ECE 449 Intelligent Systems Engineering

Intelligent Systems

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Intelligent Systems

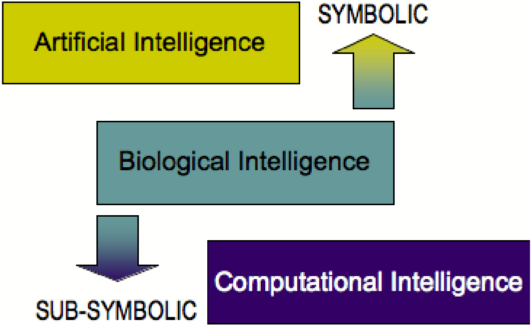
Intelligent systems

generally have a capacity to acquire and apply knowledge in an "intelligent" manner and have the capabilities of *perception*, *reasoning*, *learning*, and making inferences (or decisions) from *incomplete information*. [Karray, 2004]

Iintelligent agent

is any device that *perceives* its environment and takes *actions* that maximize its chance of successfully achieving its *goals*. [AI on wikipedia]

The A-B-C of Intelligence



(Biological) Intelligence

Biological Intelligence

represents "components of intelligence that can be directly attributed to the anatomy and physiology of the central nervous system. Biological intelligence is sometimes distinguished from artificial intelligence, i.e., intelligence demonstrated by computer behavior, and from psychometric intelligence or intelligence as documented by the performance of subjects on IQ tests." [Medical Dictionary, 2009]

- Difficult to define
- Usually described in terms of characteristics or capabilities
  - recognizes patterns
  - resourceful, smart

Artificial Intelligence (AI)

- The science of making machines do things that would require intelligence if done by men.

[Marvin Minsky, 1968]

- Automation of activities that we associate with human thinking: decision making, problem solving, learning

[Bellman, 1978]

- The mimicking of human thought and cognitive processes to solve complex problems

[Stottler, 1999]

Computational Intelligence (CI)

- Techniques able to deal with imprecise, incomplete, partially incorrect information in dynamically changing environments and large variable spaces.
- In contrast to the traditional AI, CI makes use of sub-symbolic (numerical) knowledge representation and processing.
- Includes: Artificial Neural Networks (NN), Fuzzy-Logic (FL), Evolutionary Algorithms (EA), etc.

Capabilities of CI methods

- Adaptivity;
- Fault tolerance;
- Speed of operation (close to the speed of human cognition processes, especially in the case of parallel processing); and
- Error rate optimality (relation of learning effort and error rates).

[Bezdek94]

Hard Computing vs. Soft Computing

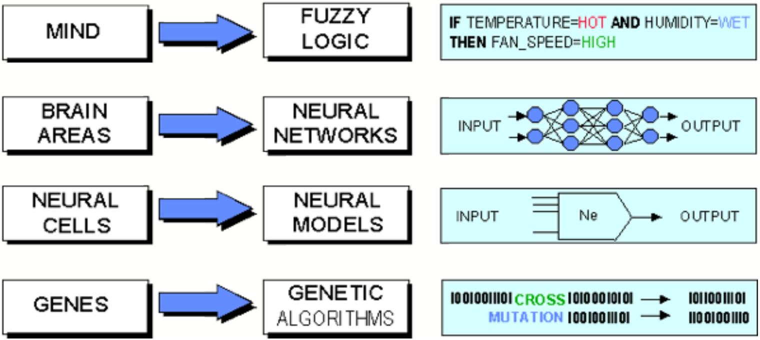
Hard Computing

- based on binary logic, crisp systems, numerical analysis and crisp software

Soft Computing (coined by Zadeh)

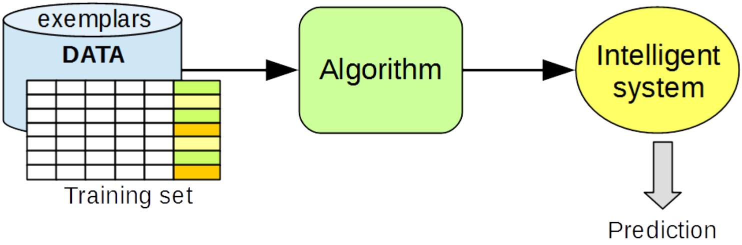
- based on fuzzy logic, neural nets and probabilistic reasoning

Various Levels of Inspiration



Use of Intelligent Systems

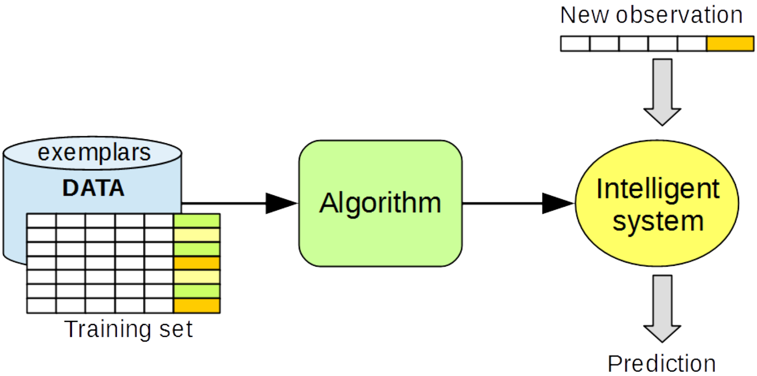
Phase 1/2: Development



Exemplars $\rightarrow$ Intelligent system (through algorithm)

