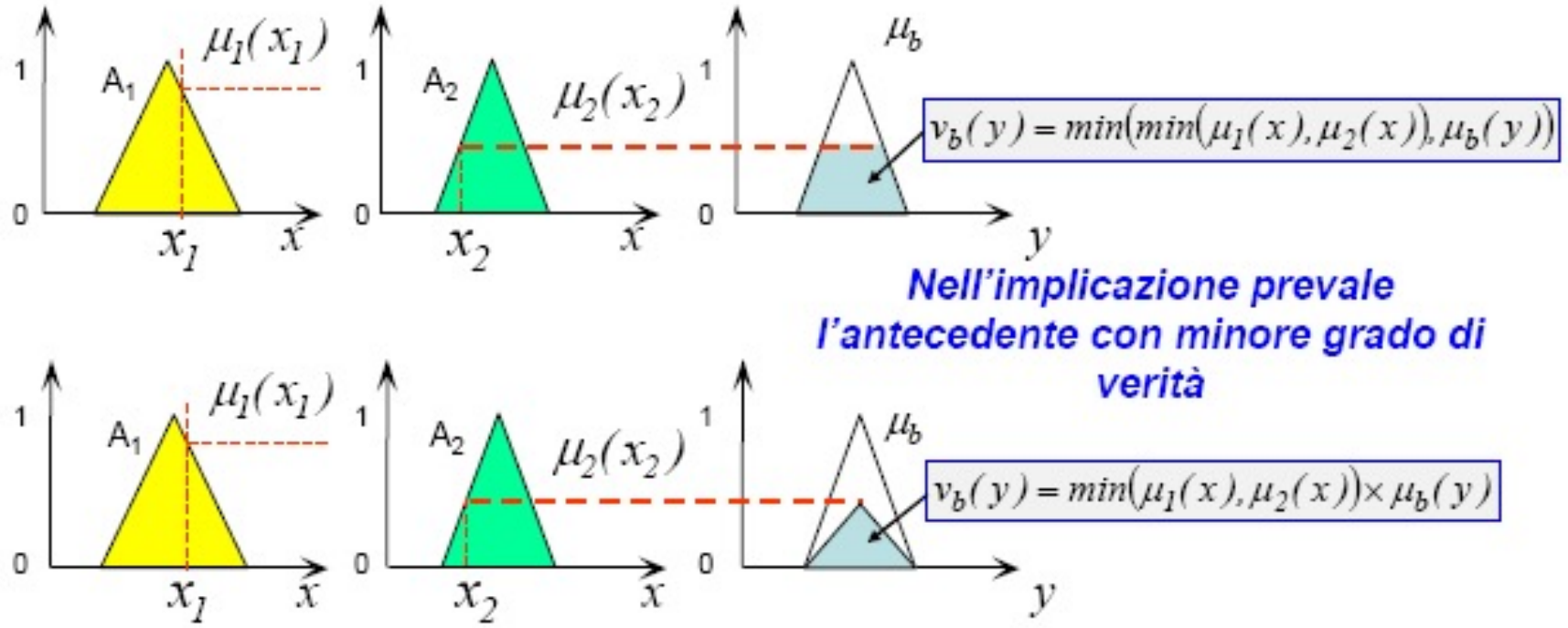
Inference rules



Inference (Mamdani)

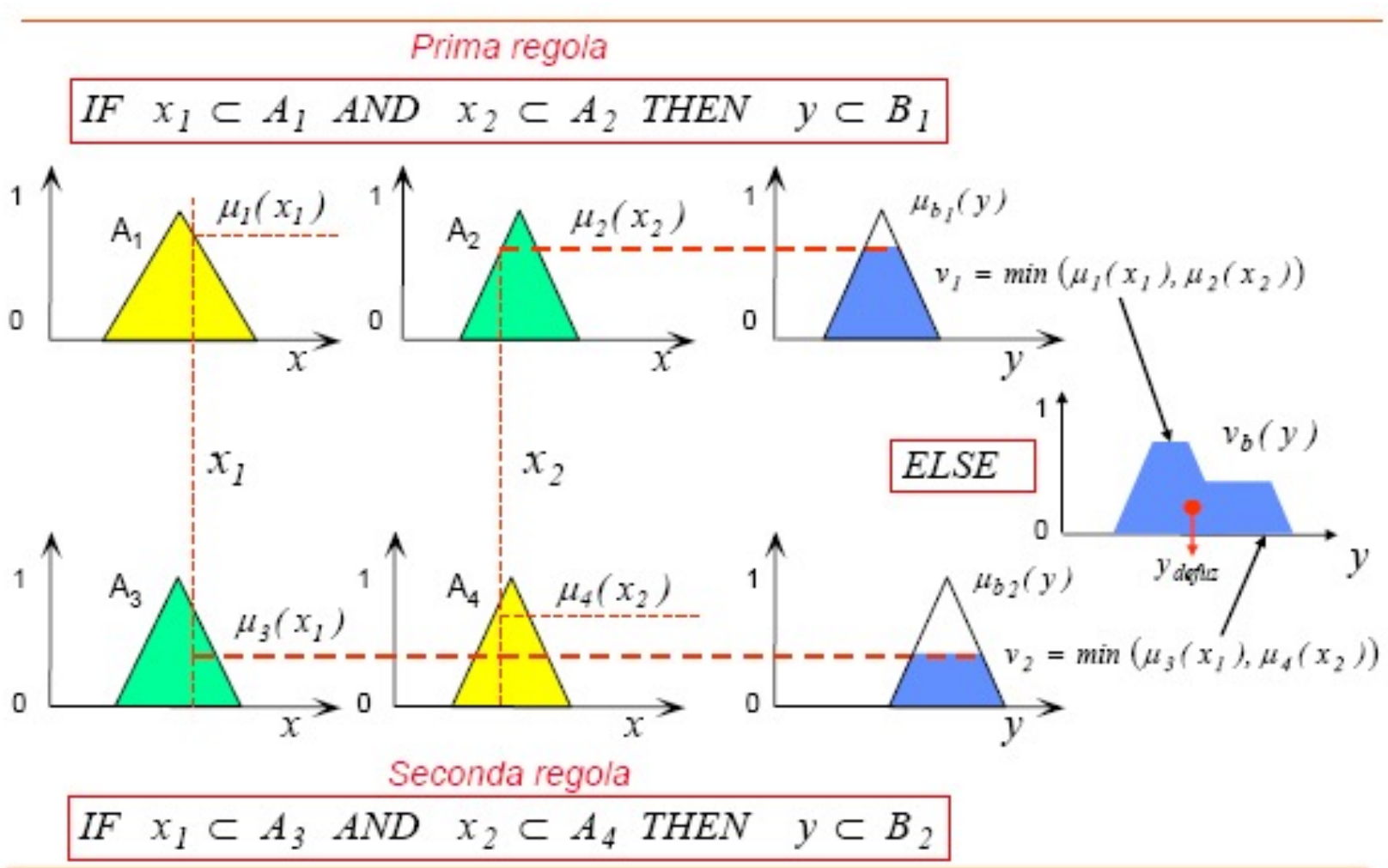
$$IF\ (x_1\ is\ A_1)\ AND\ (x_2\ is\ A_2)\ THEN\ y\ is\ B$$

