Genetic Algorithm

A genetic algorithm is a heuristic search algorithm. This algorithm reflects the process of natural selection where the fittest individuals are selected for reproduction in order to produce offspring of the next generation.

phases of Genetic Algorithm

1) Initialization
2) Fitness Assignment
3) selection
4) crossover (Reproduction)
5) Termination.

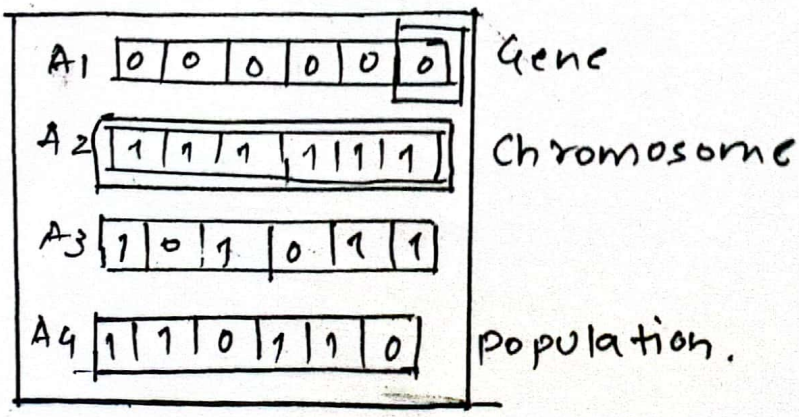
Initial population

process begins with a set of individuals which is called a population

Each individual is a solution to the problem you want to solve as chromosome.

An individual is characterized by set of parameters (variables) known as genes

Genes are joined into a string to form a chromosome (solution)

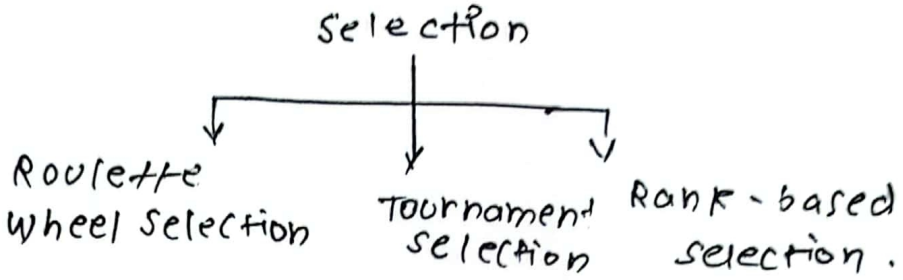


Fitness Function

- The Fitness function determine how it fit an individual is? (the ability of an individual to complete with other individuals).

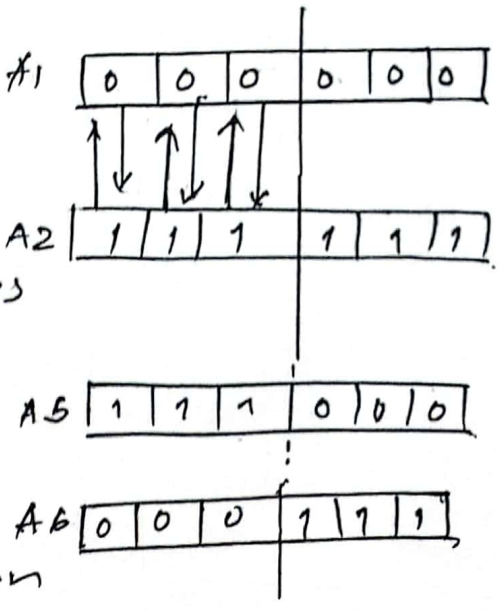
selection

The idea of selection phase is to select the fitness individual and let them pass their genes to the next generation.



crossover

- crossover is the most significant phase in a genetic algorithm.
- For each pair of parents to be mated, a crossover point is chosen at random from within the genes.
- For example, consider the crossover point to 3 as shown.



