Beyond “Classic” Search
Review

• Take five minutes with your neighbors:
  – What is "Hill Climbing" as a search technique?
  – What can go "wrong" with Hill Climbing?
  – How does "Simulated Annealing" attempt to overcome this?
Genetic Algorithms (GAs)

• Genetic Algorithms (GAs) are adaptive heuristic search algorithms.

• GAs are designed to simulate processes in natural systems necessary for evolution (based on Darwin).

• In nature, competition among individuals for scanty resources results in the fittest individuals dominating over the weaker ones.

• Although randomized, GAs are by no means random, instead they exploit historical information to direct the search into the region of better performance within the search space.
Genetic Algorithms (GAs)

• **History**
  – Were formally introduced in the US in the 1970s by John Holland at University of Michigan.

• **Characteristics of GA**
  – Belong to the class of stochastic search methods (e.g., simulated annealing) where next move uphill is chosen randomly.
  – GAs operate on a population of solutions
    • most stochastic search methods operate on a single solution to the problem at hand
  – The algorithm is separated from the representation
How the GA Works

Chromosome

Gene: 1 0 1 1

Population

Selection
Crossover
Mutation

[Diagram showing the process of genetic algorithm with chromosomes, genes, selection, crossover, and mutation]
The GA Terminologies

• Chromosome (Genome)
  – A structure to encode solutions to the problem that can be stored in the computer.

• Population, selection, crossover, mutation
  – The GA creates a population of genomes
  – Then applies crossover and mutation to the individuals in the population to generate new individuals.
  – It uses various selection criteria so that it picks the best individuals for mating (and subsequent crossover).
The GA Terminologies

• Crossover
  – Typically two parents combine to produce two or more children.
  – Can define asexual crossover or single-child crossover as well

• Mutation
  – Introduces a certain amount of randomness to the search.
  – Help the search find solutions that crossover alone might not encounter.

• Objective function
  – Your objective (fitness) function determines how 'good' each individual is.
<table>
<thead>
<tr>
<th>Initial Population</th>
<th>Fitness Function</th>
<th>Selection</th>
<th>Crossover</th>
<th>Mutation</th>
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<td>32752411</td>
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![Chessboard Diagram](image.png)
## Usage of GA

- The three most important aspects of using GA
  - definition of the objective/fitness function
  - definition and implementation of the genetic representation
  - definition and implementation of the genetic operators

- Beyond that you can try
  - Many different variations to improve performance
  - Find multiple optima (species - if they exist)

- Variations
  - Can modify the basic algorithm
  - Many parameters can be adjusted
  - If you get the objective function right, the representation right and the operators right, then variations will result in only minor improvements.
The Pros and Cons of GA

• Advantages
  – Very simple
  – Performs well on many different types of problems
  – Works well on mixed (continuous and discrete), combinatorial problems.
  – Attractive for some types of optimization
  – Less susceptible to getting 'stuck' at local optima than gradient search methods.

• Disadvantages
  – Tend to be slow
  – Tend to be computationally expensive
  – Do not adapt well to new situations