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



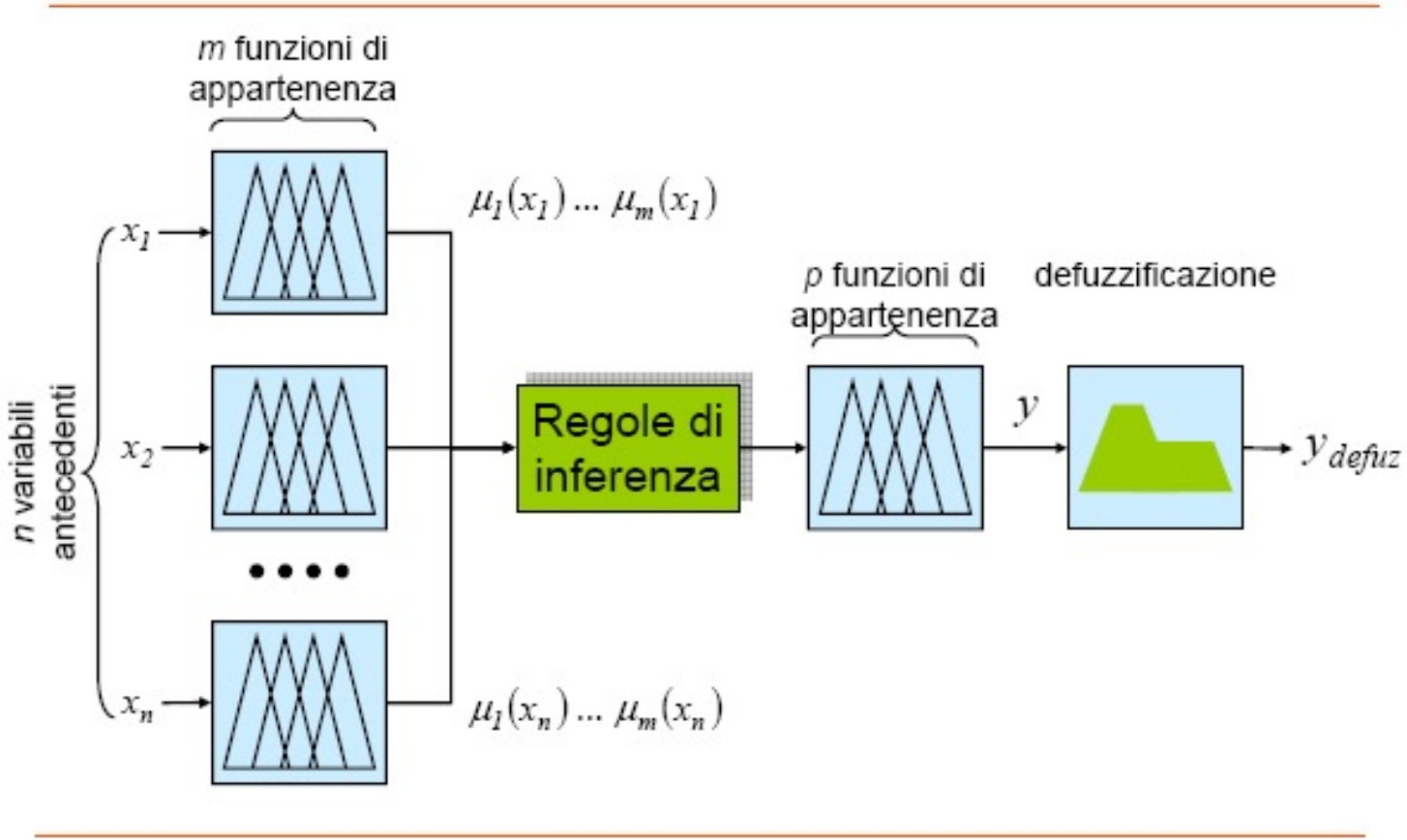
Mamdani based inference

Defuzzification



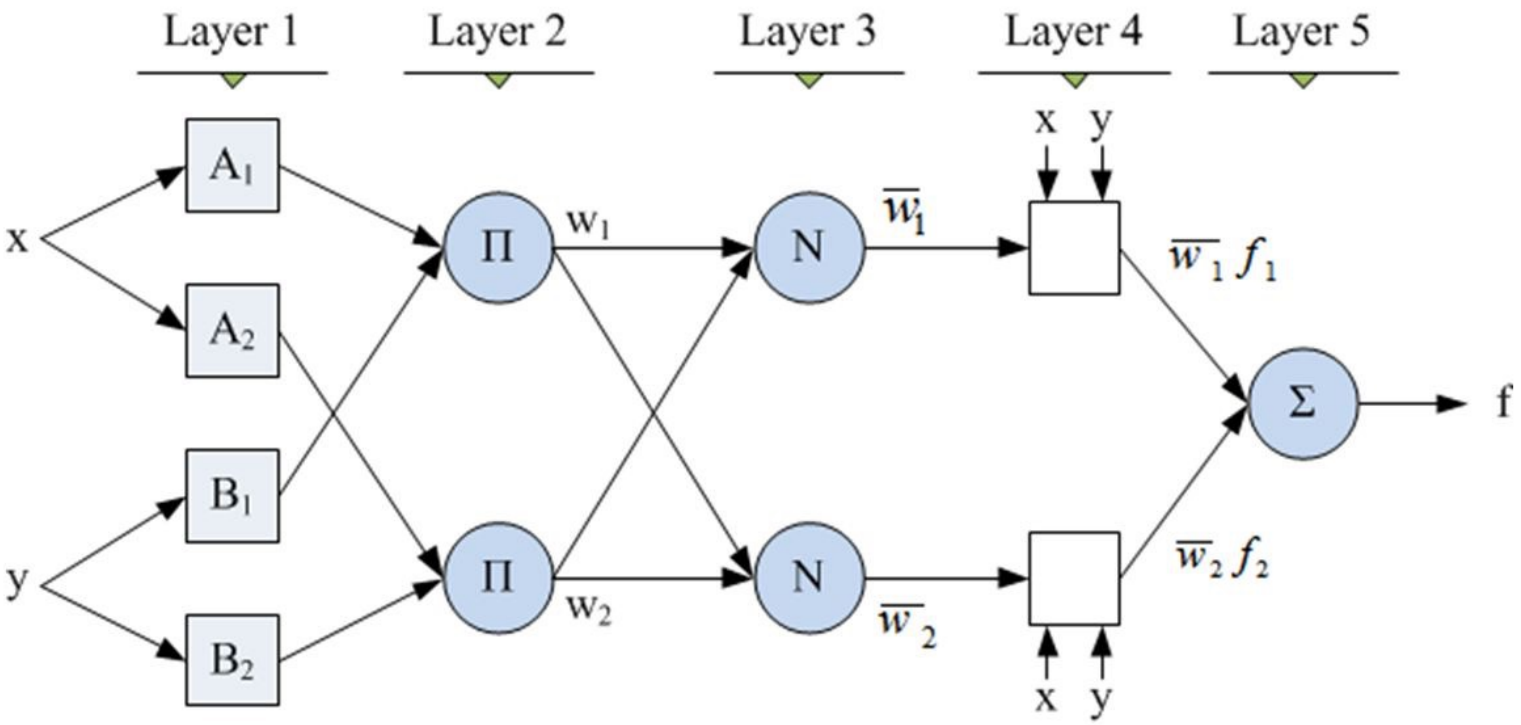
Inference and defuzzification

Fuzzy systems



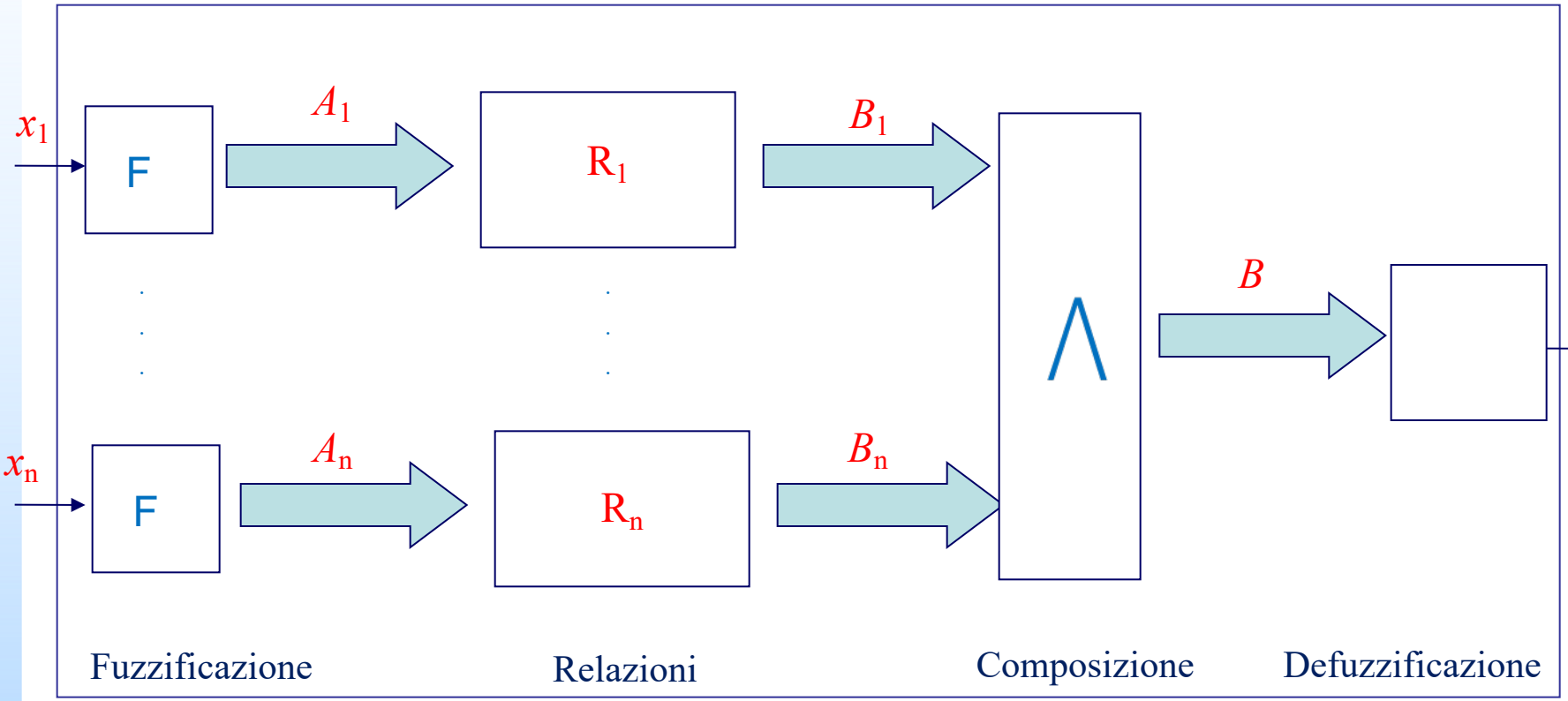
