Soft computing

Introduction to course, soft-computing vs. hard-computing

doc. Ing. Zuzana Komínková Oplatková, Ph.D.

oplatkova@utb.cz

Univerzita Tomáše Bati ve Zlíně
Fakulta aplikované informatiky

Content of Presentation

- Content of the course
- Softcomputing - basic definitions
- SC vs. HC - hardcomputing
- The most important techniques from the SoftComputing Universum

Course Content

- Introduction to soft computing
- Introduction to machine learning and data preprocessing for intelligent computational methods.
- Introduction to classification - simple *k*-nn classifiers.
- Statistical learning, naive Bayesian classifier, Bayesian networks.
- Decision trees. Random forest (bootstrap samples, bagging), boosting.
- Multi-criteria decision analysis.
- Support vector machines.
- Fuzzy theory.
- Introduction to data mining
- Clustering analysis I.
- Clustering analysis II.
- Methods of dimensional reduction. Analysis of frequented items, Ranking.
- MultiAgent / Agent systems.
- Credit week, consultation hour, discussion of topics for the exam

Soft computing

- The concept of Soft-Computing was introduced by Dr. Lotfi A. Zadeh, 1973, as an “umbrella” for three core areas, namely fuzzy (either logic or modeling), neural networks and evolutionary algorithms.
- Of course, this is an open definition, so here belong also hybrid systems that combine two or more approaches of these three areas, and emerging related areas.
- The dominant objective of soft computing is to use tolerance for imprecision and uncertainty to achieve flexible, robust and "low-cost" solution.
- SC is a fusion of techniques that have been designed for modeling and enabling to solve the complex real-world problems, which are very difficult to model or exact solution would require extreme demands on computing resources and time (called Hard computing).
- SC is a part of Artificial Intelligence field.
- ***It is not important to know the model mechanisms that controls (drive) the behavior of studied system (e.g. physical model or an economic model in the form of equations describing the mechanism - the "inside knowledge")***
- ***What is important is the existence of "external knowledge" and not internal, i.e. existence of knowledge about system behavior, not knowledge about the causes of behavior.***

Soft computing

SC “tools”:

- ✦ Fuzzy logic
- ✦ Neural Networks (Neurocomputing)
- ✦ Evolutionary computation techniques
- ✦ Theory of Chaos
- ✦ Machine Learning (SVM/SVN)
- ✦ Probabilistic computation
- ✦ Datamining
- ✦ ...

Hard computing - Properties:

- ✦ We use a model of the real situation (e.g., physical model, economic model). Which is extremely hard to create - considering all physical/economical/social laws...

- ✦ We are searching for exact solutions (e.g. physical model leads to a system of partial differential equations, subsequently we have to use the analytical solution...).

- ✦ The analytical solution is searched only on a theoretical level, in practice it is often unknown and unfindable (at least not in the required time) and we proceed to approximate solutions by means of numerical methods. ***There is no certainty, that it exists!***

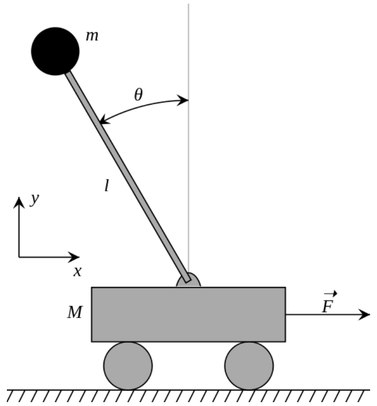
Hard computing - Negatives:

- ✦ Necessary knowledge of physical, economic or other mechanisms (eg the mentioned partial differential equations describing the given processes).
- ✦ Even in the pursuit of accuracy and precision, errors occur, by omitting of many influences, rounding, etc.
- ✦ Each model is to some extent an idealization of the real situation and is therefore again an inaccurate model (eg the “classic" physical model of free fall works with a vacuum, not the friction of air, which will also be different in different conditions).
- ✦ The HC approach requires high computational demands.
- ✦ The existence of a solution is not always guaranteed :-)
- ✦ Lack of robustness (with a small change in data or parameters at the input, the already obtained model may not work).

Soft computing vs. Hard computing
Example: Inverted Pendulum on automatically controlled cart

- In the case of finding a solution by **Hard-computing** we have to study physics, describethe process by means of partial differential equations, implement into PC a numerical algorithm of approximate calculation and we obtain a control function for the cart.

- In the case of finding a solution by **Soft-computing**, no matter what are the laws of physics for balancing control. We realize, however, external knowledge, which do not describe the causes of behavior, but the behavior itself. This knowledge will be represented as IF-THEN rules: If the pendulum is slightly turned to the right, gently move the carriage to the right also. So the logical rules describing the relationship between changes (variations) and reactions.

