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Computational Intelligence

Subject11: Genetic Algorithm

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Agenda

- Evolutionary approaches
- Genetic algorithm
- Genetic programming
- Evolution strategy

Evolutionary Approaches

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- Genetic Algorithm
  - A metaheuristic inspired by the process of natural selection
- Genetic Programming
  - A technique of evolving programs to find a fit for a particular task
- Evolutionary Strategy
  - An optimization technique based on the ideas of evolution
- Evolutionary Programming
  - One of the major evolutionary algorithm paradigms where the goal is to optimize numerical parameters

Evolutionary Approaches

- Differential Evolution
  - A method to optimize a problem by iteratively improving the candidate solution
- Cultural Algorithm
  - A branch of EC with a knowledge component along with the population
- Cooperative Coevolution
  - Dividing a large problem into subcomponents and solving them independently
- Memetic Algorithm
  - An extension of the traditional genetic algorithm

Genetic Algorithm

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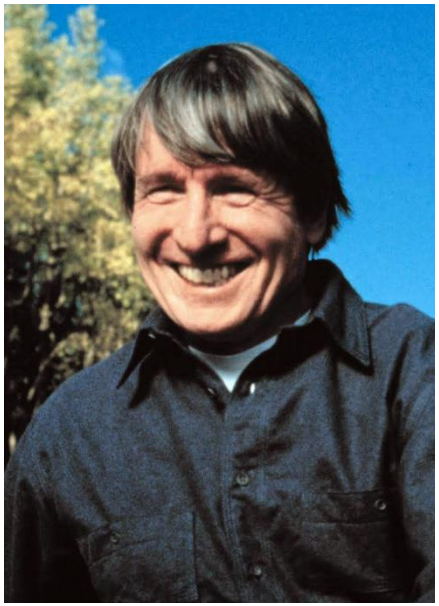
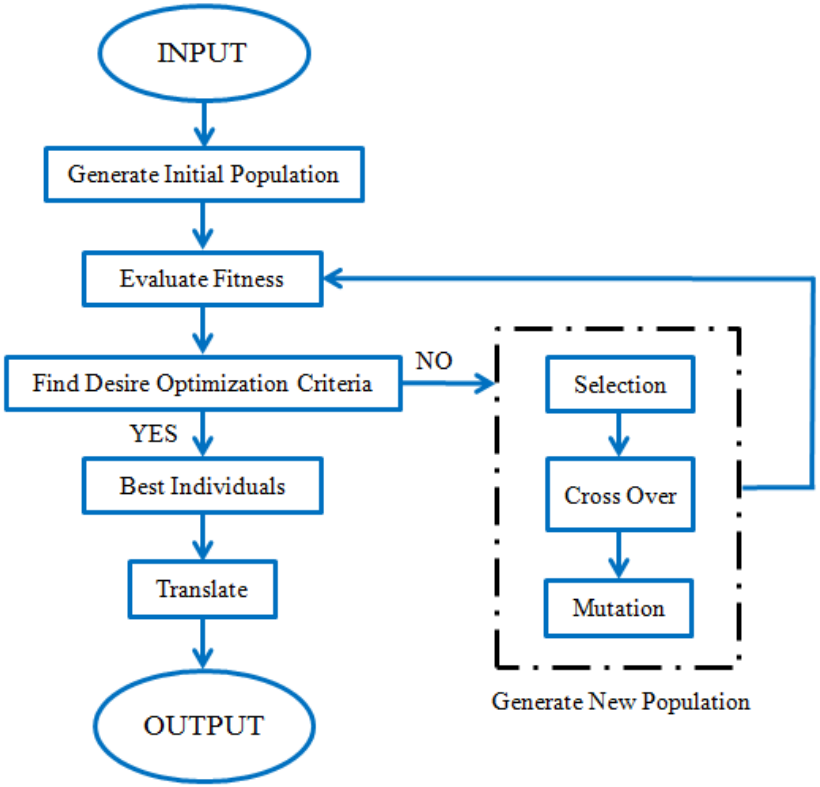
Brief history

