


*Artificial Intelligence in
Modeling and Simulation*

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Artificial Intelligence Techniques

- ❖ Artificial systems attempt to model real-world systems
- ❖ The proven AI technologies:
 - ❖ Genetic algorithms
 - ❖ Simulated annealing
 - ❖ Fuzzy logic
 - ❖ Neural networks

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Optimization Problems

- ❖ Often times, the reason for modeling a system is to improve its performance
- ❖ These AI techniques have achieved success:
 - ❖ Genetic algorithms and simulated annealing
 - ❖ Search problems
 - ❖ Fuzzy logic
 - ❖ Control systems
 - ❖ Neural networks
 - ❖ Pattern recognition and classification

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Genetic Algorithms

- ❖ Developed by Holland in the early 1970's
- ❖ Search routines which attempt to emulate the process of natural selection or “survival of the fittest”
- ❖ The search space consists of binary strings (i.e. chromosomes), each representing a different state or solution to the problem at hand
- ❖ Simulated evolution leads to better and better chromosomes which solve the search problem

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Genetic Algorithms

- ❖ The genetic operators for reproduction are called *crossover* and *mutation*
- ❖ The selection operator is a user-defined *fitness* function
- ❖ The evolution of the system takes place by:
 - ❖ initializing a population of chromosomes
 - ❖ applying reproduction operators to selected pairs of parents
 - ❖ evaluating the fitness of each of the offspring
 - ❖ saving only the fittest members for reproduction in the next generation
 - ❖ Iterate this process until no further improvement is in sight.

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Genetic Algorithms

- ❖ The evolutionary process continues until the population reaches steady state
 - ❖ at which point the most fit individual represents the best solution to the problem
- ❖ Selection of parents is done via a *roulette wheel* process
 - ❖ the probability of a chromosome being selected as a parent is directly proportional to the fitness of the chromosome

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GA Example

- ❖ Consider the following parent chromosomes:
 - ❖ {110001, 001110}
- ❖ Single point crossover works by randomly selecting a *crossover point*
 - ❖ {110001, 001110} → {110110, 001001}

A mutation probability (.01) determines if each bit is toggled

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Simulated Annealing

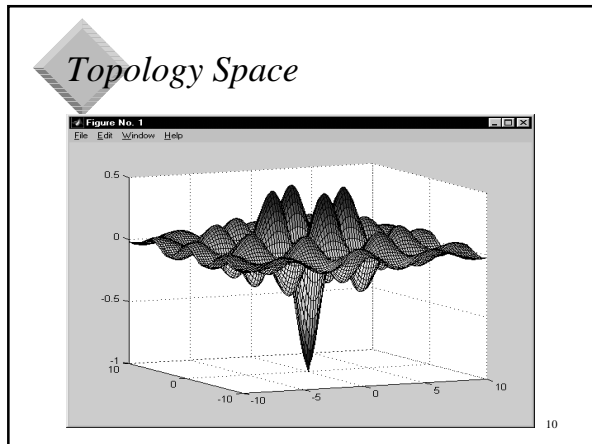
- ❖ Developed by Kirkpatrick in 1983 to address combinatorial problems
 - ❖ Based on Metropolis' alg. for the simulation of collections of atoms at thermal equilibrium, 1953
- ❖ Simulates the annealing process (metallurgy)
 - ❖ Used to produce solids with specific properties
- ❖ Used by computer chip makers to address the "VLSI Layout" problem in 80's & 90's

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Simulated Annealing

- ❖ In annealing, solids are heated until molten
 - ❖ Atoms are free to move about at high energies
 - ❖ Slowly cooled, allowing thermal equilibrium
 - ❖ At ambient temp. solid has desired properties
 - ❖ Tempered, non-brittle, maximum strength
- ❖ Search space has many clustered hills/valleys (maximums/minimums)
 - ❖ Atoms represent possible solutions to problem
 - ❖ As temp declines, atoms settle in valleys
 - ❖ Some in the minimum valley (optimum answer)

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Fuzzy Logic


- ❖ Based on Fuzzy Sets
 - ❖ Lotfi Zadeh (UC-Berkeley, 1965)
 - ❖ Set membership is a probability, not binary!
- ❖ Makes use of “fuzzy” terms
 - ❖ Hot, warm, cold
 - ❖ Fast, average, slow
 - ❖ Short, medium, tall
- ❖ Often used in complex control systems

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Neural Networks

- ❖ Based on the idea of neural receptors & transmitters
 - ❖ McCulloch-Pitts (1943), D.O. Hebb (1949)
- ❖ Feedback is used to tell each neuron how to modify its output, based on the given input
- ❖ Networks of neurons form a system which, over time, learns to adapt its output to the expected value

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 *Genetic Algorithm Demo*

- ❖ NetSAGA
 - ❖ Designs network topologies to minimize overall cost

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