MT 5103: Mathematics for Robotics

SOFT COMPUTING
Genetic Algorithms

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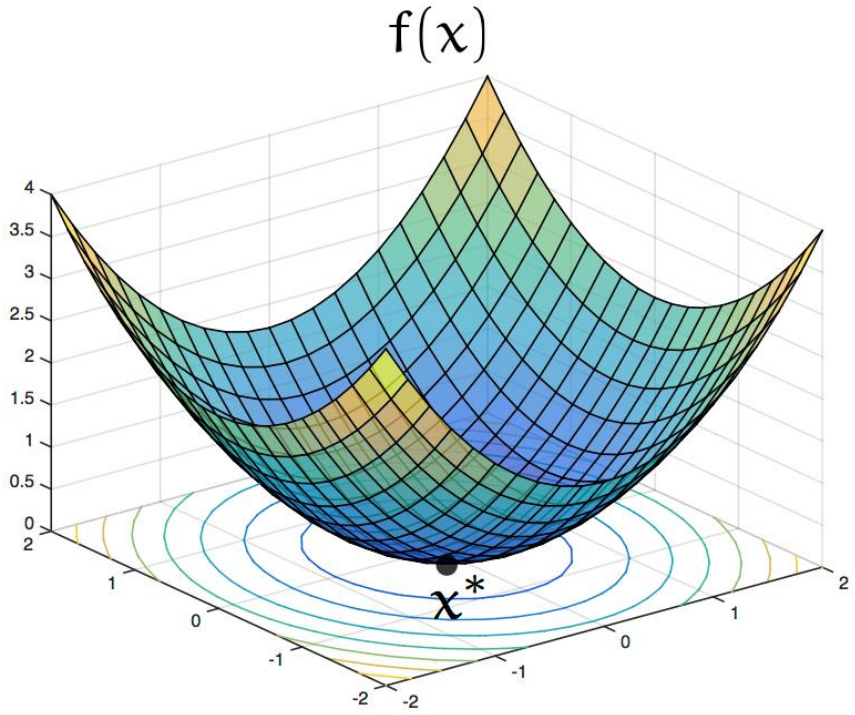
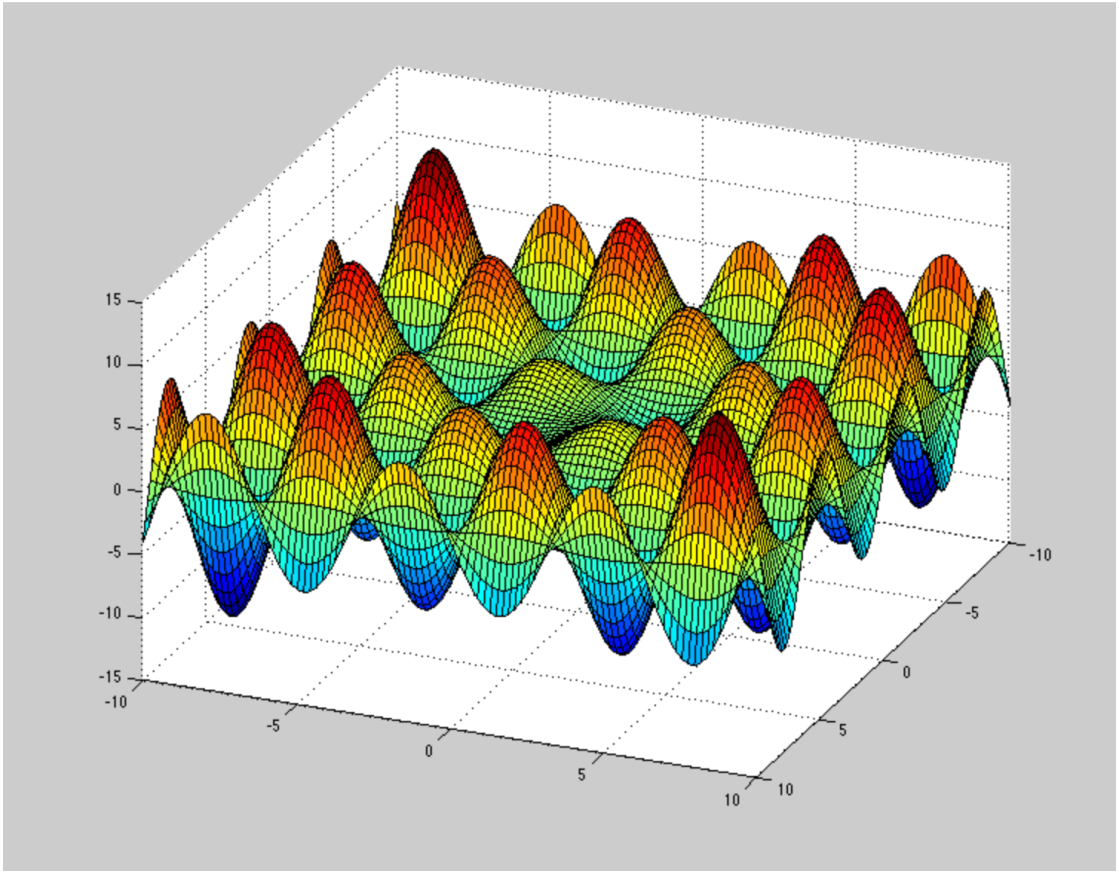