- **Alex Fraser**, simulation of artificial selection of organisms
- **Hans-Joachim Bremermann**, adopted a population of solution to optimization problems
  - Recombination, Mutation, and Selection
- **Barricelli**, simulated the evolution to play game
- **Lawrence J. Fogel** and evolutionary programming
- **John Henry Holland**, the pioneer in what became known as genetic algorithms



Genetic Algorithm



Genetic Algorithm

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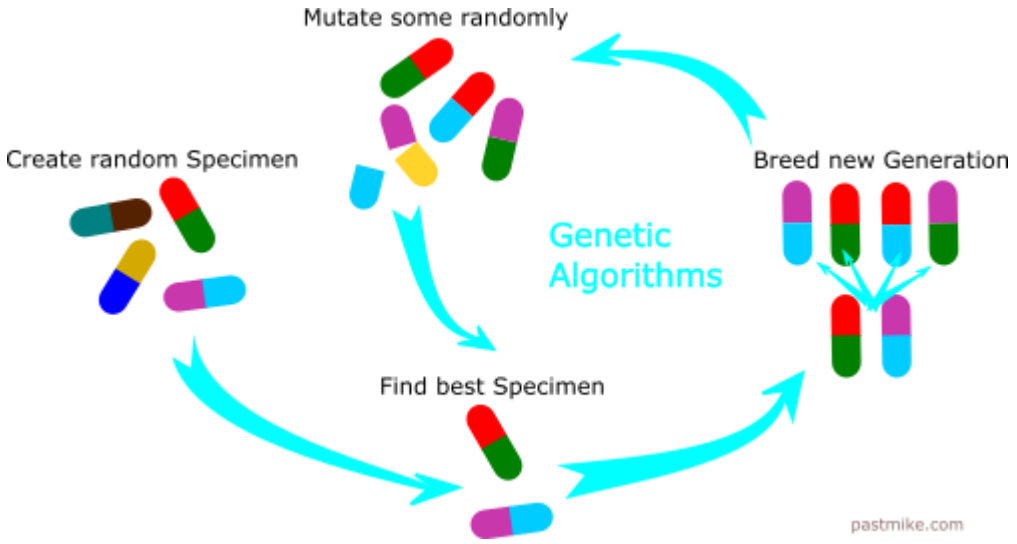
Applications of GA

- Search
- Optimization
- Machine Learning
- Robotics
- Control
- Scheduling



Genetic Algorithm

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Standard Genetic Algorithm

- Chromosomes contain binary genes
- Constant size of population during the process
- Fitness proportionate selection
- Single-point crossover
  - High crossover probability (+95%)
- Bit Flip mutation
  - Low mutation probability (chromosome's length)

Genetic Algorithm

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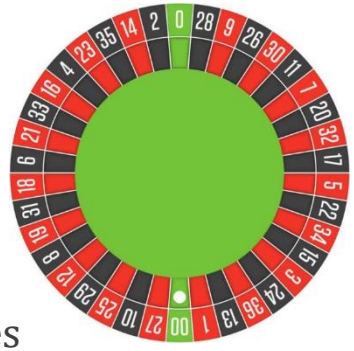

Standard Genetic Algorithm

- Selection method - Fitness proportionate selection
  - AKA Roulette Wheel Selection
  - A proportion of the wheel is assigned to each of the chromosomes
    - Based on their fitness value
    - Optimized chromosomes ➔ More chance of selection

$$P_i = \frac{f_i}{\sum f_i}$$

No.	Chromosome	Fitness	Chance
1	01101	169	14.4
2	11000	576	49.2
3	01000	64	5.5
4	10011	361	30.9

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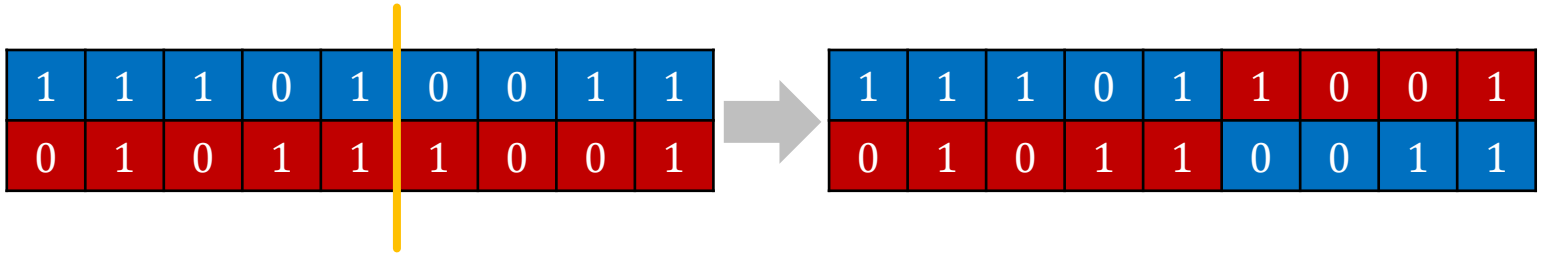
Standard Genetic Algorithm