OFFspring

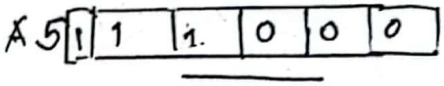
- offspring are created by exchanging the genes of parent among themselves until the crossoves point is reached.
- The new offspring are added to population

Mutation

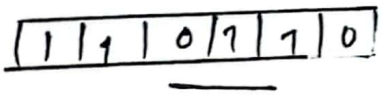
1) In certain new offspring formed, some of their genes can be subjected to a mutation with a Low random probabilities.

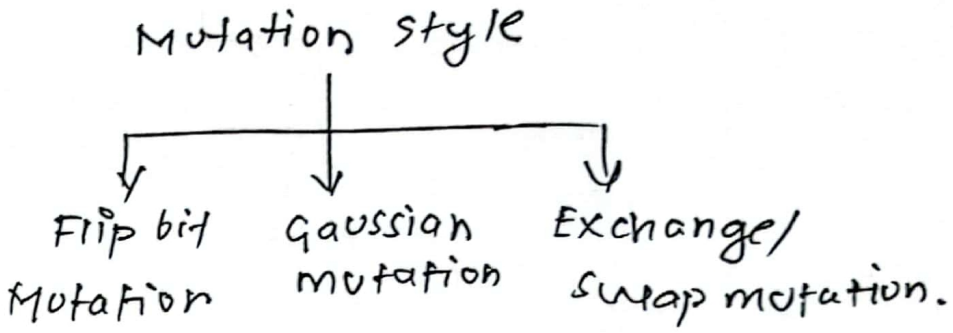
2) This implies that some of the bits in the bit string can be ~~fil~~ flipped

