COMPUTATONAL INTELLIGENCE

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Siegfried Nijssen
partially based on slides by Uzay Kaymak

Leiden Institute of Advanced Computer Science

e-mail: snijssen@liacs.nl

Katholieke Universiteit Leuven

e-mail: siegfried.nijssen@cs.kuleuven.be

Goals

- To build *intelligent* systems

Definition: ability to learn, understand, apply knowledge, or think abstractly, esp. in relation to new or trying situations

Properties:

understanding (awareness)

acting (conclusions)

reasoning

thinking

Why intelligent systems?

- Automation of repetitive tasks

- Augmenting limited information processing capability of humans

- Easy interaction with machines

- Understanding human brain and intelligence

- Find out limits of (human) intelligence

Related Areas

- Artificial intelligence

- Data mining

- Machine learning

- Natural computing

Computational Intelligence $\subseteq$ Artificial Intelligence

- AI is the activity of providing machines with behaviour that would be regarded as intelligent if it were observed by humans

- AI is the study of agents that exist in an environment and perceive and act

- Branch of computer science that is concerned with the automation of intelligent behaviour

Intelligence

- Symbolic AI:
Model the reasoning of a brain based on a mechanistic model of the brain (Newtonian age)
  - the brain as a machine

- Connectionist AI:
Model the structure of the brain (Age of neuro-science)
  - Large network of simple elements

- Evolutionary AI:
Model the process in nature that created intelligence

Mechanistic view

- Brain is a mechanical machinery that performs operations

- Ideas are results of these operations

Laws of thought
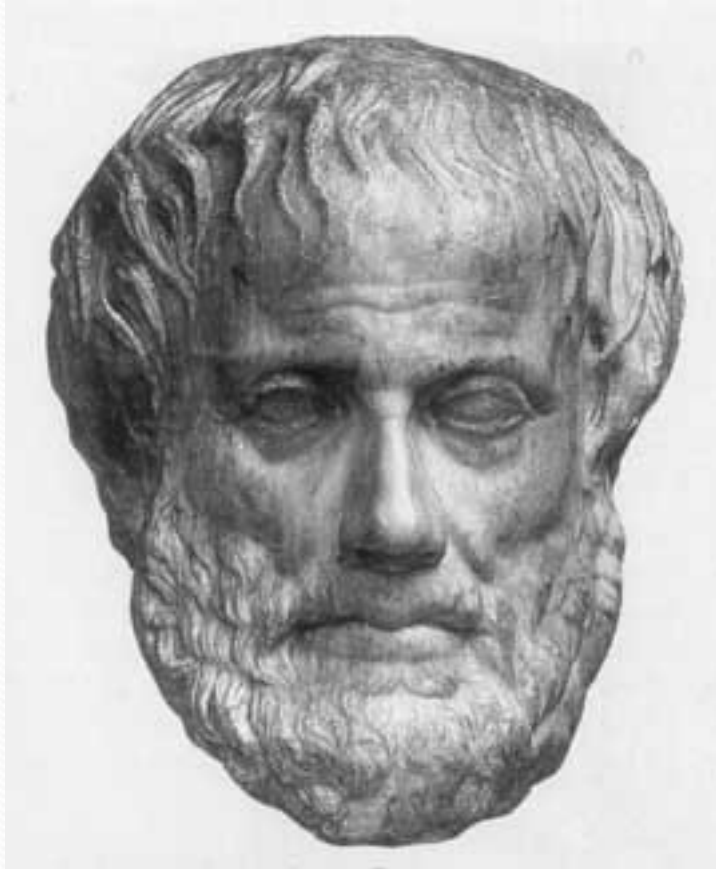
Symbolic AI: Logic

- Symbols represent the state of the world or statements about the world
"warm", "dry"
    - Statement is either true or false
- Inference is symbolic manipulation
    - rule: "warm → airconditioning"
inference when "warm": "airconditioning"
    - correct thinking is the process of finding correct conclusions given correct statements

Representation of semantics

- Symbols are void of semantics and dichotomise the world

  "warm" can be >20 degrees, >30 degrees, ...