- Recombination/Crossover

  Single-point crossover

  - A random point (Crossover Point) is picked
  - Swapping items from the selected point
  - **Outcome**: two offspring, each with some data from both parents



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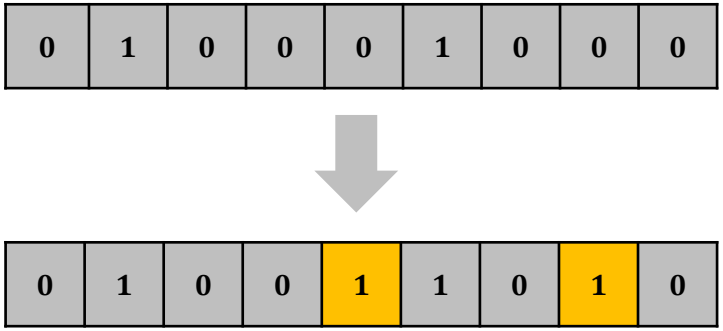
Standard Genetic Algorithm

- Mutation

  Bit Flip (binary)

  - Reverse the values of some genes



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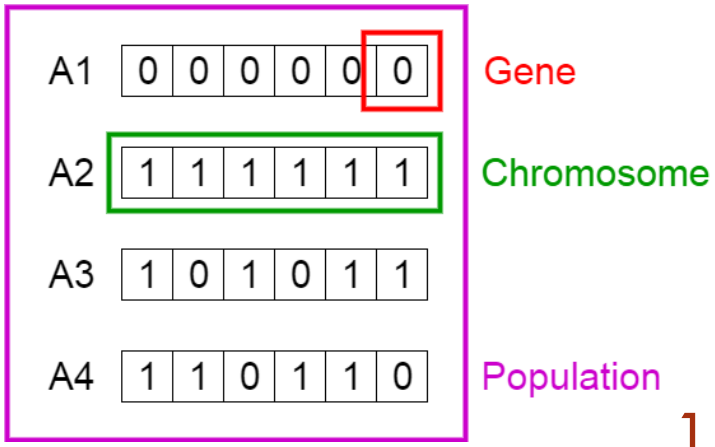
Implementation

- Init population: available solutions to solve a problem
- In the SGA, chromosomes are binary arrays
- In the extended version, they can be:
  - Graph
  - Tree
  - Struct
  - Node
  - Array members
  - etc.



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Implementation

- Fitness function: How good a chromosome is compared to others?
- Consider a weight/score to each chromosome
- Select two chromosomes holding the greatest scores

