Genetic Algorithms and Evolutionary Computing

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What are Genetic Algorithms?

- Artificial Intelligence algorithms inspired by Darwin's theory of evolution
- Solutions to problems solved by genetic algorithms (GAs) is evolved
Biological Background of GAs

- **Chromosomes**
  - Chromosomes are strings of DNA and serve as a model for the whole organism.
  - Chromosomes consist of genes, and each gene encodes a trait.
  - Each trait defines an attribute about the organism, called an allele, such as blue eyes or super strength.

Reproduction of Organisms

- Reproduction is necessary to create new offspring.
- During reproduction, a recombination, or crossover of genes occur, and form a whole new chromosome for the offspring.
- The parents for an offspring is selected by their fitness, or a measurement of the parents success in life.
From Biology to an Algorithm

- The Algorithm starts with a set of solutions
  - The set is called a population, each with a distinct chromosome, which all exist in a search space
- Solutions from one population are used to form a new population, in hopes if it being better than the last
  - May look for either the best solution or a suitable solution
- The more fit solutions are chosen to create offspring, and have a greater chance to reproduce

Mutations

- Elements of the chromosome are changed a little, caused by an error in copying genes from the parents
- Mutations are made to prevent the GA from falling into a local extreme
- If it occurs too often, the GA becomes random
Reproduction Selection Methods

- **Eletism**
  - Method where the best or few best chromosomes of a generation are copied to a new generation, and can rapidly increase performance

- **Steady State Selection**
  - The best chromosomes create offspring to replace the worst, while the middle of the pack are unchanged

- **Roulette Wheel Selection**
  - Those most fit to survive are used more often to reproduce; based entirely on individual fitness

- **Rank Selection**
  - All chromosomes are ranked individually, each getting a proportional chance to reproduce

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**Roulette Wheel Graph**

Chromosome 1 is the most fit, with the best chance to reproduce

Chromosome 4 is the least fit, with the smallest chance to reproduce
Outline of Basic GA

1. [Start] Generate random population of $n$ chromosomes (suitable solutions for the problem)
2. [Fitness] Evaluate the fitness $f(x)$ of each chromosome $x$ in the population
3. [New population] Create a new population by repeating following steps until the new population is complete
   - [Selection] Select two parent chromosomes from a population according to their fitness (the better fitness, the bigger chance to be selected)
   - [Crossover] With a crossover probability cross over the parents to form a new offspring (children). If no crossover was performed, offspring is an exact copy of parents.
   - [Mutation] With a mutation probability mutate new offspring at each locus (position in chromosome).
   - [Accepting] Place new offspring in a new population
4. [Replace] Use new generated population for a further run of algorithm
5. [Test] If the end condition is satisfied, stop, and return the best solution in current population

[Loop] Go to step [Fitness]
Application of GAs

- Good at satisfying NP-hard problems
- Traveling Salesman Problem and Example
  - Crossover Types
    - One point - part of the first parent is copied and the rest is taken in the same order as in the second parent
    - Two point - two parts of the first parent are copied and the rest between is taken in the same order as in the second parent
    - None - no crossover, offspring is exact copy of parents

Traveling Salesman Cont.

- Mutations
  - Normal random - a few cities are chosen and exchanged
  - Random, only improving - a few cities are randomly chosen and exchanged only if they improve solution (increase fitness)
  - Systematic, only improving - cities are systematically chosen and exchanged only if they improve solution (increase fitness)
  - Random improving - the same as "random, only improving", but before this is "normal random" mutation performed
  - Systematic improving - the same as "systematic, only improving", but before this is "normal random" mutation performed
  - None - no mutation
Various GA Notes

- Tradeoffs:
  - Advantage: Parallelism, simple to implement
  - Disadvantage: Slow, many computations
- Best crossover rates: ~ 80% - 95%
- Best mutation rates: ~ 0.5% - 1%
- Population Size: 20-30, also dependant on size of chromosome