before Mutation :-



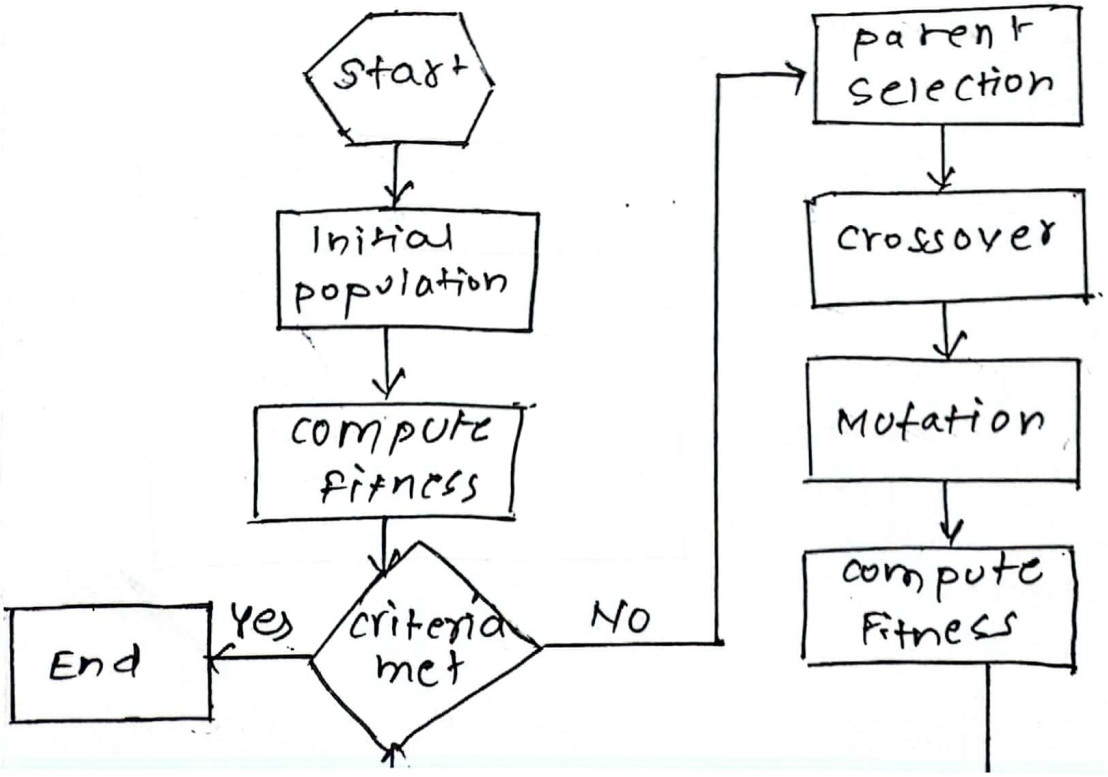
After Mutation :-



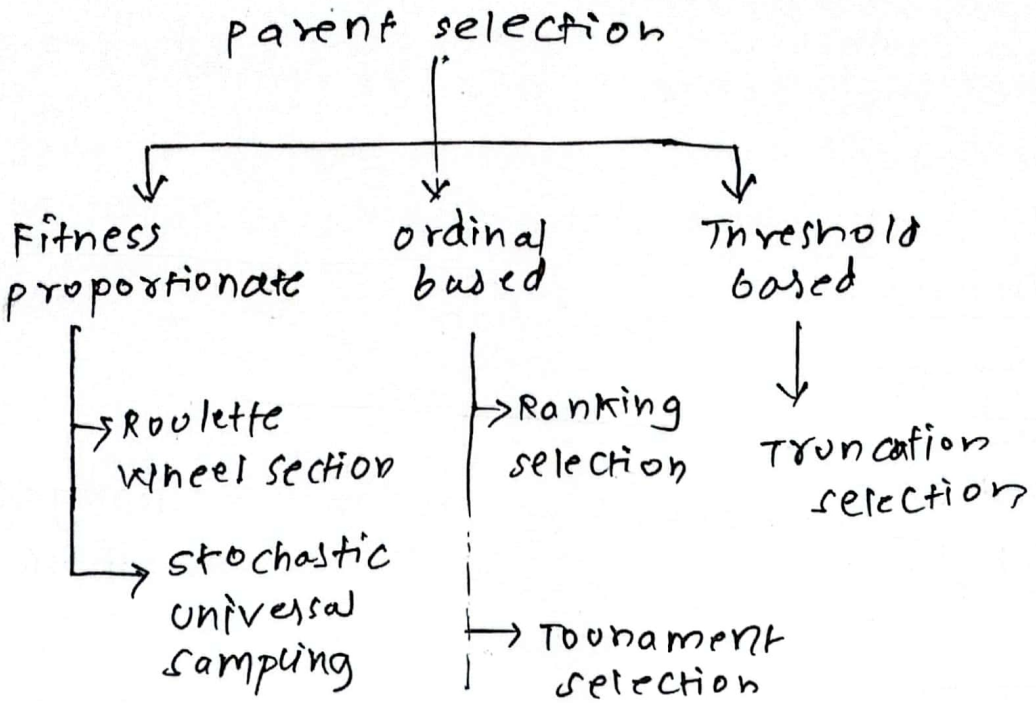


Termination

The algorithm terminates, if the population has converged (does not produce offspring which are significantly different from previous generation).

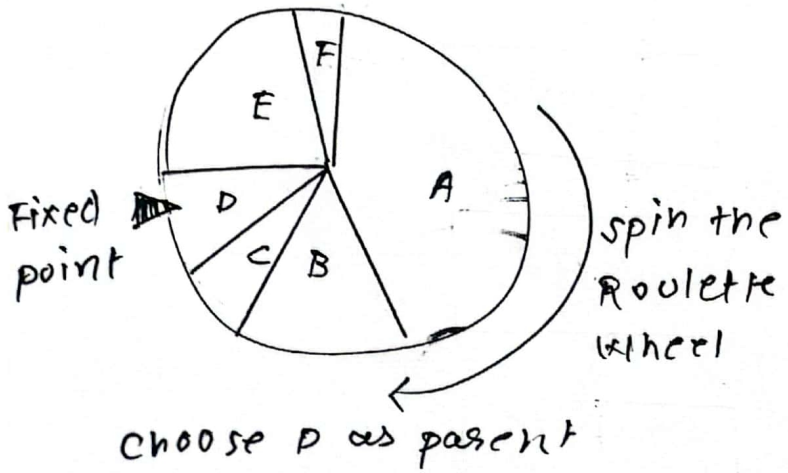


parent selection is a process of choosing a set of chromosomes as a parent a parent for the next generation of the population, based on its fitness value, threshold



Fitness proportionate : Fitter the individuals have higher chance of selection and propagating their features to the next generation.