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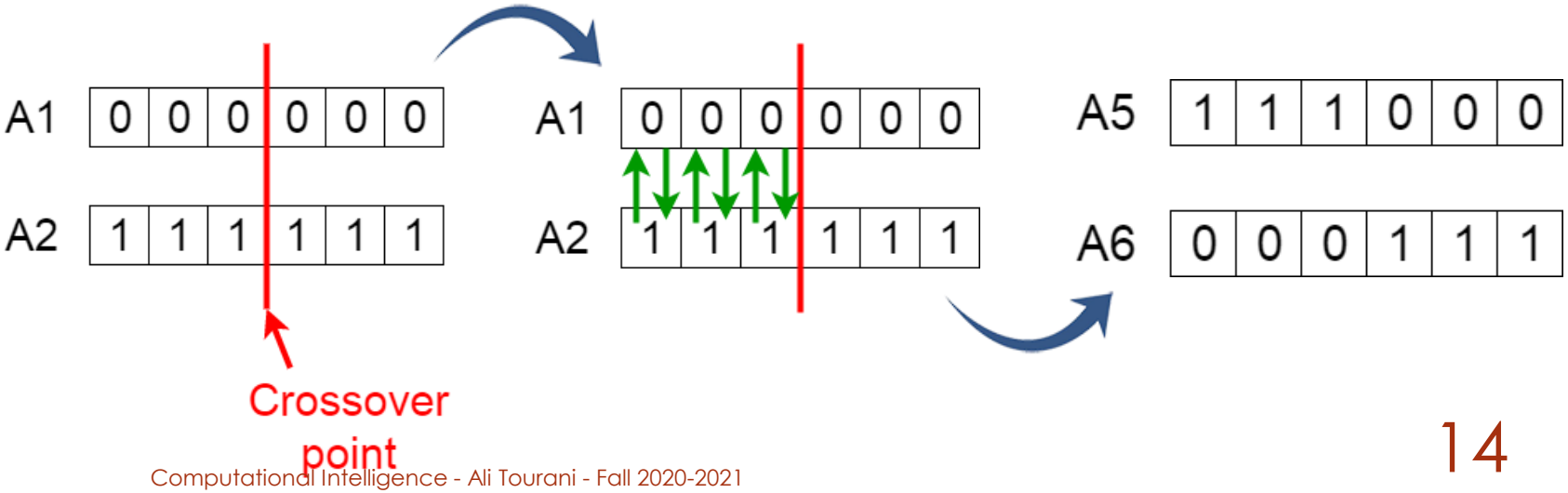
Implementation

- In recombination, randomly choose a break point
- Start replacing the items from the given point
- Add new items to the main population



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Implementation

- In Mutation, reverse some random genes
- Add new items to the main population
- Check the Termination condition: no new offspring

Before Mutation

A5	1	1	1	0	0	0

After Mutation

A5	1	1	0	1	1	0

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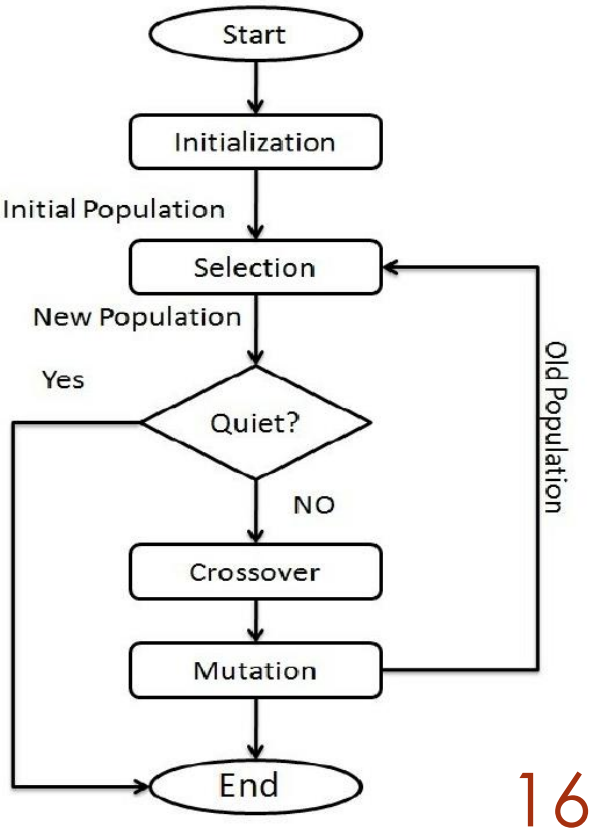
Pseudo Code:

START
Generate the initial population
Compute fitness
REPEAT
    Selection
    Crossover
    Mutation
    Compute fitness
UNTIL the population is converged
STOP



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Sample Code:

```
class Individual {
   int fitness = 0;
   int[] genes = new int[5];
   int geneLength = 5;

   public Individual() {
      Random rn = new Random();
      //Set genes randomly for each individual
      for (int i = 0; i < genes.length; i++) {
         genes[i] = Math.abs(rn.nextInt() % 2);
         fitness = 0;
      }
```

