POLITECNICO MILANO 1863

AIRLAB ARTIFICIAL INTELLIGENCE AND ROBOTICS LAB

Soft Computing
Introduction

Andrea Bonarini
andrea.bonarini@polimi.it

Artificial Intelligence and Robotics Lab
Dipartimento di Elettronica, Informazione e Bioingegneria
Politecnico di Milano

What is Soft Computing?

Soft computing is the idea of computing like people, because people and the world are “soft”

The systemic view: modeling techniques to implement input/output mapping

Modeling techniques for real world situations, where “hard” models (e.g., mathematical formulations) are not suitable.

The term Soft Computing was proposed by Lotfi Zadeh, the father of fuzzy sets, in the early ‘90s

The community started later to call it also «*Computational Intelligence*» to distinguish it from «*Artificial Intelligence*», which had taken a more «logic-based» approach for similar situations.

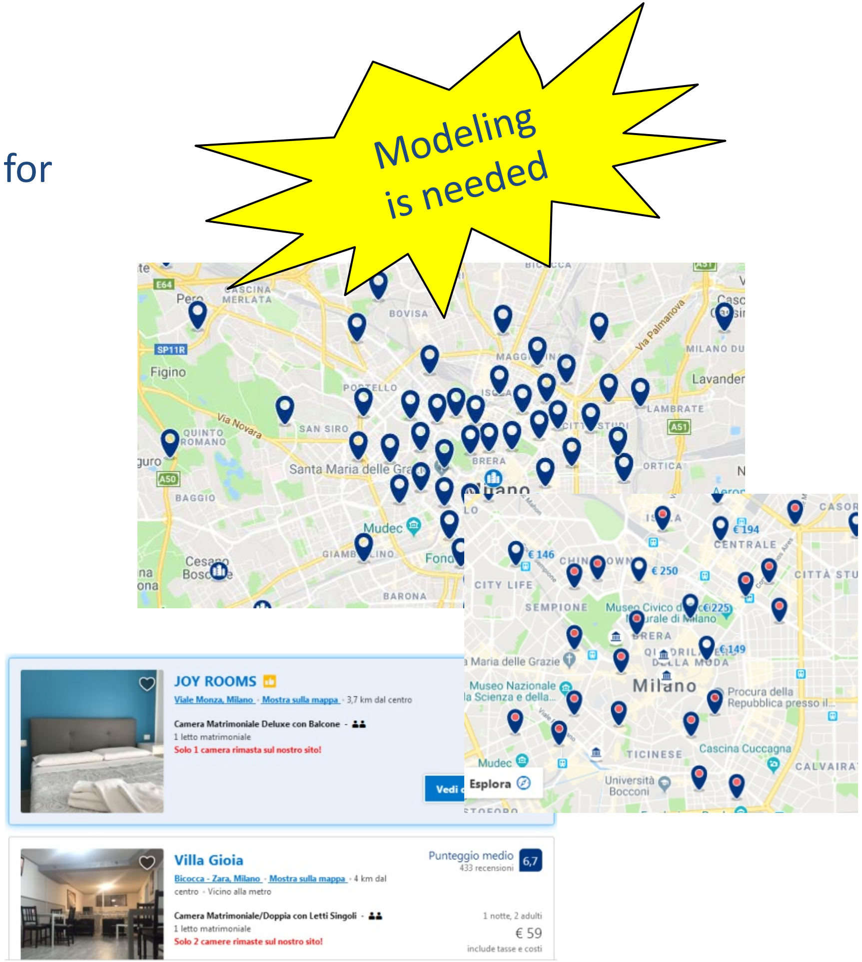
Modeling

A model is a **representation** of some entity, defined for a specific **purpose**

A model captures **only** the aspects of the entity modeled that are relevant for the **purpose**

A model is necessarily different from the modeled entity: **the map is not the land**

So, intrinsic to modeling are: approximation, uncertainty, imprecision, …



Approximation and uncertainty

Approximation: the features represented in the model are similar to the real ones, but not the same, (e.g., a *green* thing, all mathematical models of classical physics, most computational models requiring to compute functions, all empirical measurements)

Uncertainty: we are not sure that the features of the model are the same of the entity (e.g., «I'm not sure it's broken», (Broken 0.8), «The probability of rain for this evening is 0.6»,…)

Some quotes

Einstein (1921):

“So far as **laws of mathematics** refer to **reality**, they are **not certain**, and so far they are certain they do not refer to reality”

Russell (1923):

“All **traditional logic** abitually assumes that **precise symbols** are being employed. It is therefore **not applicable to this terrestrial life**, but only to an imagined celestial existence”

Zadeh (1973):

“As the **complexity** of a system increases, our ability to make precise and yet significant statements about its behavior diminishes until a threshold is reached beyond which precision and significance (or relevance) become almost mutually exclusive characteristics”

What is Soft Computing?