… neuro-fuzzy systems

ANFIS



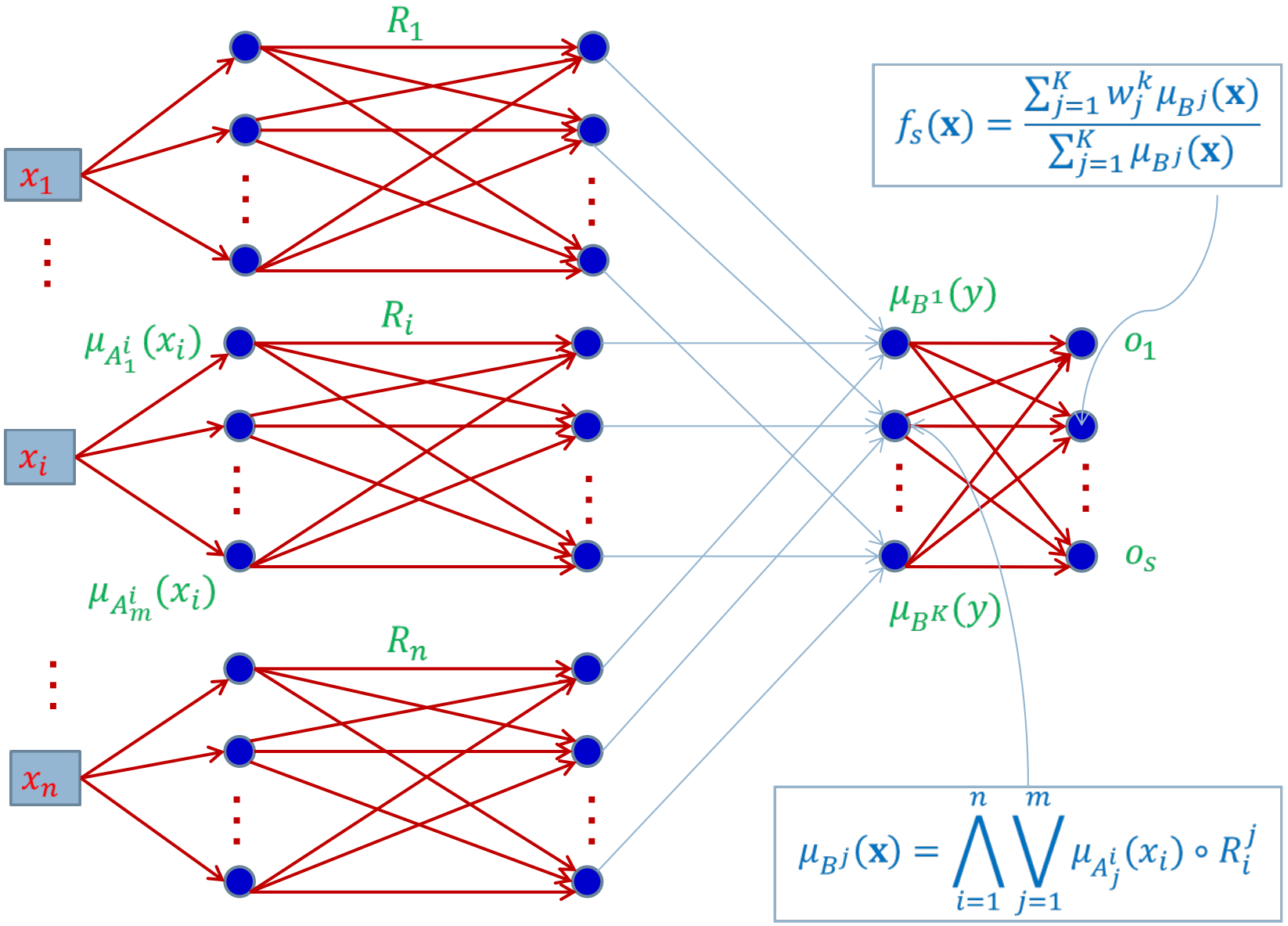
ANFIS model

FRNN

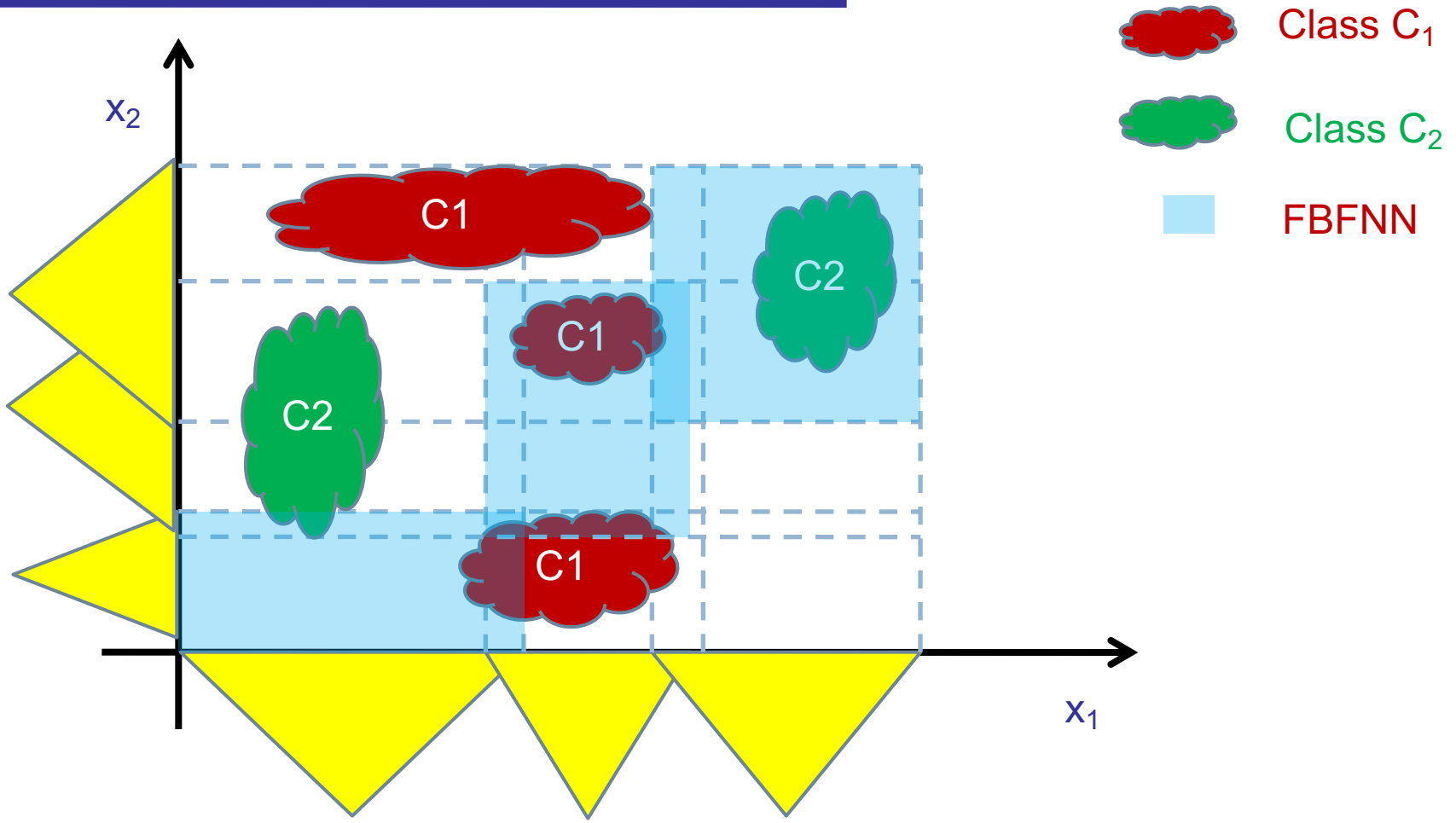


Fuzzy Relation Neural Network Model

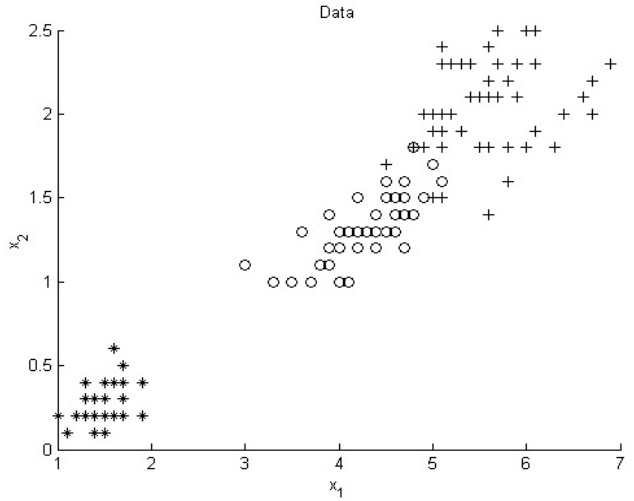
FRNN


R_1
x_1
R_i
$\mu_{A_1^i}(x_i)$
x_i
$\mu_{A_m^i}(x_i)$
R_n
x_n
$\mu_{B^1}(y)$
o_1
o_s
$\mu_{B^K}(y)$
$f_s(\mathbf{x}) = \frac{\sum_{j=1}^{K} w_j^k \mu_{Bj}(\mathbf{x})}{\sum_{j=1}^{K} \mu_{Bj}(\mathbf{x})}$
$\mu_{Bj}(\mathbf{x}) = \bigwedge_{i=1}^{n} \bigvee_{j=1}^{m} \mu_{A_j^i}(x_i) \circ R_i^j$