- Rules of inference are independent of the semantics
  - same symbol manipulation leads to the same conclusions, irrespective of the context

Disadvantages of Symbolic AI

- Deals badly with noisy & imprecise environments

- Is very sensitive to representation choices

- It can be hard to find a usable formal representation

- Deals badly with quantitative measurements

Computational Intelligence: Soft computing

- Main premise is to deal with uncertainty and imprecision in the environment
  "soft computing is an emerging approach to computing which parallels the remarkable ability of the human mind to reason and to learn in an environment of uncertainty and imprecision" (L.A. Zadeh)

- Extensive numeric computation as opposed to symbolic manipulation only

Symbolic AI - History

- Cybernetics (1947)

- Artificial intelligence (1956)

- LISP programming language (1960)

- Knowledge engineering and expert systems (mid 1970's)

Topics of this course

- Fuzzy Logic

- Neural networks

- Evolutionary computation

Advantages of symbolic AI

- Interpretable knowledge

- Experts can directly contribute or correct knowledge

- Interpretable inference

- Close to other areas in computer science that study and use formal logic
  - Easier to use for computer scientists
  - Connects well to databases

Fuzzy set theory

- "Softer" version of logic

- Pure symbolic AI:
  if *A is true* then *B is true*

- Fuzzy logic:
  if *A is true to a high degree / A is likely* then *B is true to a high degree / B is likely*

Fuzzy set theory

- Systematic calculus to deal with imprecise, incomplete and vague information

- Natural interface to deal with fuzziness in natural language

- Numerical computations performed by using membership functions that represent linguistic labels

Fuzzy set theory

- Essentially a rule based system

- Conclusions are drawn by the inference system, given the knowledge in the rule base

- Sets a link between numeric computations and symbolic representation

Fuzzy set theory - History

- Fuzzy sets (1965)
- Fuzzy controller (1974)
- Fuzzy c-means clustering (1974)
- Fuzzy modelling - TSK model (1985)
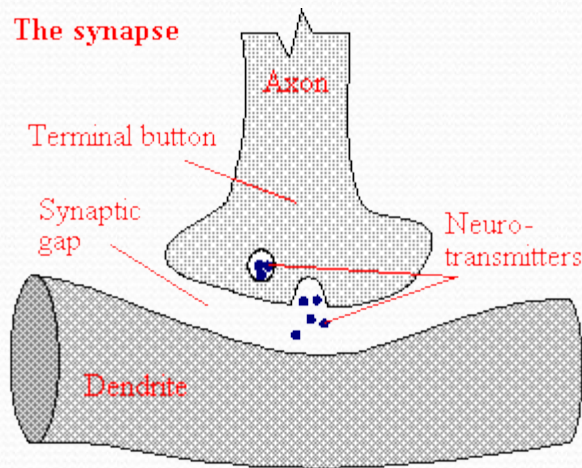- ANFIS (1991)
- CANFIS (1994)

Connectionist AI: Neural networks

- Inspired by biological nervous systems

- A lot of active research in brain modelling

- Intelligence arises out of co-ordinated actions of many computational elements (neurons)

Schematic of biological neuron.
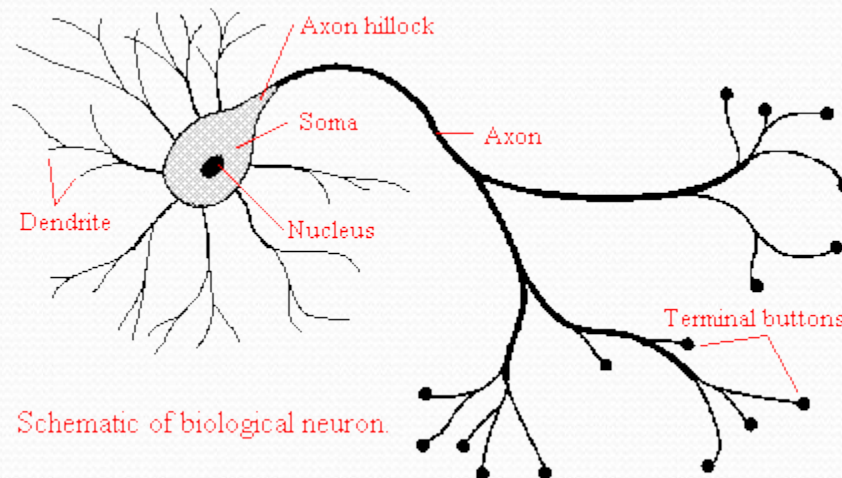
Neural networks

- Biological neurons are connected together by synapses
- Synapses can modify their strength
- Weight factors model synapses that modify their strength

Neural networks

- NN is a network of simple processors (units, neurons)
  - The units are connected by connections
  - Each connection has a numeric weight associated with it
  - The units operate only locally - on their weights and the inputs they receive via the connections

- Many types of neural networks
  - feed-forward neural networks
  - self-organizing maps
  - recurrent networks
  - radial basis function networks

Neural networks - History

- McCulloch-Pitts neuron model (1943)
- Perceptron (1957)
- Backpropagation algorithm (1974)
- Self organizing map (1980)
- Hopfield net (1982)
- Boltzmann machine (1983)
- Backpropagation boom (1986)

Advantages Connectionist AI

- Massive parallelization

- Robust in the face of errors in weight factors

- Robust to loss of connections or connection elements

- Good algorithms for learning networks

- Might provide insight in how human intelligence works

Disadvantages Connectionist AI

- no insight into the presence of information (black box approach)