A set of **different** modeling techniques to cope with approximation, uncertainty, imprecision:

- Fuzzy systems
- Neural Networks
- Stochastic systems (Genetic Algorithms, Evolutionary Algoritms, Reinforcement Learning Systems, Bayesian Networks, Graphic systems …)

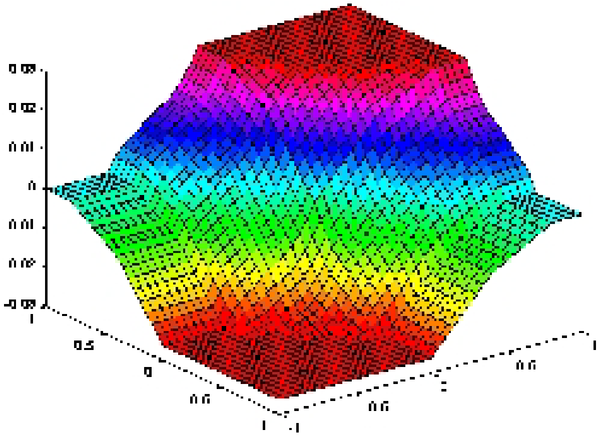
They are appropriate in different contexts, for different purposes, and when different information is available

The main point is that their modeling process considers a relatively small sample of the phenomenon to be modeled to make a possibly approximate, general model => generalization

In short: fuzzy systems

Mapping **numerical values** on **words** denoting concepts using functions.

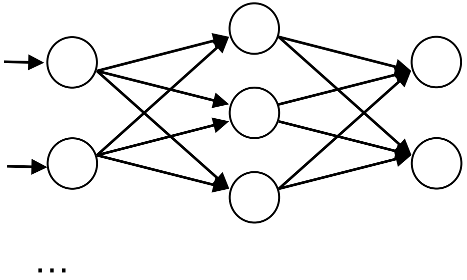
This may lead to easily defined non-linear models such as the one plotted here.



E.g.: control of a power plant

- We can define as functions what a «high» steam temperature, and a «high» steam pressure are and state with fuzzy rules that when the the temperature is high and the pressure is high, then the burner should reduce the temperature «a lot», which is in turn defined by a function and can be translated back to a number

In short: Neural Networks



Input-output samples are used by a learning algorithm to generate a model that can provide a generalization of the samples, so correct output even for unseen input.

E.g.: Classification of components of an image

A lot of images in input and the corresponding expected classification in output. The network learns, and then can provide the classification for images different from the ones already seen.

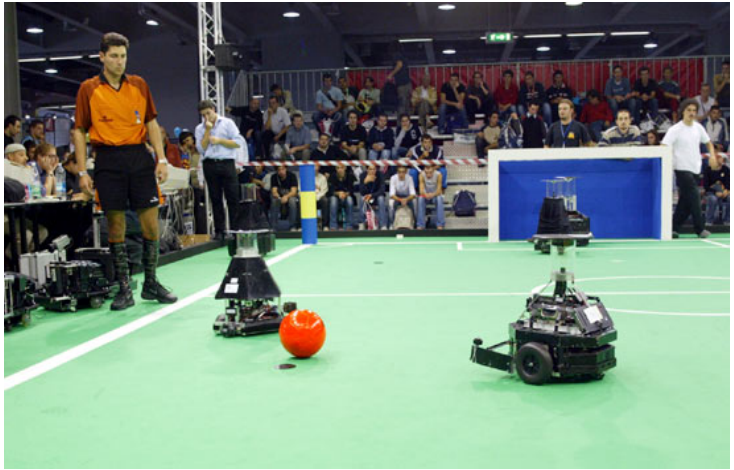
(Since last year we offer a course about NN and Deep Learning, so this topic is no longer included in this course)

In short: stochastic algorithms

In general, they are algorithms were part of the control depends on stochastic decisions on data.