f(x)
x*



Limitations of the traditional optimization approaches

- Computationally expensive.
- For a discontinuous objective function, methods may fail.
- Method may not be suitable for parallel computing.
- Methods may not necessarily adaptive.

- Evolutionary algorithms have been evolved to address the above mentioned limitations of solving optimization problems with traditional approaches

Evolutionary Algorithms

The algorithms, which follow some biological and physical behaviors:

- Biologic behaviors: Genetics and Evolution –> Genetic Algorithms (GA)
- Behavior of ant colony –> Ant Colony Optimization (ACO)
- Human nervous system –> Artificial Neural Network (ANN)

Genetics
Evolution

In addition to that there are some algorithms inspired by some physical behaviors:

- Annealing process –> Simulated Annealing (SA)
- Swarming of particle –> Particle Swarming Optimization (PSO)
- Learning –> Fuzzy Logic (FL)

Genetic Algorithm

It is a subset of evolutionary algorithm:

- Ant Colony optimization
- Swarm Particle Optimization

Models biological processes:

- Genetics
- Evolution

To optimize highly complex objective functions:

- Very difficult to model mathematically
- NP-Hard (also called combinatorial optimization) problems (which are computationally very expensive)
- Involves large number of parameters (discrete and/or continuous)

Background of Genetic Algorithm

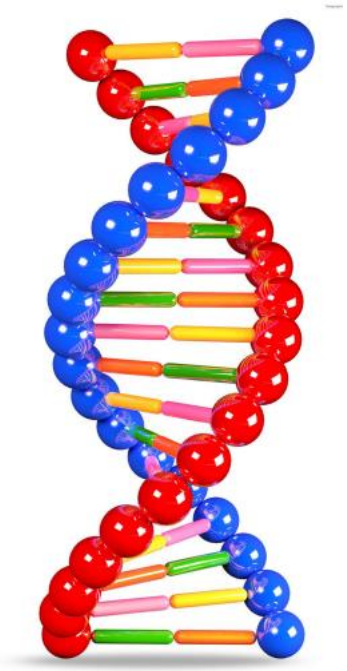
- First time introduced by Prof. John Holland (of Michigan University, USA, 1965).
- But, the first article on GA was published in 1975.

Principles of GA based on two fundamental biological processes:

- Genetics: Gregor Johan Mendel (1865)
- Evolution: Charles Darwin (1875)

A brief account on genetics

- The basic building blocks in living bodies are cells. Each cell carries the basic unit of heredity, called gene



Genetic code

For a specie, DNA code is unique, that is, vary uniquely from one to other.

DNA code (inherits some characteristics from one generation to next generation) is used as biometric trait.

Evolution :

