CE-317 GIS/RS Application to Civil Engineering
Spring 2011

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- Lecture 08: Geo - computation

Presentation Outline

- Definition
- Area of Research
- Description of Each Area

Geocomputation

- Geocomputation is a set of computational methods that has been customized to address the special characteristics of spatial data.
- The term 'computational' has come to replace what used to be known as artificial intelligence techniques.

Areas of Research

- 05 Areas of research are:
  1. fuzzy reasoning (not implemented in software)
  2. neural networks
  - genetic algorithms (not implemented in software)
  1. cellular automata
  2. agent-based modeling systems

Fuzzy Reasoning

- Rather than categorizing everything as yes/no, black/white, zero/one etc., as introduced in Boolean logic, fuzzy logic extends the hard values **zero** and **one** to everything **in between**.
- An attribute can now be a little bit of green and a little more of blue rather than either green or blue.
- And applied to geographic phenomena, Florida can be 10% tropical, 80% subtropical, and another 10% moderate in climate.

Fuzzy Reasoning

- The best everyday illustration of how fuzziness works is a shower knob that this author found in the bathroom of a New Zealand.

Fuzzy Reasoning

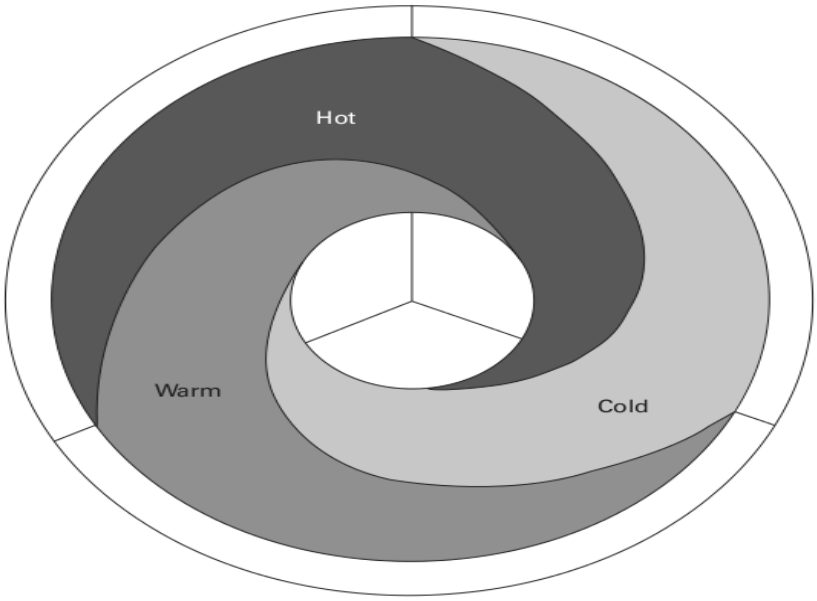

Figure 63 Shower tab illustrating fuzzy notions of water temperature

Fuzzy Reasoning

- Data in fuzzy sets can be manipulated using basic operations that are similar to those found in Boolean logic – union (OR), intersection (AND) and negation (NOT).
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Neural Networks

- With the advent of large spatial databases, sometimes consisting of terabytes of data, traditional methods of statistics become untenable.

- Using a very large number of extremely simple processing units, the brain manages to perform extremely complex tasks
- Each performing a weighted sum of its inputs, and then firing a binary signal if the total input exceeds a certain level.