Roulette wheel selection



chromosomes	Fitness value
A	8.2
B	3.2
C	1.4
D	1.2
E	4.2
F	0.3

Roulette wheel selection

[sum]: calculate sum of all chromosome fitness in population - sum s

[select]: Generate random number from interval (0, s) - r.

[Loop]: Go through the population and sum fitness from 0 and sum <: when the sum s is greater then r, stop and return the chromosome where you are.

chromosome	Fitness value	sum (s)
A	8.2	0 - 8.2
B	3.2	8.2 - 11.4
C	1.4	11.4 - 12.8
D	1.2	12.8 - 14
E	4.2	14 - 18.2
F	0.3	18.3 - 18.6

(6, 5) - (7) = 0

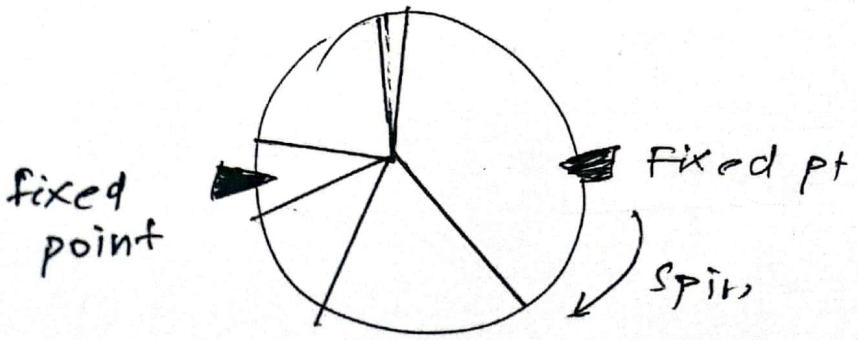
(8) = 1

(13) =>

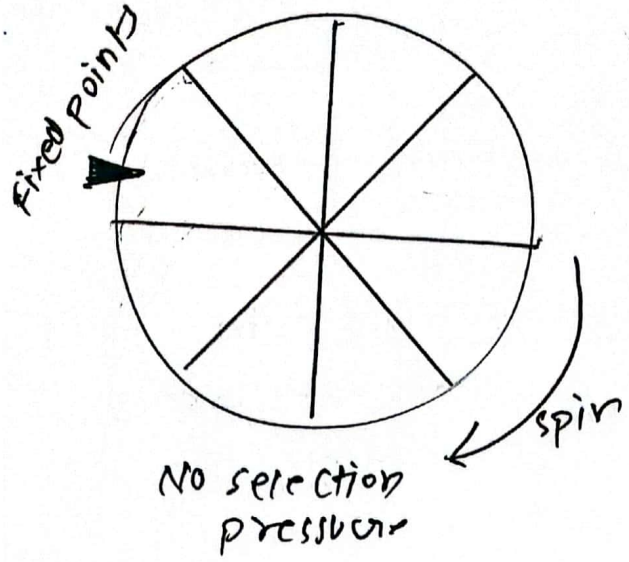
(OT

Stochastic Universal sampling (SUS)