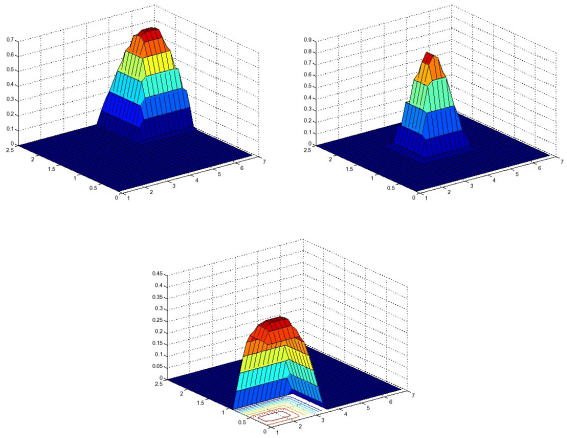
Granulation



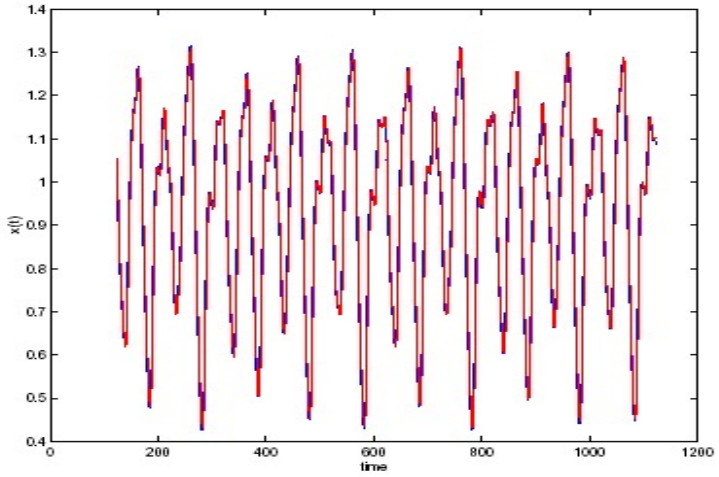
Some results



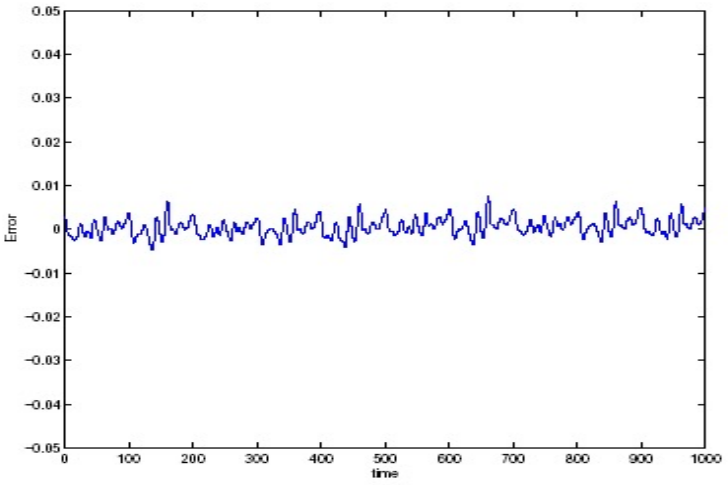
IRIS data set



Memberships

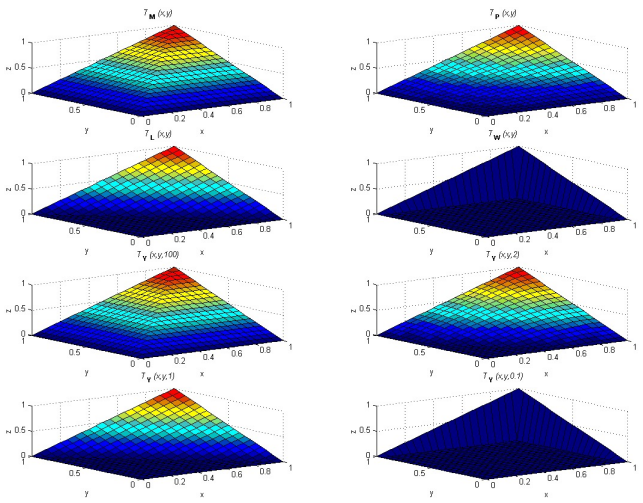


Mackey-Glass chaotic time series



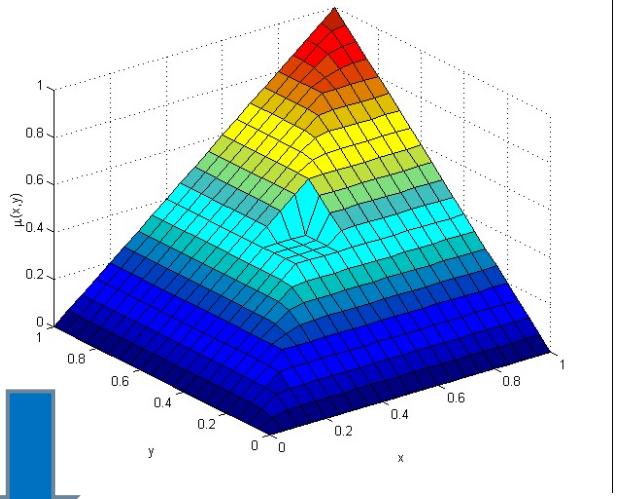
Residum

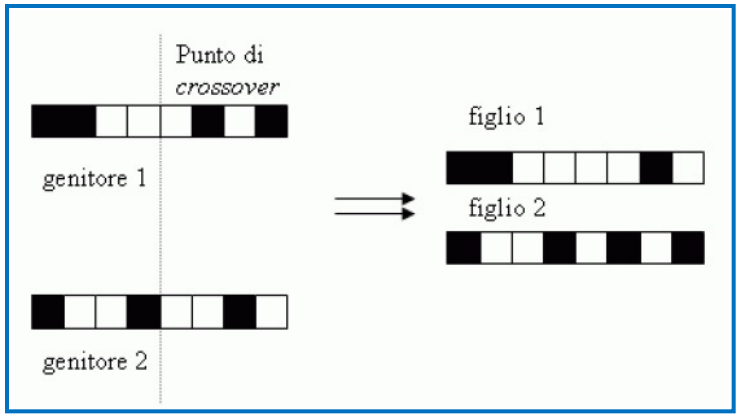
Norm generalization



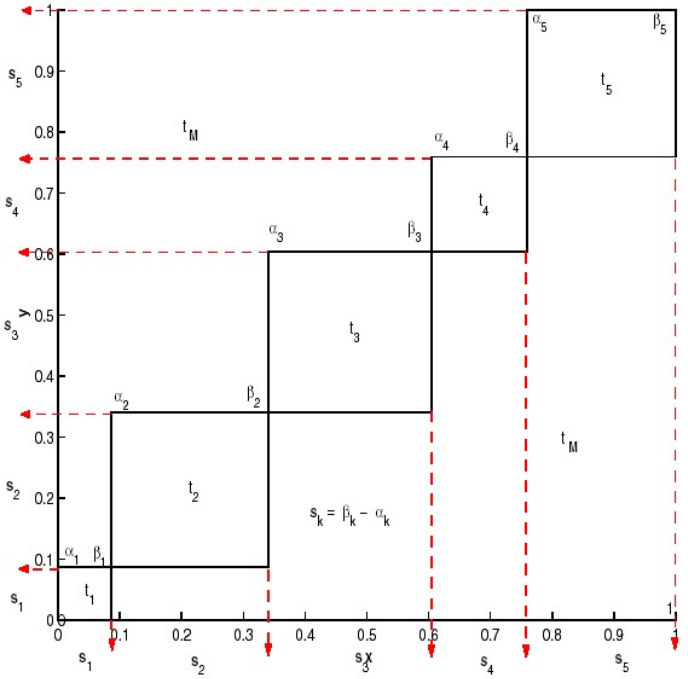
t-norms and t-conorms

Ordinal sums



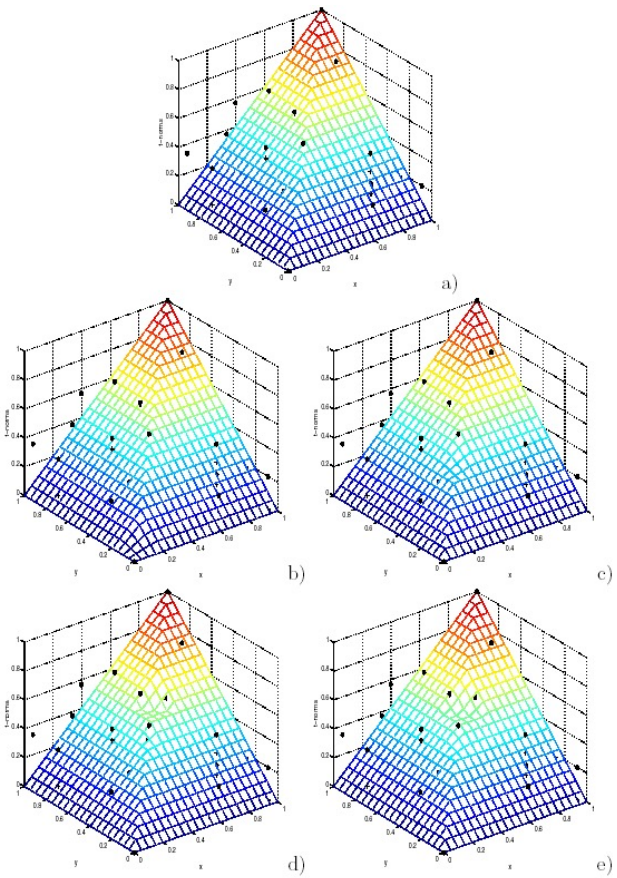


Chromosome

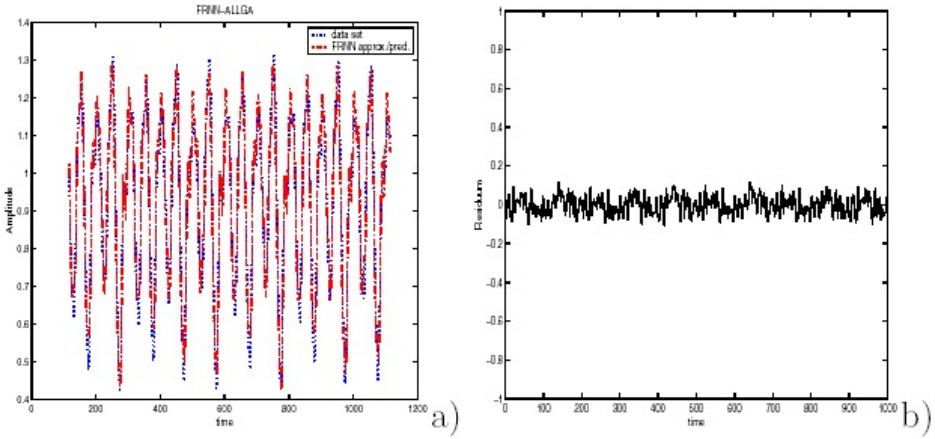


Parameters of Ordinal Sums

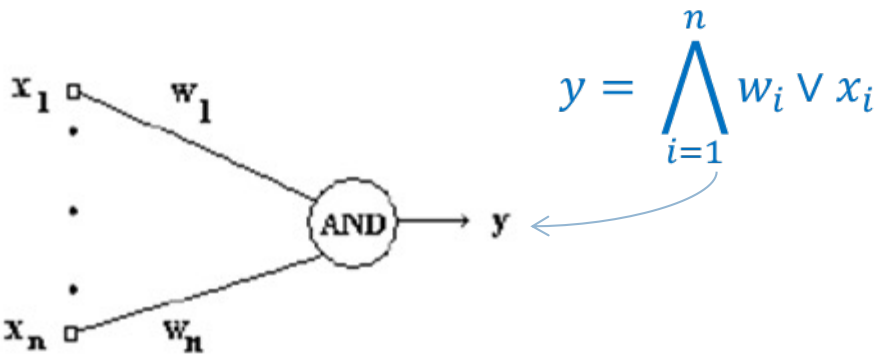
