

Introduction to Genetic Algorithms (GAs)

- **What is a Genetic Algorithm ?**

- A stochastic optimization approach based on the concepts of natural selection and reproduction.
- GAs were first proposed and investigated by John Holland at the University of Michigan in 1975.

- **What are their main characteristics ?**

- GAs are *global* optimization techniques.
- GAs work with a coding of the parameter set, not the parameters themselves.
- GAs operate on a population of points, not a single point.
- GAs use objective function information, not derivatives.
- GAs use probabilistic transition rules, not deterministic rules.

- **Main components**

Encoding schemes

- Transform points in parameter space into finite length strings (*chromosomes*) over some finite alphabet (e.g., binary strings).

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Fitness function

- Evaluates the goodness of a solution (e.g., for a maximization problem, the fitness function is just the objective function).

$$Fitness = f(\text{decode}(\text{chromosome}))$$

Reproduction

- It is responsible for the survival of the fittest and for the death of others based on a probabilistic treatment.
- It copies chromosomes with highest fitness into the next generation.
- The probability that a chromosome is reproduced into the new population is given by its relative fitness in the current population.

Crossover

- Generate new chromosomes that, hopefully, will retain good features from the previous generation.
- It is applied to randomly selected pairs of chromosomes with a probability equal to a given *crossover rate*.

Mutation

- It protects GAs against irrecoverable loss of good solution features.
- It changes a character of some chromosome with a probability equal to a very low given *mutation rate*.

- **Steps**

1. Initialize a population with randomly generated individuals.
2. Evaluate the fitness of each individual.
3. Reproduce high fitness chromosomes in the new population, remove poor fitness chromosomes (*selection*).
4. Construct new chromosomes (*crossover*).
5. Recover lost features (*mutation*).
6. Repeat steps 2-6 until a stopping criterion is met.

- **Practical issues**

- Choose an appropriate encoding scheme.
- Choose an appropriate fitness function.
- Crossover and mutation rates.
- Stopping criterion.

- **Example**

- Function maximization