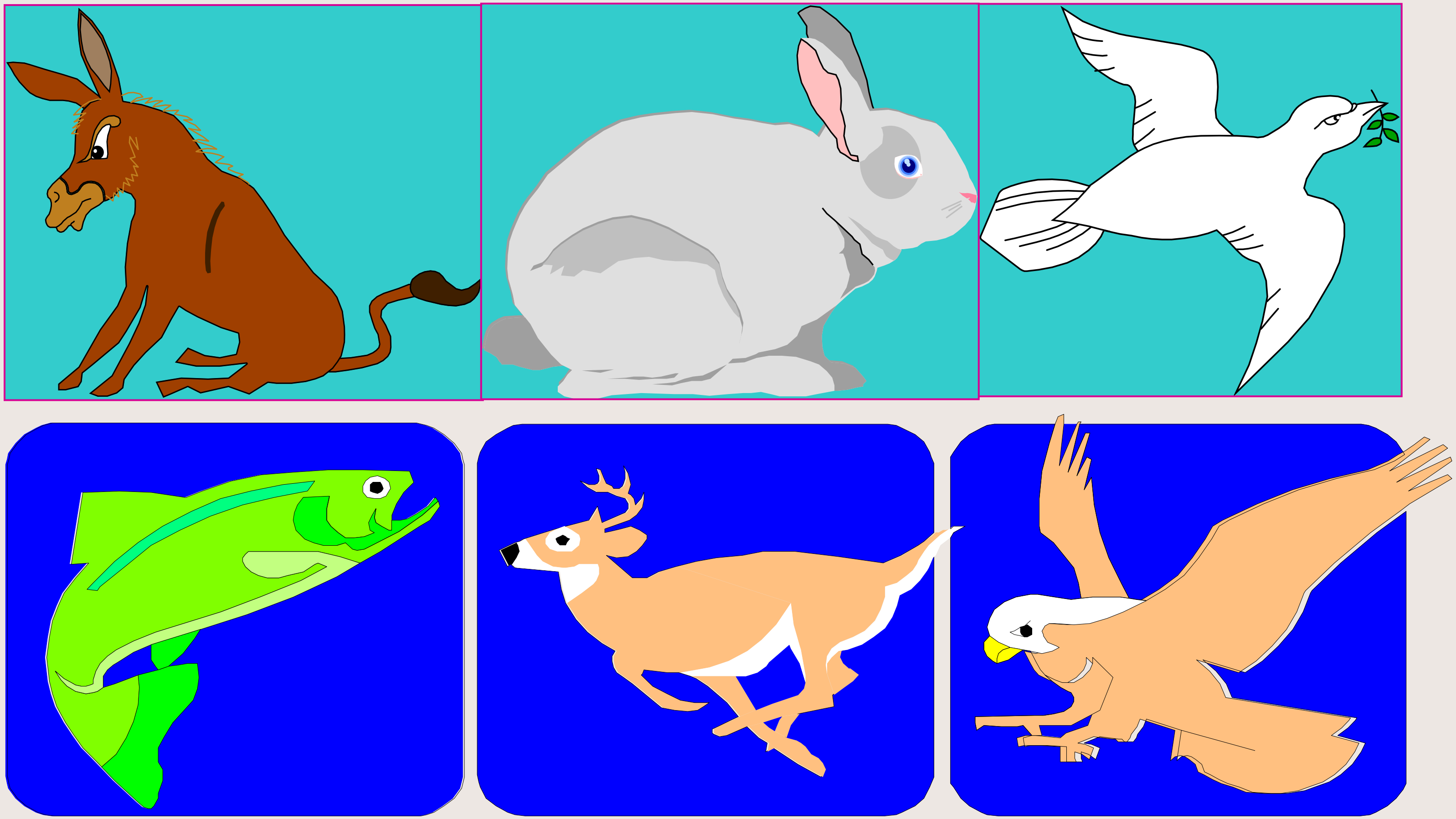
Genetic Algorithm



Survival of the fittest basis

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Genetic Algorithm

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GA Introduction

- The Genetic algorithm, developed by John Holland [1962] is an optimization (search) technique that operates over a population of encoded candidate solutions to solve a given problem.
- GA belongs to a class of stochastic search method based on biological evolution (first observed by Charles Darwin). They represent a highly parallel adaptive search process.
- In natural (biological) evolution, species search for increasingly beneficial adaptations for survival within their complex environments.
- The search takes place in the species' chromosomes where changes, and their effects, are graded by the survival and reproduction of the species. This is the basis for survival of the fittest.
- Central to the idea of GA is a population where individuals in the population represent possible solutions. An individual is called chromosome, in analogy with the genetic chromosome.
- The chromosome is usually represented by a bit string consisting of 0's and 1's.
- New population is generated from old population with two basic genetic operators namely cross-over and mutation.