E.g.: Genetic algorithm to learn the behavior of an autonomous robot

In this case, the model is made of rules.
Some rules to control the robot are randomly generated at the beginning. The behavior (e.g., Go to a ball) is evaluated, the good rules implementing it are kept in the population of rules, and recombined to improve the population, the bad rules are eliminated.



Potential applications

No limit to imagination:

control of washing machines, helicopters, and rice-cookers, selection of personnel, quality control, classification (images, movies, users, ...), design of devices, route optimization, data mining, data analysis, finance, speech and natural language understanding, information retrieval, security management, forecasting, bidding, decision support, resource allocation, autonomous robots, ...

... whenever a model is needed, but...

let’s learn what are the correct models for which applications and how to use them!

How is the course organized?

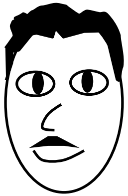
For each technique we will see:

- Theory
- Examples
- Applications

Andrea
Bonarini

Fuzzy Systems
Genetic Algorithms

Matteo
Matteucci



Bayesian Networks
Graphic Systems

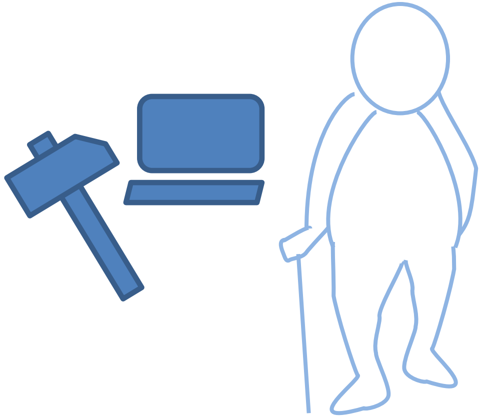
The exam

- Written examination in two parts: FS+GA and BN (GS); time: 2h.15’
- It is possible to recover possibly undesired or insufficient marks on any exam date
- 32 points maximum, of which 2 dedicated to the quality of the presentation if done by hand writing: exercise your writing!
- At least 18 is required as sum of marks of the two parts.

It might be possible to volunteer to participate to trials of systems made by your colleagues as a thesis work.

  - positive rounding of any final mark (eg.: 26.2 -> 27)

Support Tools



Course web site: on **BEEP** (please ask to be added if not present)

Detailed program including topics of each lesson: on BEEP

Slides: on the **course site** at last the night before the lesson

Books: on line or in libraries (**suggestions on the site**)

Online courses, MOOCS, and web resources are welcome: please **share** the interesting ones you find

Past exam tracks: on **BEEP** (please, consider only the parts included this year)

Contacts: Ask by **e-mail** or at the **end of the lesson** to **meet** the teachers

How could you study?

Before each lesson:

- Look for material on the web about topics of each lesson, which are available from the detailed program
  Why? You have to **learn to find the info** you may need
- Write a **summary** of what you have found, trying to organize it
- Prepare a **list of questions** to be submitted to the teachers on the next lesson

At each lesson:

- Be **present** and **participate** to the lesson
- Be **curious, be hungry** (Steve Jobs)
- **Exploit at best** the moments where you could **directly** talk with the teachers

After each lesson:

- **Revise** your notes
- **Complete** the notes with material you have found on the **web**
- Check that you **know** the lesson topic
- Eventually, **make exercises**, and bring us your solutions

https://kahoot.com

Kahoot!

Why are we meeting in a classroom?

Andrea Bonarini

We know that…

Only a small part of the concepts presented in the traditional classroom are remembered by students at the end of a lesson

Students learn what they can **study at home**

Missing basics

It has been observed that even if students can get knowledge specific of the courses, also excellent students often miss basic skills such as the ability:

- to ask questions
- to label (give names to things)
- to model (create causal relationships)
- to decompose (splitting a problem into components)
- to measure
- to visualize and ideate
- to communicate

David Goldberg, Carl Wieman, …

Goals of the lesson

Obtain the **best return** from **the co-presence** of teacher and students

that is…

build **together with most of the students** the desired output of the formative process

knowledge + skills

How we organized the course

Online lessons mostly to provide knowledge and stimulate activity

Onsite lessons to interact and develop skills