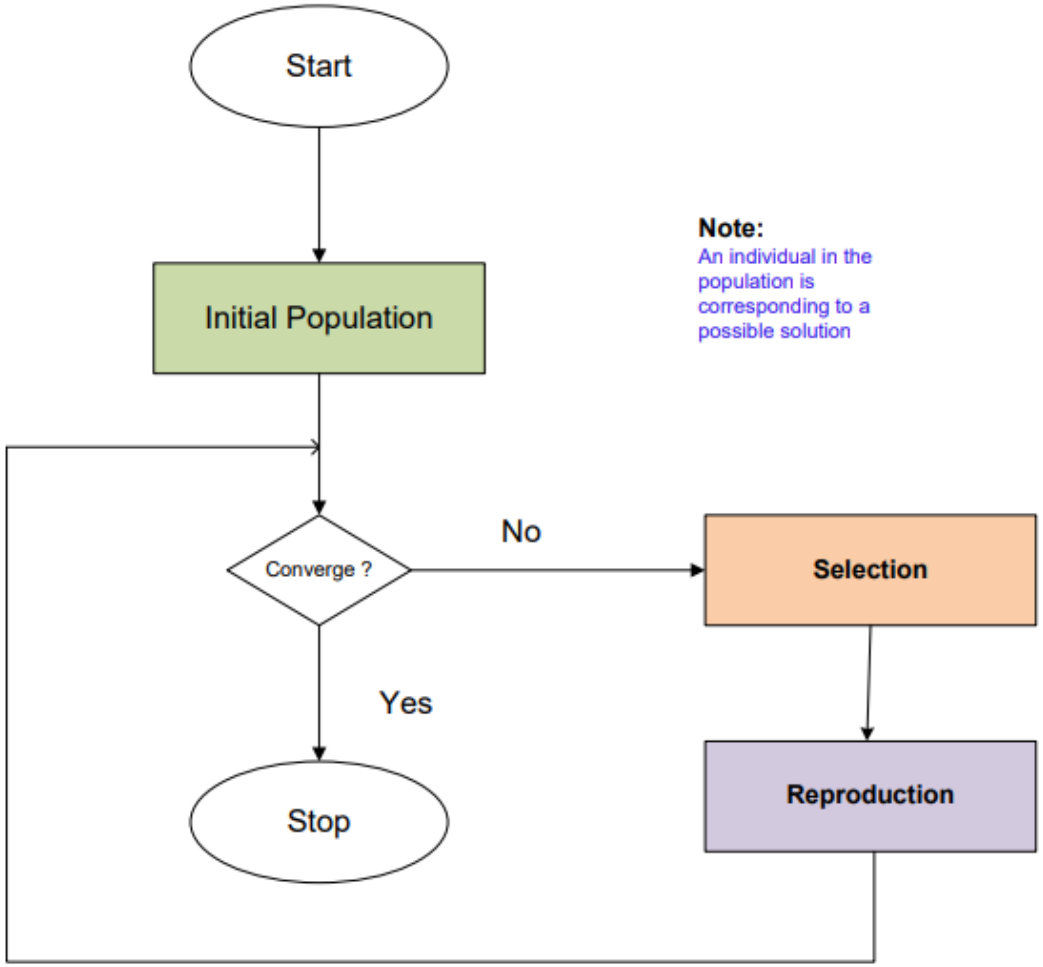
Four primary premises:

- Information propagation: An offspring has many of its characteristics of its parents (i.e. information passes from parent to its offspring). [Heredity]
- Population diversity: Variation in characteristics in the next generation. [Diversity]
- Survival for existence: Only a small percentage of the offspring produced survive to adulthood. [Selection]
- Survival of the best: Offspring survived depends on their inherited characteristics. [Ranking]

Working of Genetic Algorithm

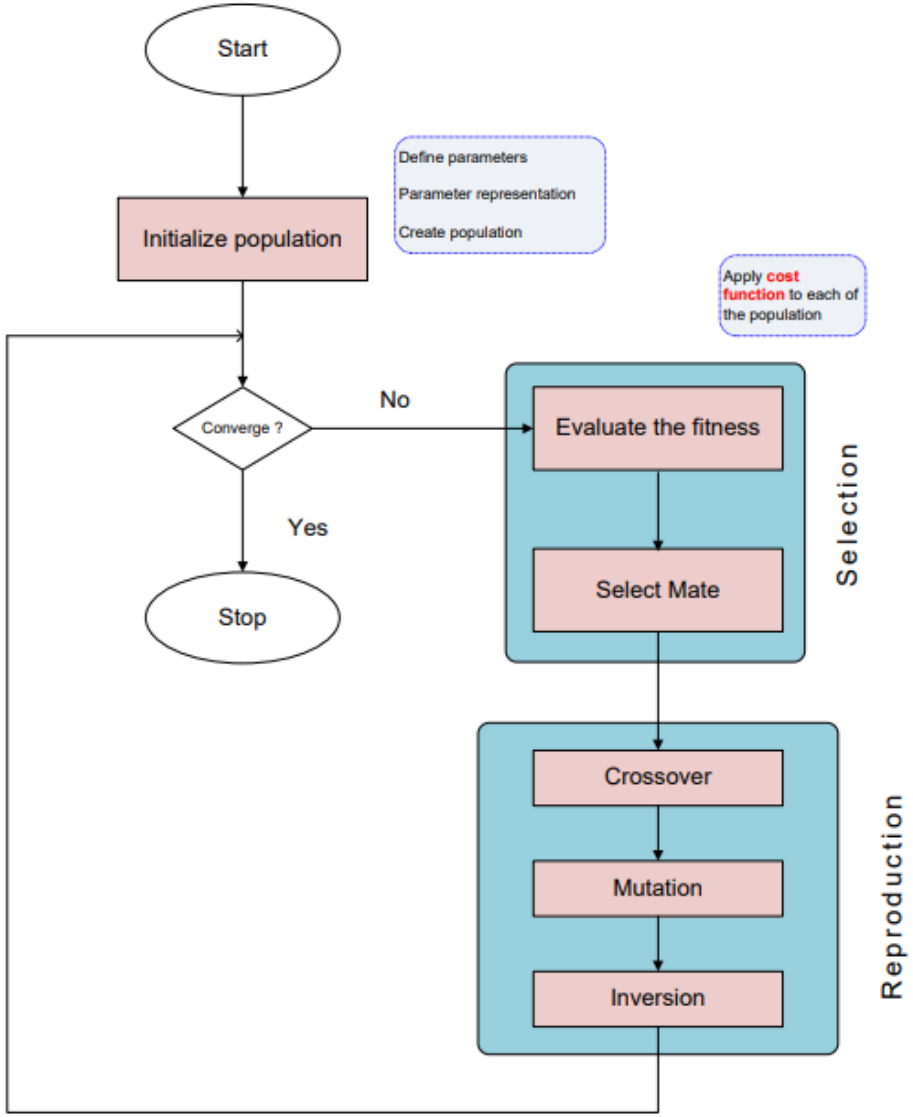
- Definition of GA: Genetic algorithm is a population-based probabilistic search and optimization technique, which works based on the mechanisms of natural genetics and natural evaluation.