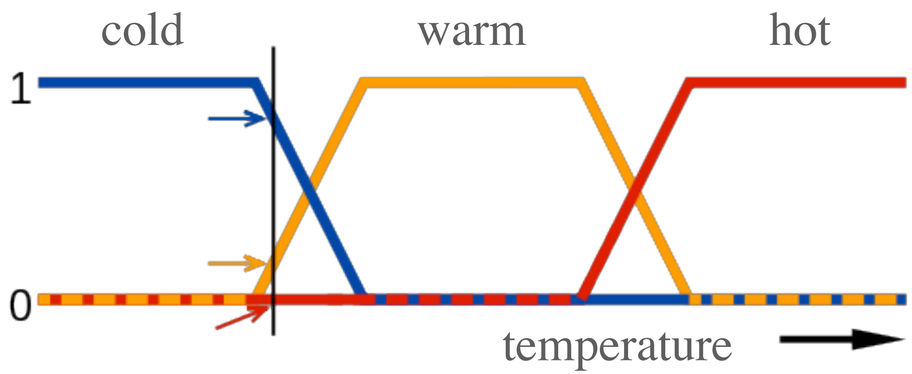


Fuzzy Logic

- Albert Einstein: „*If mathematics describes reality, it is not accurate. And if it is accurate, it does not describe the reality*“.
- Trying to meet the reality with its imprecision and uncertainty.
- The basic element is a fuzzy set. Fuzzy set is a set that besides full membership or no membership admits partial membership.
- Thus fuzzy logic can operate with all the values from the interval <0; 1>, which is infinite.

Fuzzy Logic

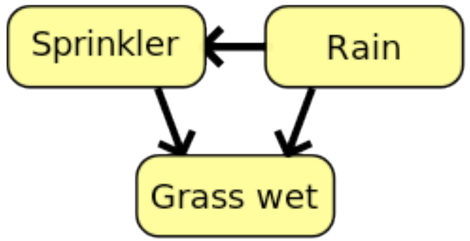
- ✦ Fuzzy logic belongs to multivalued logics.
- ✦ Fuzzy logic may be more suitable for many real decision-making tasks than classical logic, because it allows the design of complex systems.
- ✦ The application of fuzzy logic allows the use of a number of "vague" terms - for classical logic unimaginable. For example, when measuring temperature, it allows the use of terms such as "cold water", "hot water", "hot water", which do not have strict limits.



Probabilistic “computation”

The most important method: Bayesian network

- ✦ Powerful probabilistic model that uses a graphical representation to show probabilistic relationships between events.
- ✦ acyclic directed graph, where each node corresponds to a random variable.
- ✦ used for modeling across different fields, decision support, and calculation of the probability (Bioinformatics, finance, medicine, image processing, data fusion ....).
- ✦ Examples: Calculating the probability of disease based on symptoms, modeling sequences of symbols - speech, proteins in bioinformatics, as well as decision-making in the economy / financial markets, law ...



Machine Learning

- Machine Learning is a sub-field of artificial intelligence, dealing with algorithms and techniques that allow the computer system 'to learn'...
- One of the aims of machine learning is modeling the mechanisms form the basis of human learning. In this framework, learning algorithms are developed in the way, that are consistent with human way to explore and how to store knowledge and relationships among them.

- ***Machine learning is primarily the algorithms science***:
  - Supervised learning/ Unsupervised learning/ Combinations of both
  - Feedback Learning (i.e. Reinforcement learning)

Machine Learning

✦ Applications of Machine Learning:

- Classification
- Regression
- Clustering
- Ranking
- Structuring....

✦ The most often used techniques:

- Decision trees
- Statistical analysis (Linear, Quadratic...)
- “Covering from the bottom to up” (AQ algorithm)
- Bayesian networks, Neural networks/Perceptron
- Support vectors (Support Vector Machines - SVM)....

Datamining

- ✦ Sub-discipline of "computer science" / AI / SC for obtaining non-trivial hidden and potentially useful information from data, i.e. hidden "dependency-pattern" in the data, using methods from the intersection of AI, neural networks, machine learning, statistical analysis, etc ...
- ✦ The analytic part of *Knowledge Discovery in Databases, KDD*.
- ✦ Its methods include decision trees, association rules, neural networks, regression analysis, clustering, etc. …
- ✦ Difference between Machine Learning and Datamining:
  - Machine learning focuses on the prediction based on the known properties learned from the training data.
  - Data mining is focused on the discovery of (previously) unknown properties in the data.

Evolutionary Computational Techniques

- In computer science, the evolutionary computing are sub-discipline of soft computing and artificial intelligence.
- Evolutionary techniques are inspired by Darwin's principle of natural selection as the key mechanism of evolution and Mendel's laws of heredity.
- These techniques use an iterative process of simulating the evolution of the population. They also use special operators to control the evolutionary processes such as mutation and crossover.
- Area of evolutionary techniques often includes:
  - Evolutionary algorithms (EA)
  - Genetic algorithms (GA)
  - Genetic programming (GP)
  - Evolutionary programming (EP)
  - Evolutionary strategies
  - Swarm intelligence (SA)

Other SC (or related) techniques

- ✦ Chaos theory
- ✦ BigData!!!
- ✦ Hybridization of several methods:

  Neuro-fuzzy classifiers

  Fuzzy-evolutionary systems

  ....
- ✦ Multi-agent systems with the elements of Softcomputing
- ✦ ...