Use of Intelligent Systems

Phase 2/2: Application



Intelligent system can be, e.g., predictor, classifier, controller

Fuzzy Sets

- Allow for imprecision, uncertainty, ambiguity
- Allow “computers to be less precise”
- Involve the “grey areas”
- Use gradual membership

Fuzzy “mathematics”

Extension of conventional mathematics to handle fuzzy constructs:

- Fuzzy logic
- Fuzzy relations
- Fuzzy arithmetic
- Fuzzy probability
- Fuzzy integrals

When can Fuzzy sets help?

- There is a high level of uncertainty, complexity; and/or non-linearity
- There is human expertise that cannot be easily expressed using analytical methods
- Problem can be described using qualitative terms

Note

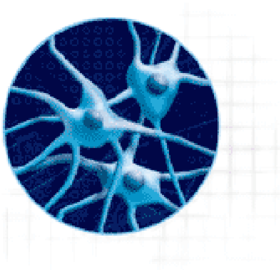
FS are *transparent*, one can understand how system works from its structure and parameters.

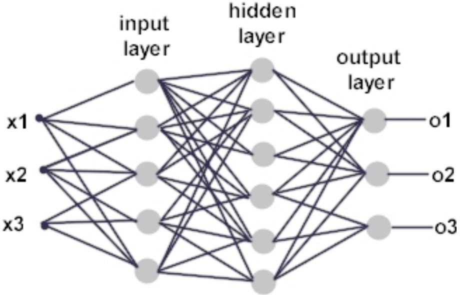
Applications of Fuzzy Sets

- Areas that involve a high level of uncertainty, complexity, or nonlinearity - economics, data analysis, others.
- Decision-support and expert systems - medicine, management and financial decision-modeling
- Pattern recognition and classification - allowing belongingness to more than a single class
- Control - electronically stabilized camcorders, autofocus cameras, washing machines, air conditioners, transmissions, subway trains
- Modeling of uncertainty and its propagation - e.g. in maufacturing process, cost estimation

Neural Networks

NNs are based upon the parallel architecture found in animal brains





NN - A New Sort of Computer?

Conventional (von Neumann) computer systems are

Good at

- Fast arithmetic
- Doing precisely what the programmer programs them to do

Not so good at

- Interacting with noisy data or data from the environment
- Fault tolerance
- Adapting to circumstances
- Massive parallelism

What is a Neural Network?

- Different paradigm for computing:
  - Von Neumann machines are based on processing/memory abstraction of human information processing.
  - Neural networks are based on the parallel architecture of animal brains.

Note

Most NNs are opaque (black boxes); they do not provide much insight into *how* a problem is solved!

When can Neural Nets help?

- Cannot formulate an algorithmic solution.
- Can obtain lots of examples of the behavior/function/classification we require
- Need to derive the structure from existing data

Applications of Neural Networks

- Forecasting - weather, energy consumption, investment analysis (predicting stock movements, currencies etc., from historical data)
- Classification - sorting mail by ZIP/PC, occupancy classification
- Signature analysis - comparing signatures made (e.g. in a bank) with those stored (first large-scale applications of neural networks in the USA, also one of the first to use a neural network chip)
- Process control - most processes cannot be determined as computable algorithms, NNs can learn to control the process from data
- Monitoring/diagnostics - the state of aircraft engines or train diesel engines.

Evolutionary Computing

Mimics the processes of biological evolution

- natural selection
- survival of the fittest

to provide effective solutions for (optimization) problems

The first approach to EC - genetic algorithm (GA)

- Solution states encoded as binary-valued strings
- Population of candidate solution states is generated and evaluated
- Fitness function to evaluate the solutions
- Better solutions are recombined using genetic operators to form new solutions (i.e., offspring) which are generally more fit than the previous iteration (i.e., generation).
- The process is repeated until an acceptable solution is found within specific time constraints.

Other EC Paradigms

- Genetic programming,
- Evolution programming,
- Evolution strategies,
- Learning classifier systems.

EC approaches are helpful when

- Other optimization approaches have failed - often because the search space is too large.
- Although form of desired solution is not known, it is possible to evaluate quality of candidate solutions (fitness)

Applications of Evolutionary Computing

- <u>Scheduling</u>, resource allocation,
- <u>Training</u> of artificial neural networks
- <u>Selecting</u> or <u>tuning</u> rules for fuzzy systems
- PCB <u>layout</u>, circuit <u>design</u>
- <u>Telecommunications</u> (routing, switching, etc.)

Other Interesting Paradigms

- Artificial Immune Systems
  - learn to distinguish self from non-self
  - use concept of affinity (a.k.a. fitness)
- Swarm Intelligence
  - modeling of social animals: self-organization, no leader; flexibility, collective problem solving