Main Steps of GA

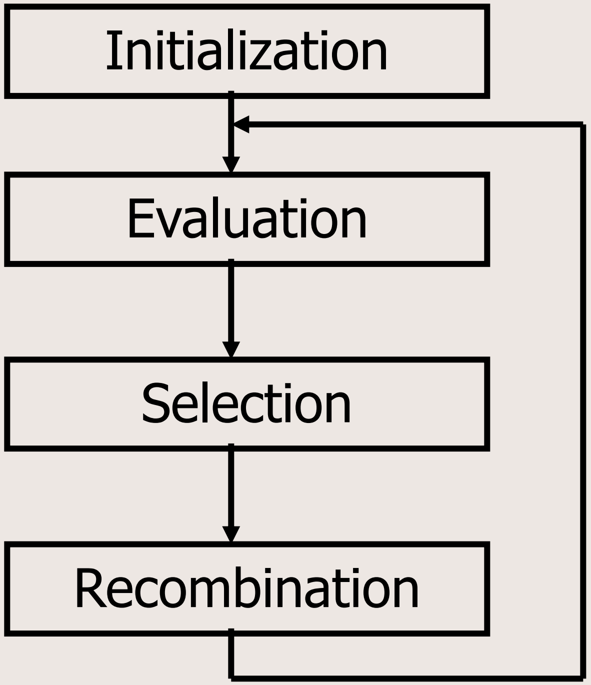
- A GA represents an iterative process. Each iteration is called a generation. The entire set of generations is called a run. At the end of a run, we expect to find one or more highly fit chromosomes.
- The GA consists of three fundamental steps, excluding the initialization. These are: Evaluation, Selection, and Recombination

Initialization: initial creation of the population

Evaluation: fitness of the population is calculated.

Selection:a subset of the the population is selected based upon a predefined selection criterion.

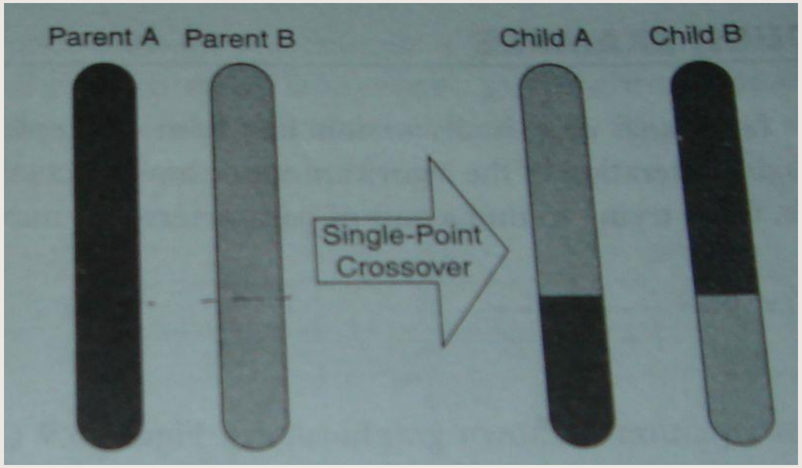
Recombination: selected subpopulation is recombined to result a new population.