Framework of GA



1. GA is an iterative process.
2. It is a searching technique.
3. Working cycle with / without convergence.
4. Solution is not always guaranteed.

Framework of GA: A detail view



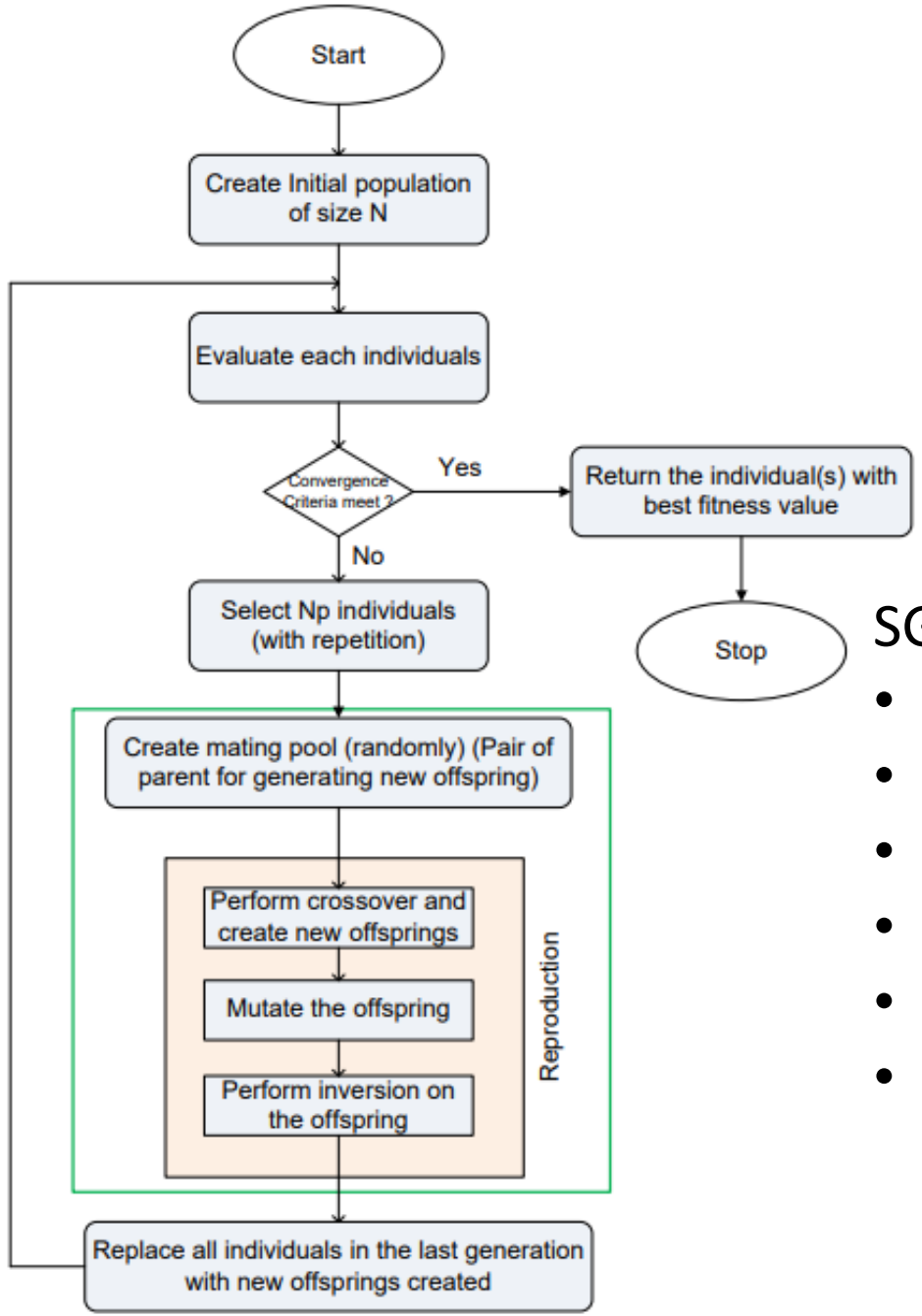
Optimization problem solving with GA

- For the optimization problem, identify the following:
- Objective function(s)
- Constraint(s)
- Input parameters
- Fitness evaluation (it may be algorithm or mathematical formula)
- Encoding
- Decoding

GA Operators

- Encoding: How to represent a solution to fit with GA framework.
- Convergence: How to decide the termination criterion.
- Mating pool: How to generate next solutions.
- Fitness Evaluation: How to evaluate a solution.
- Crossover: How to make the diverse set of next solutions.
- Mutation: To explore other solution(s).
- Inversion: To move from one optima to other.

Simple GA



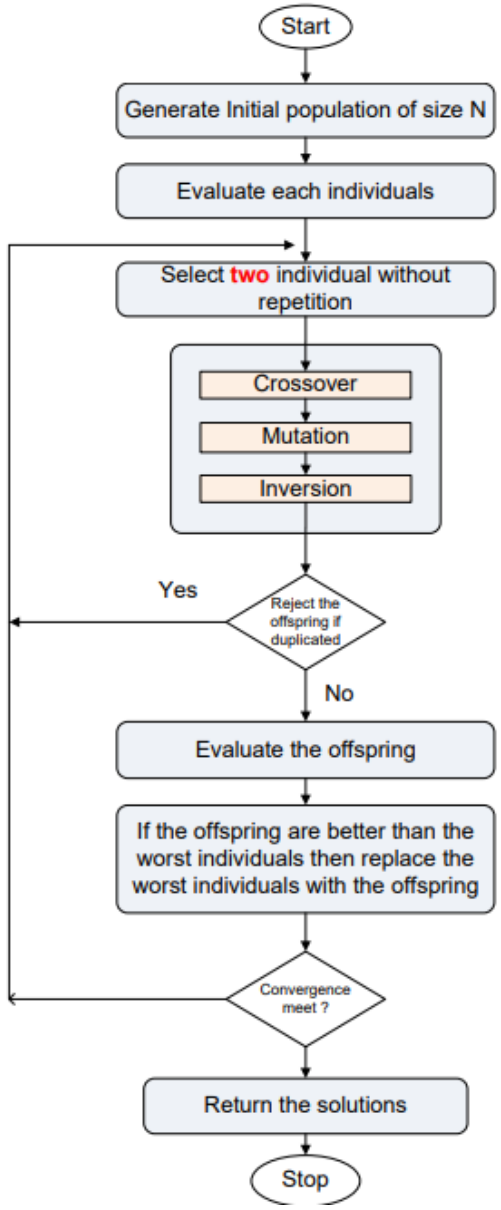
SGA Parameters:

- Initial population size : N
- Size of mating pool, Np : Np = p% of N
- Convergence threshold δ
- Mutation μ
- Inversion η
- Crossover ρ

Features in SGA

- Simple GA features: Have overlapping generation (Only fraction of individuals are replaced).
- Computationally expensive. Good when initial population size is large.
- Selection is biased toward more highly fit individuals;
- Hence, the average fitness (of overall population) is expected to increase in succession.
- The best individual may appear in any iteration.

Steady State Genetic Algorithm (SSGA)



Features in Steady-state GA

- Generation gap is small.
- Only two offspring are produced in one generation.
- It is applicable when Population size is small
- Evaluation operation is less computationally expensive (compare to duplicate checking)

Limitations in SSGA:

There is a chance of stuck at local optima, if crossover/mutation/inversion is not strong enough to diversify the population).

Premature convergence may result.

It is susceptible to stagnation.

Inferiors are neglected or removed and keeps making more trials for very long period of time without any gain (i.e. long period of localized search).