- no interpretable rules of inference; why the machine works is often unclear

- requires many numerical computations and a good understanding of mathematics

Evolutionary computation

- "A system is intelligent if it finds an intelligent solution"
- "Intelligence is an emergent behaviour"
- Intelligence is achieved by a population, not by one individual
- Inspired by evolution of biological systems
- Evolution of "better" individuals in a society with competition
- Competition can be for limited resources or through "survival of the fittest"
- Requires a mechanism for selecting successful individuals

Evolutionary computation

Several forms of evolutionary computation:

- genetic algorithms
- genetic programming
- evolutionary strategies
- ant colony optimization

Other randomized search approaches:

- simulated annealing
- random search

Evolutionary computation

- Genetic algorithm (1970's)

- Artificial life (1980's)

- Immune modelling (1980's)

- Genetic programming (1990's)

- Swarms, ants (2000's)

Advantages Evolutionary AI

- Highly adaptive to fast changes in the environment

- Can find solutions for problems for which it is hard to derive a closed-form solution

- Fault tolerant

- Basic EAs are easy to implement

- Allow for parallelism

- Attractive nature inspired motivations

- May provide insight in evolution in nature

Disadvantages Evolutionary AI

- Can be resource intensive

- Can not ensure the quality of a solution due to its stochastic nature

- May not provide an explanation for the good quality of a solution

Characteristics of soft computing

- Fault tolerance
  deleting neurons or rules degrades performance gracefully
  handling of uncertainty and imprecision, adaptability

- Biologically inspired computing models

- New optimization techniques
  e.g. evolutionary search for non-gradient based optimization

- Numerical computation

Course overview

- Introduction [Today]

- Fuzzy logic [Today, 2 weeks]

- Neural networks [2 weeks]

- Evolutionary computation [3 weeks]
  - genetic algorithms
  - ant colonies
  - particle swarms

Course overview

- 8 lectures of 3 hours, spread over 10 weeks
  29 September 2011 - 1 December 2011

- Final mark obtained 70% from a written exam and 30% from a course assignment handed out beginning of November

Suggested literature
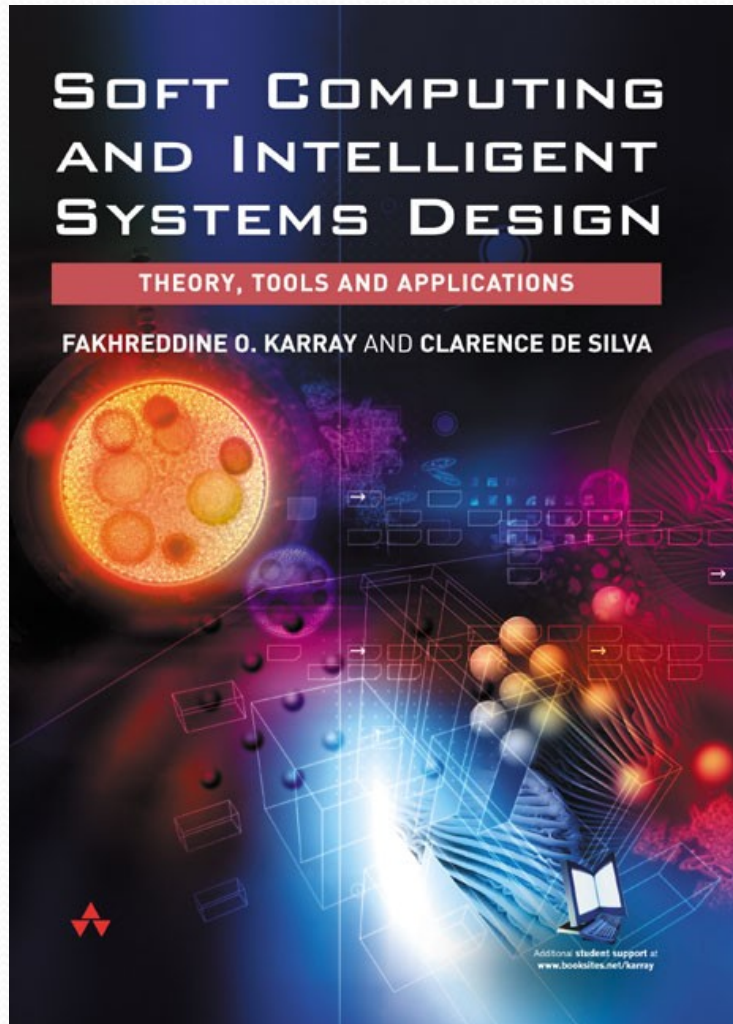
- Fakhreddine O. Karray & Clarence De Silva, *Soft Computing and Intelligent Systems Design,* Addison Wesley, 2004. ISBN : 0-321-11617-8