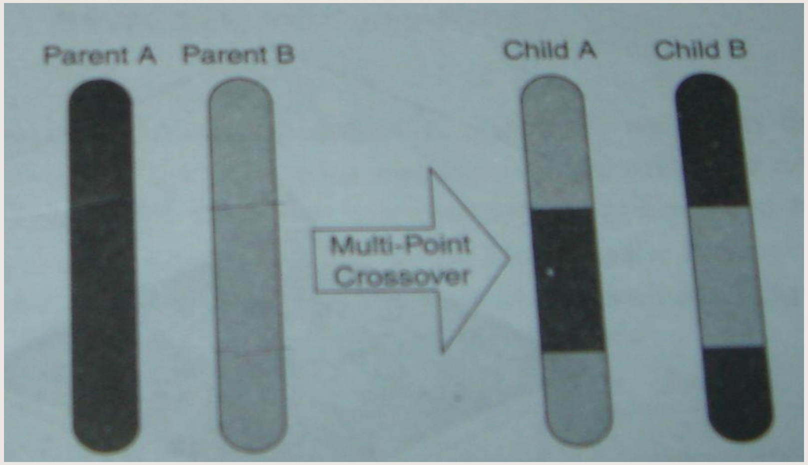


Flow chart of GA

Genetic Operator: Cross-over

- Cross-over: takes two chromosomes (parents), separates them at a random site (in both chromosomes) and then swaps the tails of the two, resulting in two new chromosomes (children).



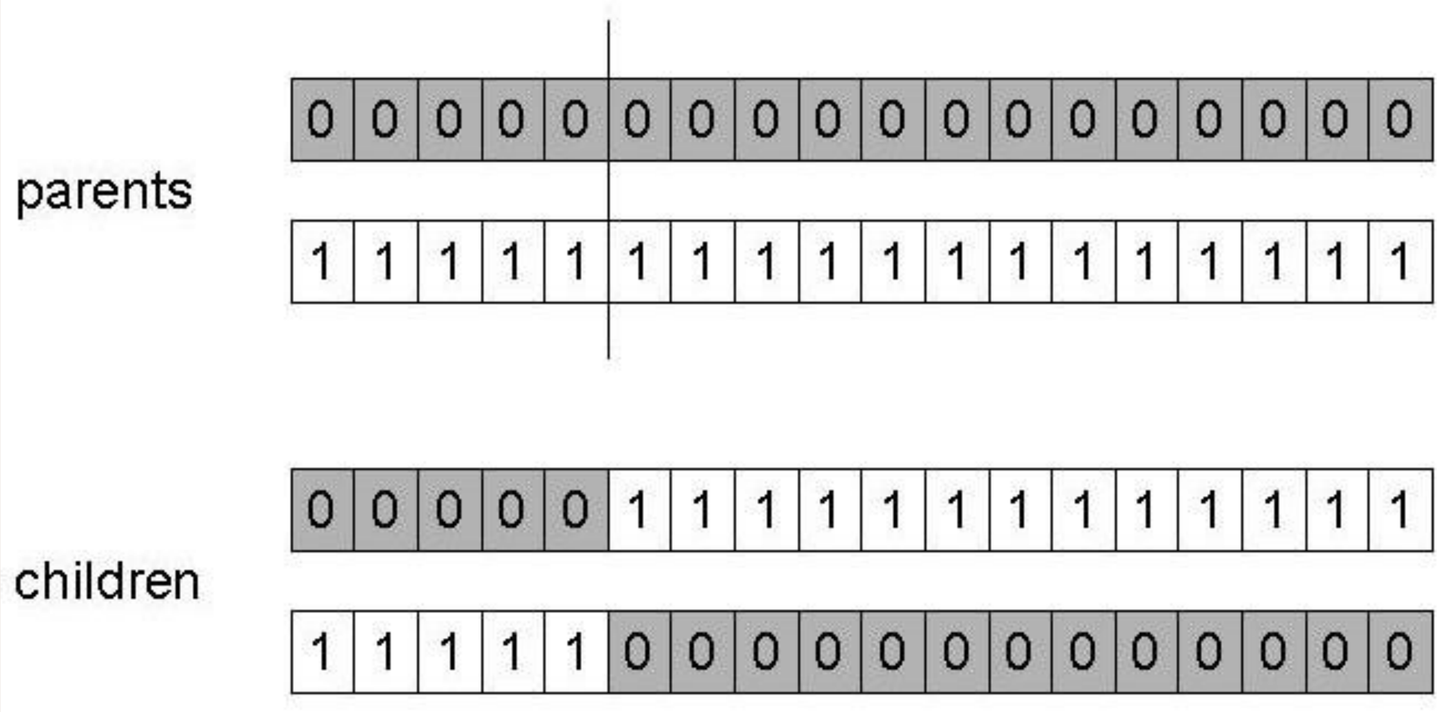


- Cross over operator randomly chooses a crossover point where two parent chromosomes ‘break’ and then exchanges the chromosome parts after that point.
- A value of 0.7 for the cross-over probability generally produces good results.