Neural Networks

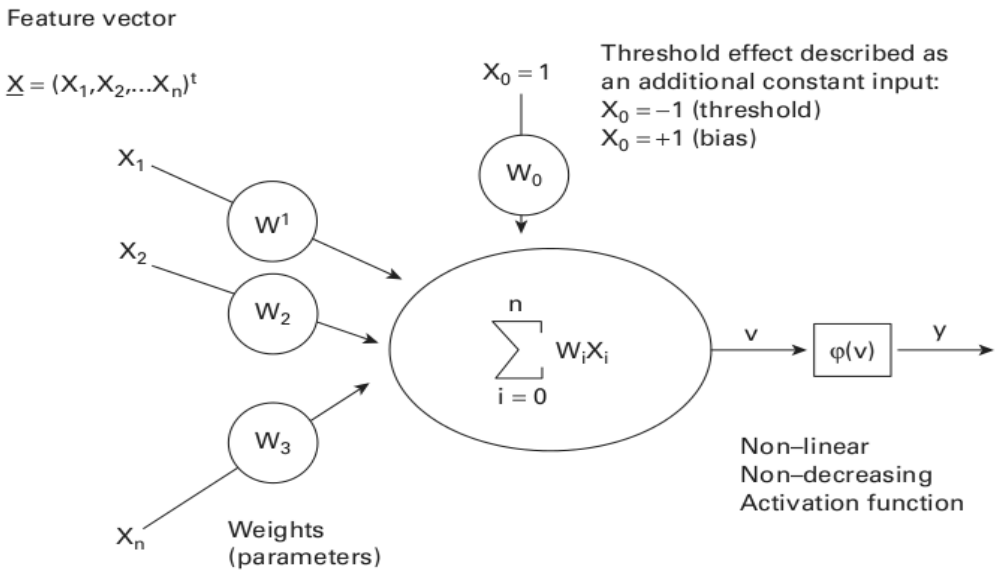

Figure 64 Schematics of a single neuron, the building block of an artificial neural network

Neural Networks

- Examples include adaptive learning, self-organization, error tolerance, real-time operation and parallel processing.
- As data is given to a neural network, it (re-)organizes its structure to reflect the properties of the given data.
- All artificial neural networks can be divided into two learning types – supervised and unsupervised.

Neural Networks

- In supervised learning, a desired output result for each input vector is required when the network is trained.
  - It uses the target result to guide the formation of the neural parameters.
- In unsupervised learning, the training of the network is entirely data-driven and no target results for the input data vectors are provided.

Pros & Cons of NN

- First, given the data volume, we could not have arrived at these results, which is the positive aspect.
- On the downside, the results are data and do not give us any insight into what is actually happening.
  - From a scientific perspective, statistics is supposed to help us understand how things work.
  - Neural networks, however, act like a black box

Genetic Algorithms

- NN are used when we have a large amount of data
  - while
- Genetic Algorithms are used when we have a large number of possible solutions.

Genetic Algorithms

- A nice spatial example is the traveling salesman problem, where the task is to find the optimal sequence of customers in a sequential path.
- The problem cannot be solved for more than a handful of points because of the combinatorial explosion of options.
- Genetic algorithms cannot claim to find the absolute best solution, but they are very good at finding better solutions than anyone or anything else.