Neuron generalization



Zimmermann and Zysno data set

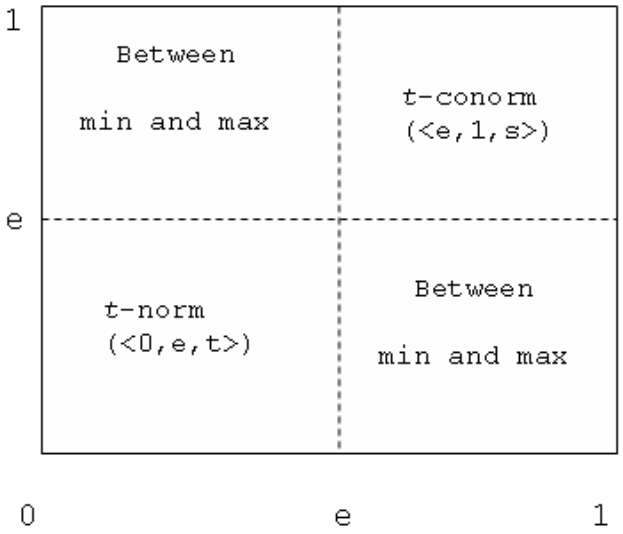


FRNN inference system

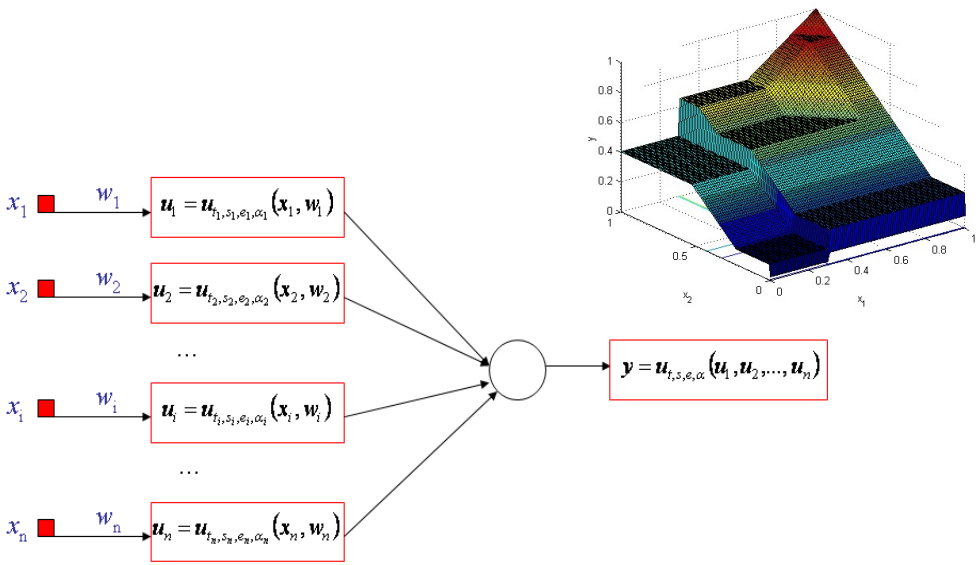


AND/OR neuron based on OS

Uninorm

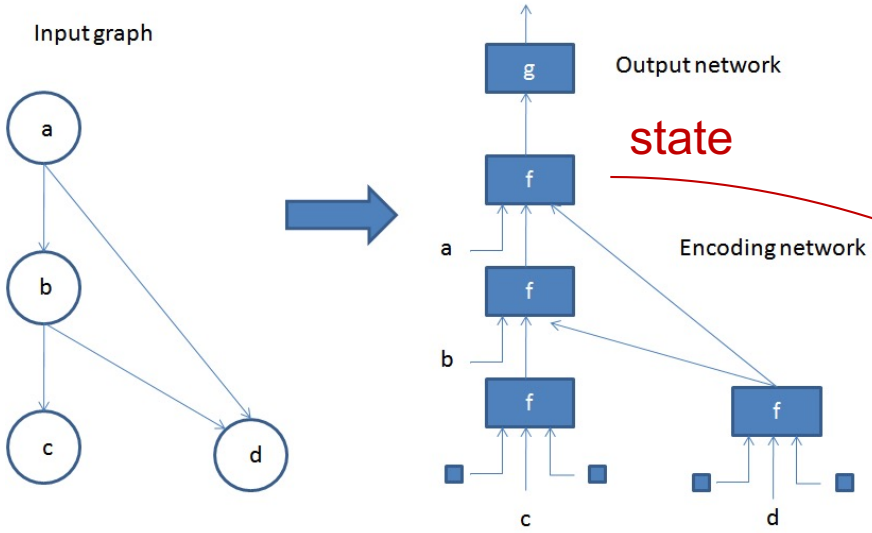


Uninorm representation



Uninorm based neuron

Structured data



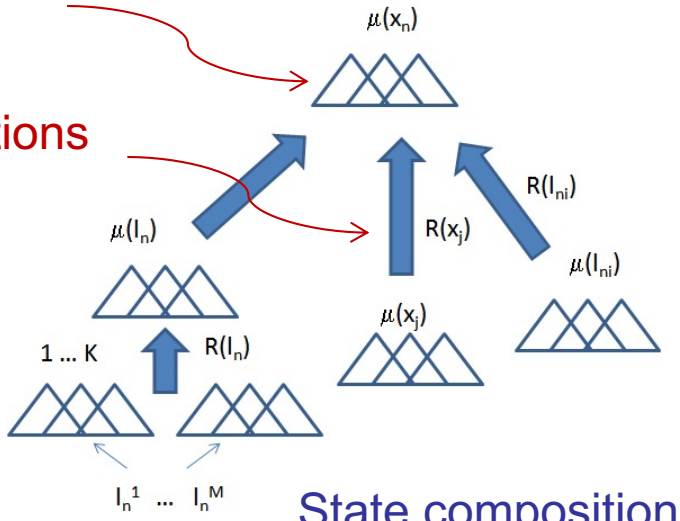
Graph mapping

state

fuzzy state

Uninorm

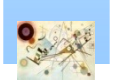
Relations



State composition

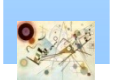
Multimedia Event Database

- 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

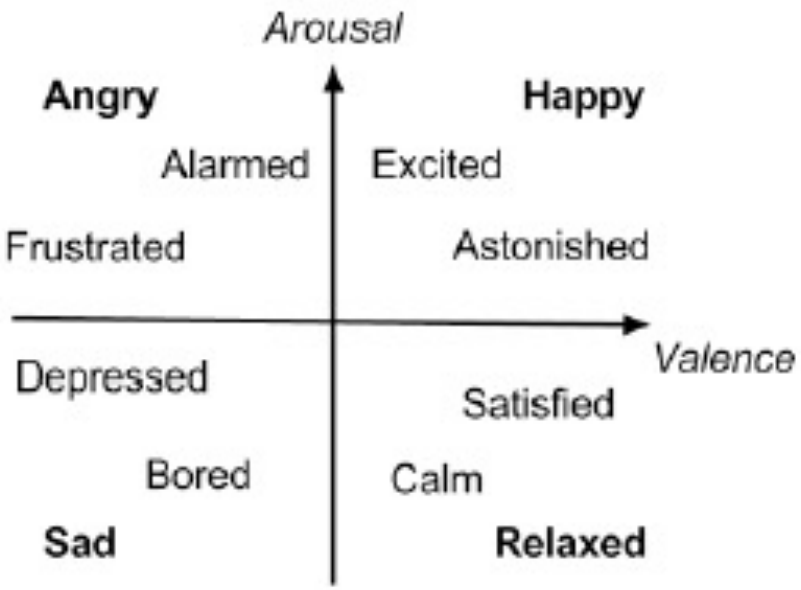