More genes with the value of 1 represent more fitness

```
   }
      // Calculate fitness
      public void calcFitness() {
         fitness = 0;
         for (int i = 0; i < 5; i++) {
            if (genes[i] == 1) {
               ++fitness;
            }
         }
      }
   }
```

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Sample Code:

```
// Initialize population
   public void initializePopulation(int size) {
      for (int i = 0; i < individuals.length; i++) {
         individuals[i] = new Individual();
      }
   }

// Selection
   void selection() {
      //Select the most fittest individual
      fittest = population.getFittest();
      //Select the second most fittest individual
      secondFittest = population.getSecondFittest();
   }
```

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Sample Code:

```
void crossover() {
    Random rn = new Random();
    //Select a random crossover point
    int crossOverPoint = rn.nextInt(population.individuals[0].geneLength);
    //Swap values among parents
    for (int i = 0; i < crossOverPoint; i++) {
       int temp = fittest.genes[i];
       fittest.genes[i] = secondFittest.genes[i];
       secondFittest.genes[i] = temp;
    }
  }
```

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```
void mutation() {
    Random rn = new Random();
    //Select a random mutation point
    int mutationPoint = rn.nextInt(population.individuals[0].geneLength);
    //Flip values at the mutation point
    if (fittest.genes[mutationPoint] == 0) {
       fittest.genes[mutationPoint] = 1;
    } else {
       fittest.genes[mutationPoint] = 0;
    }
    mutationPoint = rn.nextInt(population.individuals[0].geneLength);
    if (secondFittest.genes[mutationPoint] == 0) {
       secondFittest.genes[mutationPoint] = 1;
    } else {
       secondFittest.genes[mutationPoint] = 0;
    }
}
```

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Sample Application – Travelling Salesman Problem:

Tehr	Esfh	Mshh	Shrz	Tbrz	Zhdn

- Init population:
  - Sample: Tbrz→Tehr→Mshh→Esfh→Shrz→Zhdn
- **Chromosomes**: all possible variations of the array
- **Fitness**: distance travelled
- **Selection**: random, FPS, rank, etc.
- **Crossover**: SPC or TPC
- **Mutation**: Relocation, Insertion, etc.

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Sample Application

- Aircraft and train scheduling
- Memory allocation in RAM
- Robots antenna to receive signal
- Medical business to find proper remedy
- Application scheduling in a computer
- etc.

Genetic Programming

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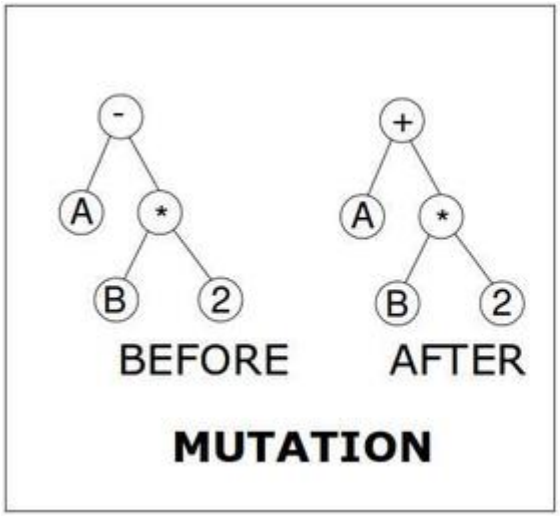
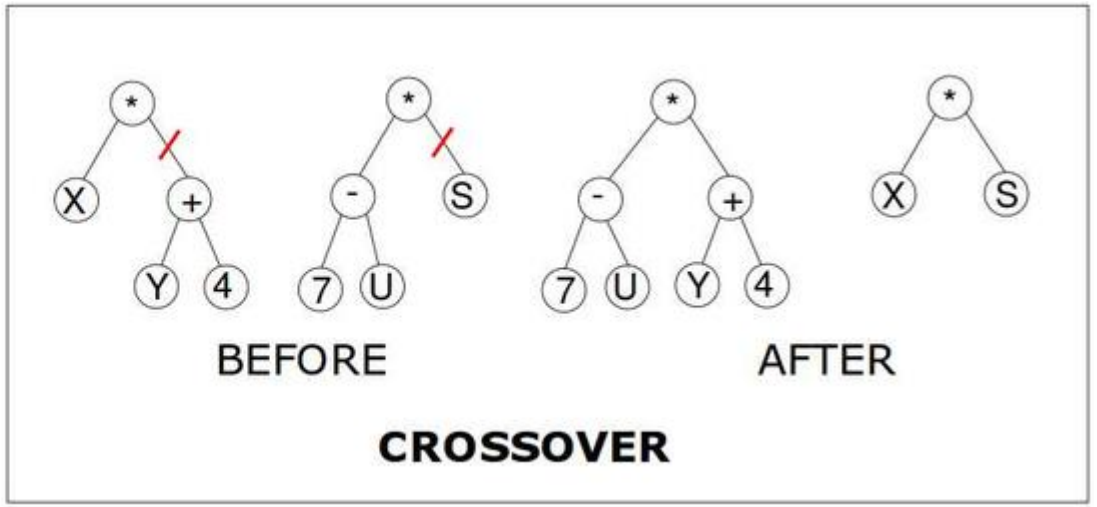
- A technique of evolving programs
- Used as an automatic programming tool
- Starting from a population of random programs, fit for a particular task
- Searching for an **optimal** or at least suitable program
  - Generally using Hill-climb algorithm
- **Selection** of the fittest programs
- Swapping random parts of selected pairs **(Crossover)**
- Substitution of some random part of a program with some others **(Mutation)**

Genetic Programming

Codes are usually implemented in a tree structure





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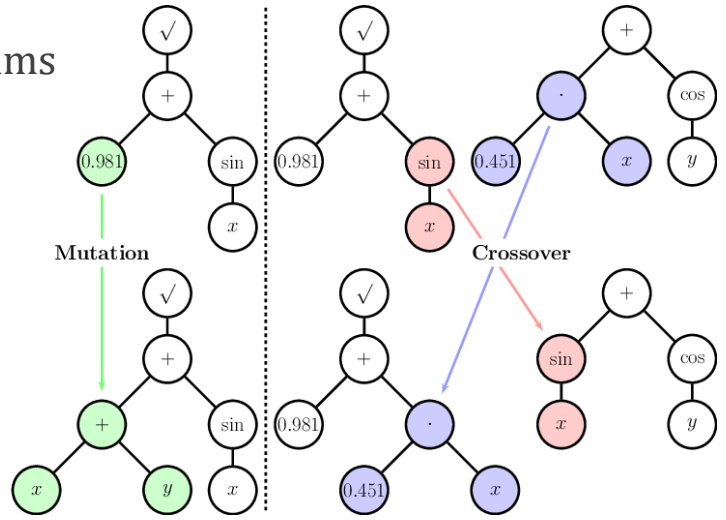
Genetic Algorithms vs. Genetic Programming

- GP applies GA to a population of computer programs
- GP utilizes tree structures
- GP: creating entire software programs
- GA: creating shorter pieces of code



Evolution Strategy

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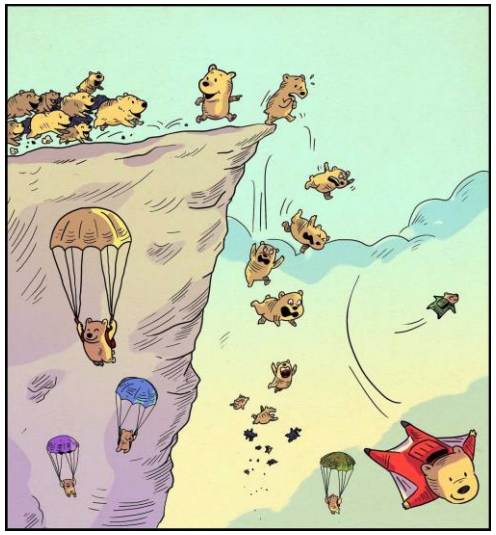
Study Yourself

- An optimization technique based on ideas of evolution
- Has Mutation and Selection, but not Crossover
- The most basic and canonical version: Gaussian ES
- Other approaches:
  - Covariance Matrix Adaptation
  - Natural Evolution Strategies
- Applications:
  - Deep Reinforcement Learning
  - Deep Learning



What's Next?

- Swarm Intelligence

Questions?