Genetic Operator: Cross-over

Single-point cross-over

- Choose a random point on the two parents
- Split parents at this crossover point
- Create children by exchanging tails



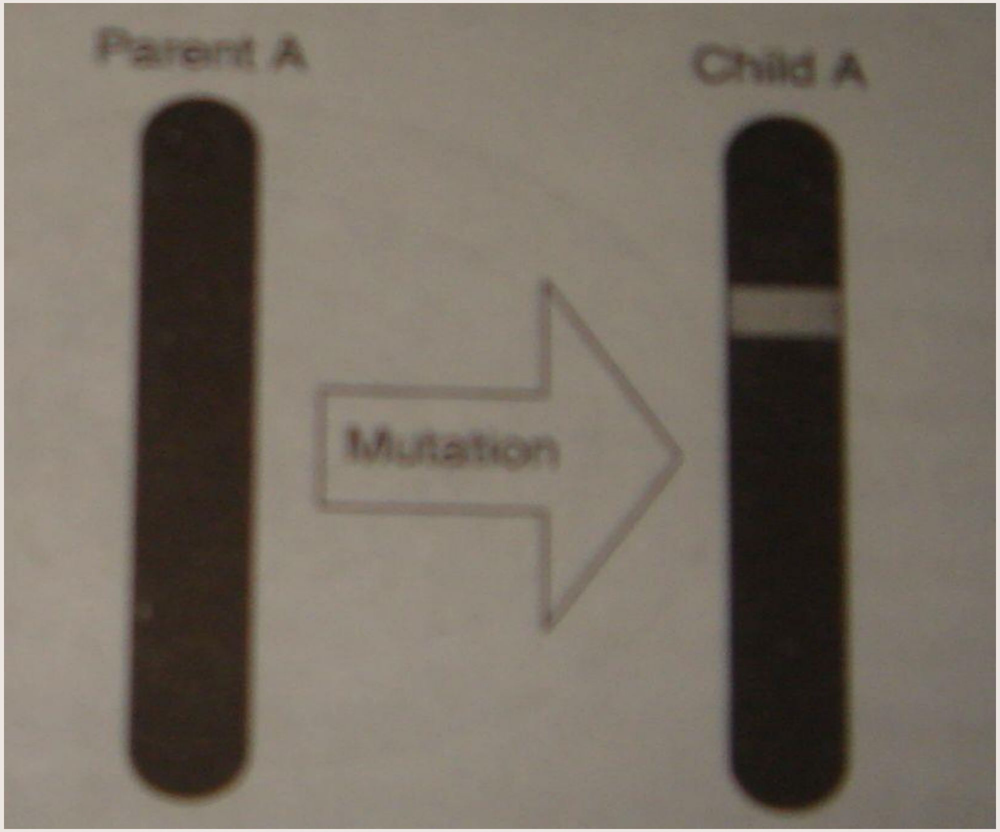
Genetic Operator: Mutation

- Mutation, which is rare in nature represents a change in the gene. It may lead to a significant improvement in fitness, but more often has rather harmful results.
- The mutation operator introduces a random change into a gene in the chromosome. It provides the ability to introduce new material into the chromosome.
- The mutation probability is quite small in nature, in the range 0.0001 and 0.01.

Why use Mutation:

- Mutation's role is to provide a guarantee that the search algorithm is not trapped on a local optimum. The sequence of selection and crossover operations may stagnate at any homogeneous set of solutions. Under such conditions, all chromosomes are identical, and thus the average fitness of the population cannot be improved. The search algorithm is not able to proceed further. Mutation aids us in avoiding loss of genetic diversity.

Genetic Operator: Mutation



A Simple GA Example

- f(x) = {MAX(x^2): 0 <= x <= 32 }
- Encode Solution: Just use 5 bits (1 or 0).
- Generate initial population.

A	**0**	**1**	**1**	**0**	**1**
B	**1**	**1**	**0**	**0**	**0**
C	**0**	**1**	**0**	**0**	**0**
D	**1**	**0**	**0**	**1**	**1**

- Evaluate each solution against objective.