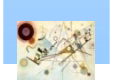


Fig. 1 Two-dimensional emotion representation in Thayers model.

Features

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



System architecture

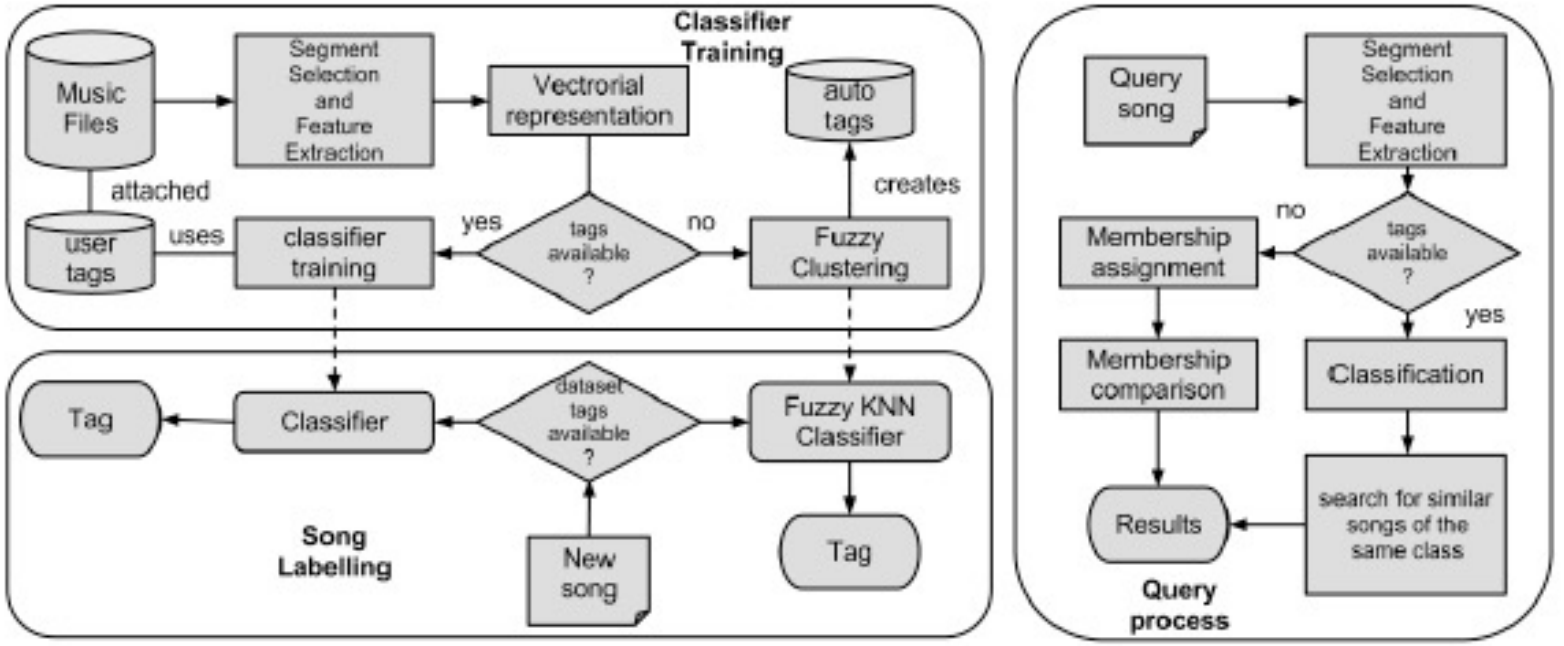


Fig. 2 System archiecture.

Fuzzy c-means

- Objective function

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

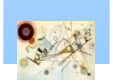
- centroids and memberships

$$\mathbf{v}_i = \frac{\sum_{k=1}^{N} (\mu_{ik})^m \mathbf{x}_k}{\sum_{k=1}^{N} (\mu_{ik})^m} \qquad \mu_{ik} = \frac{1}{\sum_{j=1}^{c} \left(\frac{d_{ik}}{d_{jk}}\right)^{\frac{2}{m-1}}}$$

- where

$$d_{ik} = \|\mathbf{x}_k - \mathbf{v}_i\|^2 \qquad \sum_{i=1}^{c} \mu_{ik} = 1$$

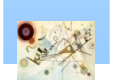
- Update: rough fuzzy c-means



Classification

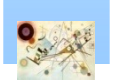
Table 1 Results for 10-fold cross-validation with three different machine learning approaches considered for the automatic song labeling task.

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



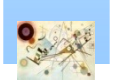
Results exampkes

- Target: "La domenica delle salme" – De Andrè
  - Classified as Sad
  - The firs 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)