POLITECNICO MILANO 1863

AIRLAB
ARTIFICIAL INTELLIGENCE AND ROBOTICS LAB

Soft Computing
Introduction

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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.

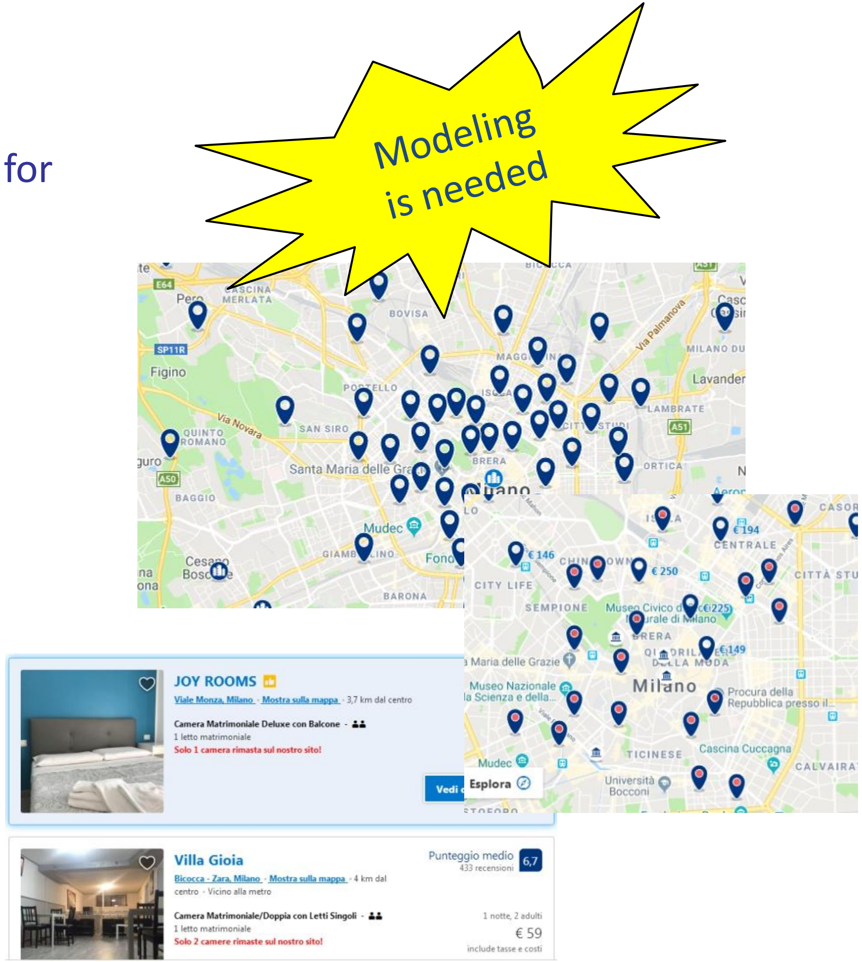
Modeling

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, uncertainty, imprecision

Approximation: the model features 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»,…)

Imprecision: the model feature values (e.g.,quantities) are incorrect, but of the same nature and close to the real ones (e.g., a temperature measured as integer C)

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 …)

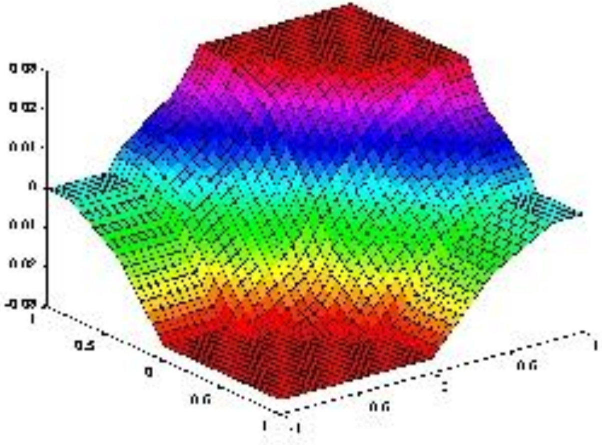
They are appropriate in different contexts, for different purposes, and when different information is available

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.

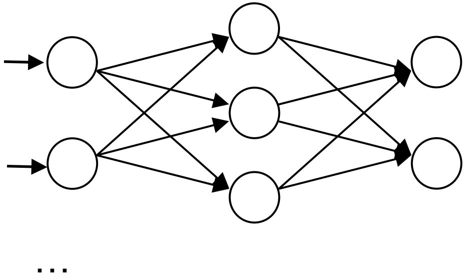


E.g.: control of a power plant

- 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

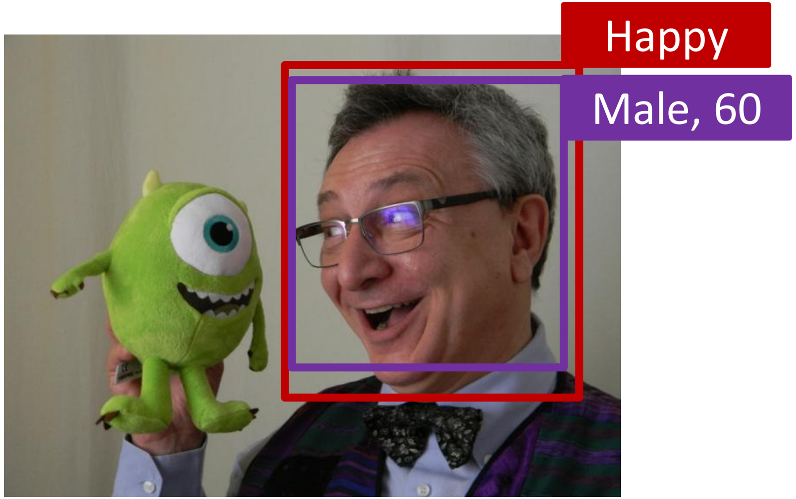
In short: Neural Networks

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.