Sol.	String	Fitness	% of Total
A	01101	169	14.4
B	11000	576	49.2
C	01000	64	5.5
D	10011	361	30.9

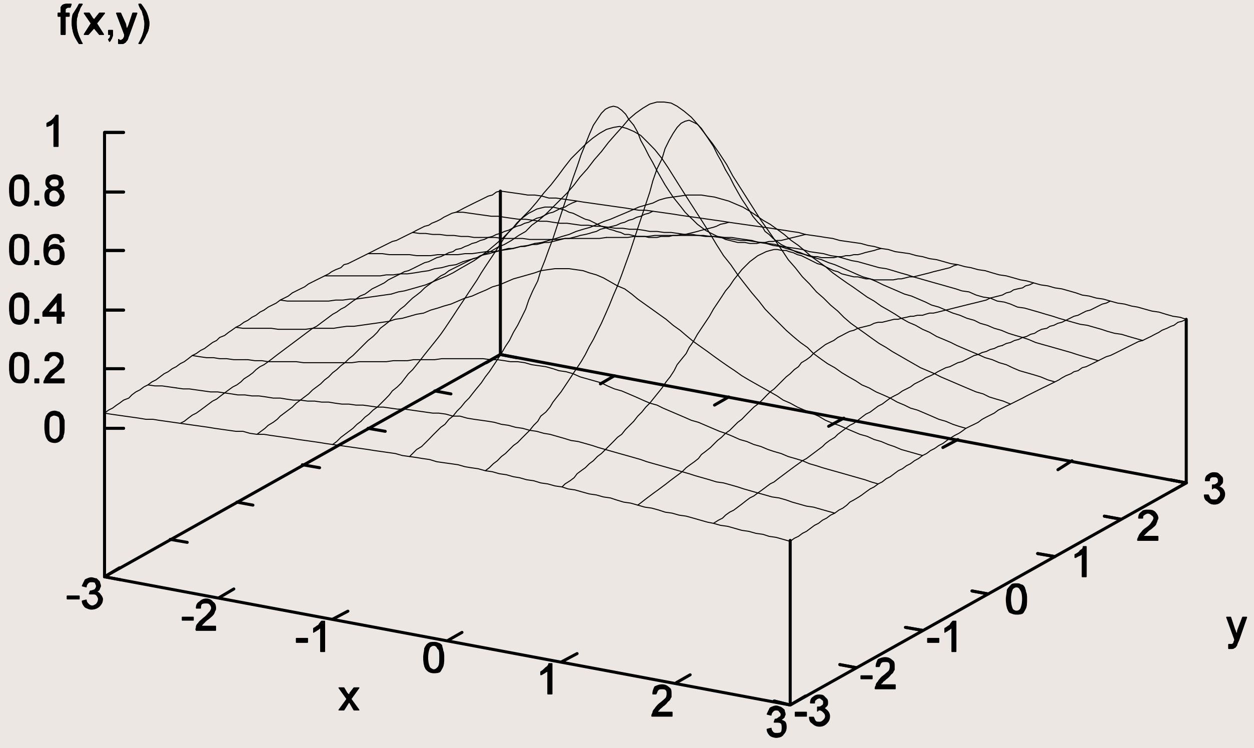
A Simple GA Example (cont.)

- Create next generation of solutions
  - Probability of "being a parent" depends on the fitness.
- Ways for parents to create next generation
  - Crossover
    - Cut and paste portions of one string to another.
  - Mutation
    - Randomly flip a bit.
  - COMBINATION of all of the above.

Another GA Example

Let try to find a pair of parameters that maximizes the following equation:

$$f(x,y) = \frac{1}{1 + x^2 + y^2}$$



GA Example (using cross-over only)

Initial population & fitness (Initialization and Evaluation):

	x	y		fitness
C_0	-1.0	2.0		0.167
C_1	-2.0	3.0		0.007
C_2	1.5	0.0		0.31
C_3	0.5	-1.0		0.44

Average fitness: 0.231

Immediate next generation (using cross-over only) & fitness Selection and Recombination):

	x	y		fitness
$C_0\,(x_{C3}\ y_{C2})$	0.5	0.0		0.800
$C_1(x_{C2}\ y_{C3})$	1.5	-1.0		0.240
$C_2(x_{C3}\ y_{C0})$	0.5	2.0		0.190
$C_3(x_{C0}\ y_{C3})$	-1.0	-1.0		0.330

Average fitness: 0.390

GA Summary

- GA is a heuristic method based on ` survival of the fittest.
- Useful when search space is very large or too complex for analytic treatment.
- GA has been employed in a wide variety of practical problems related to pattern recognition and image processing, computer-aided design, scheduling, economics and game theory, and so on. on.