Genetic Algorithms

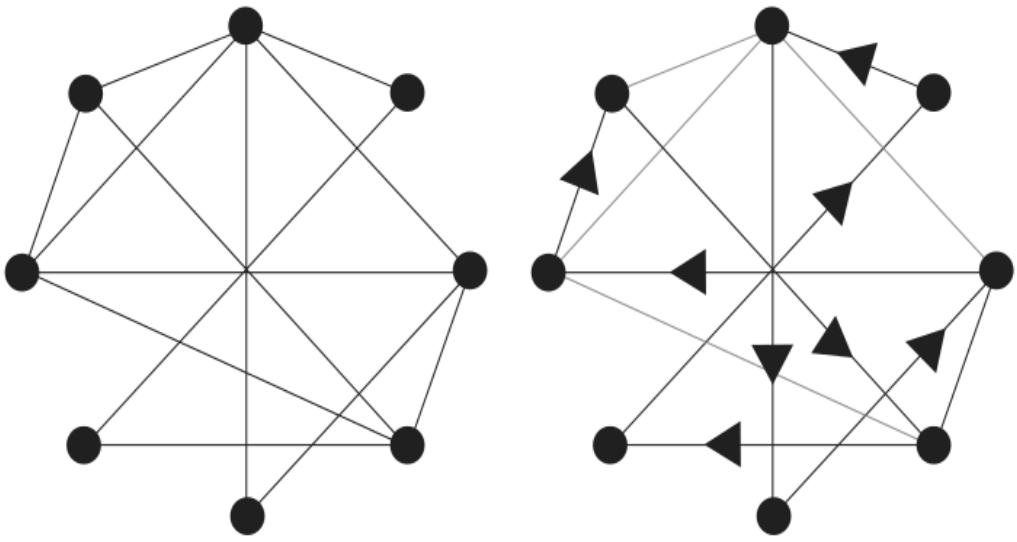

Figure 65 Genetic algorithms are mainly applied when the model becomes too complicated to be solved deterministically

Genetic Algorithms

- Evolutionary programming starts by generating a population of purely random expressions – that is, random model equations.
- These are evaluated in terms of a fitness function.
- The best expressions are reused and sent to compete with a new generation of **crossovers** and slightly **mutated** versions of previously successful expressions.
- This process is repeated until no improvement is achieved.

Genetic Algorithms

- A crossover is a mixing of previously successful strategies, while a mutation is a slight alteration.

Cellular Automata

- CA are a modeling framework for spatially continuous phenomena such as landscape processes or urban sprawl.
- They are simple models used to represent the diffusion of things such as matter, information or energy, over a spatial structure.

Cellular Automata

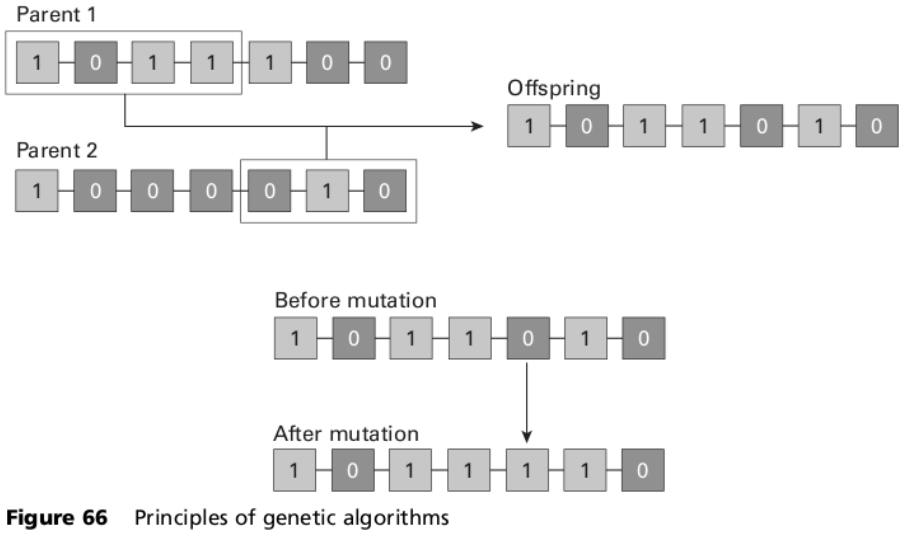

Figure 66 Principles of genetic algorithms

Agent-based modeling systems

- Agent-based modeling (ABM), synonymous with individual-based modeling in ecology, is a simulation methodology focused on mobile individuals and their interaction.
- 'Agent' is a generic term used for any constituent entity whose behavior we wish to model, and for its representation within the model.
- Agent-based models offer the ability to capture the dynamic interactions of individuals and the context in which they occur.

Agent-based modeling systems

- Agent-based models enable the creation of 'artificial societies' which can be viewed as laboratories in which to conduct experiments.
- The primary distinction between CA and ABM is the conceptual primitive used to represent phenomena.

Agent-based modeling systems

- In CA, this primitive is a static cell or pixel, a collection of which composes a layer of cells. Its dynamics involve each cell transferring information to its neighboring cells.

- An ABM, in contrast, is composed of distinguishable objects, the same geometric primitives of point, line or polygon data models found in GIS.

Q n A