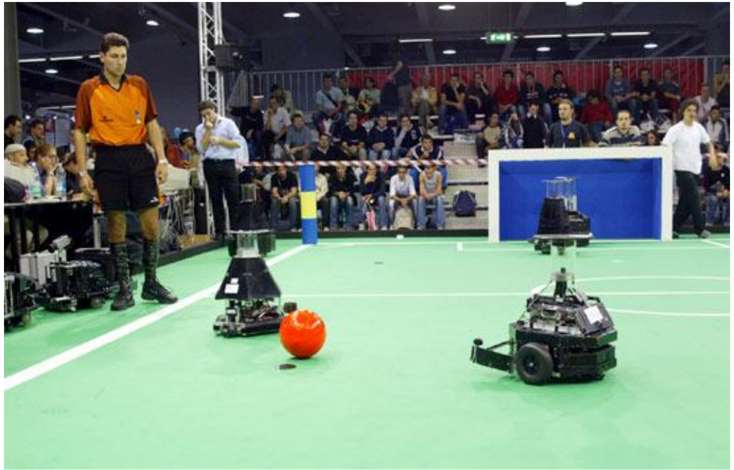


In short: stochastic algorithms

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

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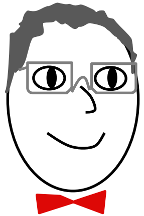
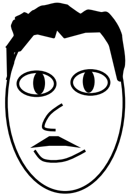


Fuzzy Systems
Genetic Algorithms

Matteo
Matteucci



Bayesian Networks
Graphic Systems

A NEW course!
Neural Networks
and Deep Learning

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: exercise your writing!
- At least 18 is required as sum of marks of the two parts.

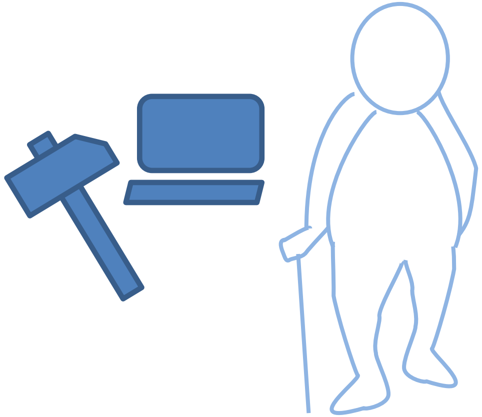
It might be possible to volunteer to participate to trials of systems made by your colleagues as a thesis work.

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

For people who take this course as integrated with Artificial Intelligence

- the same as above, but the exam is NOT done the SAME day as AI, and the marks obtained in the two parts of the exam are averaged -> IT IS MUCH BETTER TO PUT THE SEPARATE COURSES IN THE STUDY PLAN

Support Tools



Course web site: on **BEEP** (AI+SC students, please ask to be added)

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

Some considerations about the role of the lessons

Consideration1:

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

Students learn (mostly) what they study at home

Consideration2:

Colleagues said: «The classical teaching way was better», but only **30% of enrolled students reached the degree, today they are more than 70%** (and we would like to have 100%)

Transversal learning goals

All over the world, it has been observed that even when students can show to have developed specific knowledge from the courses, also excellent students often miss basic skills such as the ability:

1. to **ask** questions
2. to **label** (give names to things)
3. to **model** (create causal relationships)
4. to **decompose** (splitting a problem into components)
5. to **measure**
6. to **visualize** and **ideate**
7. to **communicate**

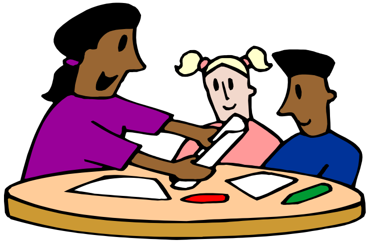
David Goldberg, Carl Wieman, …

Consideration 3:
The **missing basics** should be developed at **the same time** as **topic knowledge**

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** result of the formative process

knowledge + skills

Two models of teaching

Knowledge transfer

Knowledge and skill growth

The best students succeed anyway, the others need motivation and stimuli to learn

What can be done in the classroom?

- **Motivate** home study
- Support the **organization** of home study: remove potential obstacles
- **Structure** and eventually **fix** what has been studied

Formative goal:

“**knowledge + basic skills**”

~~“Explain topics”~~

~~“Summary of the book”~~

~~“Solve exercises at the blackboard”~~

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