same as Roulette wheel but has multiple fixed points



Ranking selection

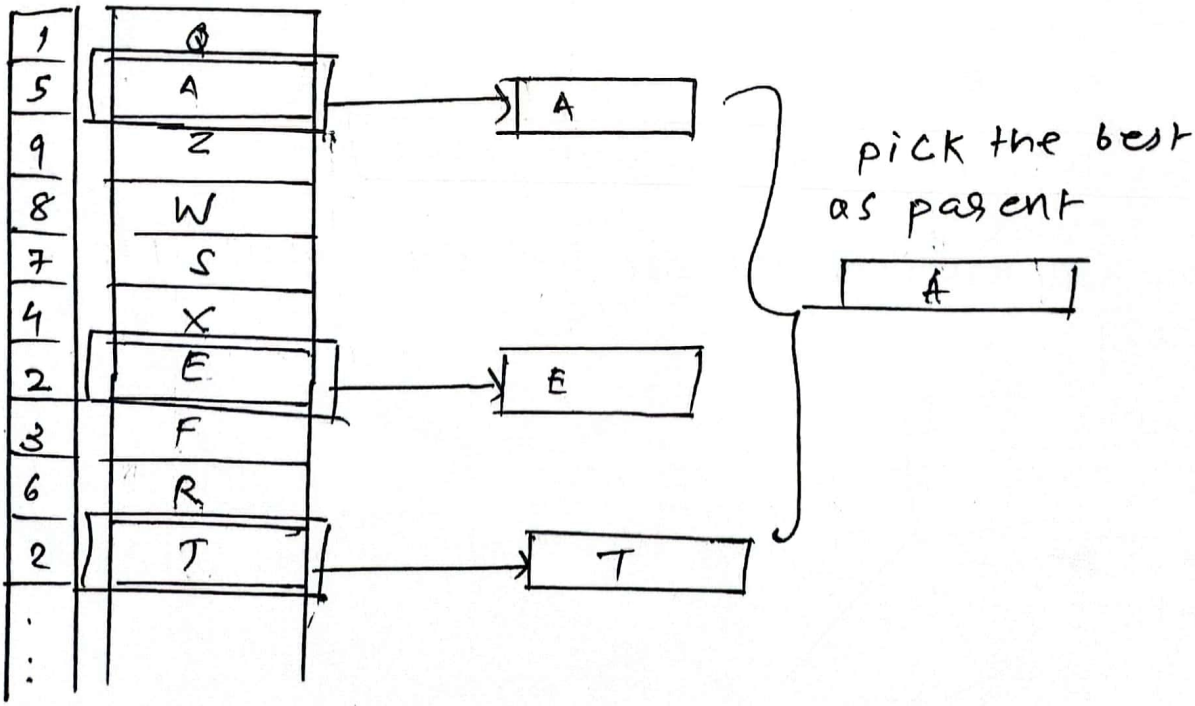


Every individual in the population is ranked according to fitness

selection depends on rank of each individual & not according to fitness

Tournament selection

k-way tournament selection we have k individuals from the population at random and select the best out of these to become parent

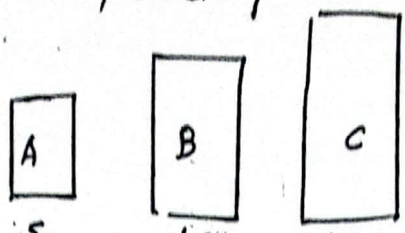


Encoding Techniques.

Binary - Encoding

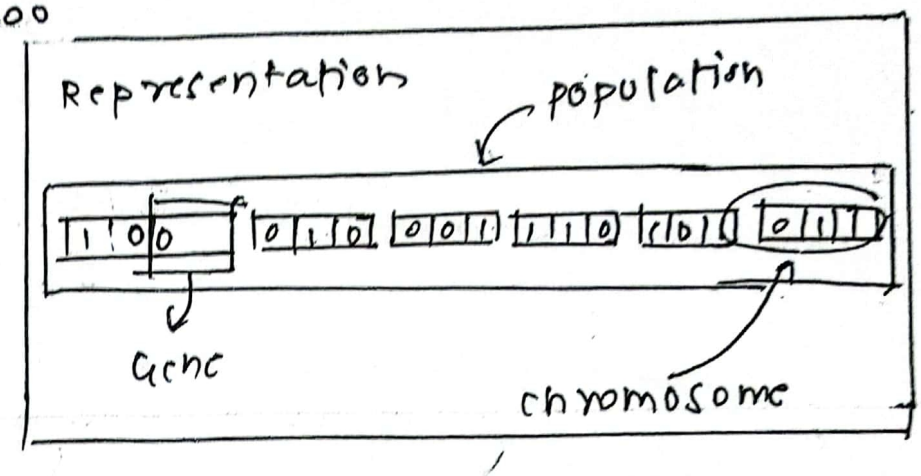
0-1 knapsack problem example :-

Q1)



A, B, C, AB, AC, BC

weight(W	5	10	15
profit($)	100	150	200

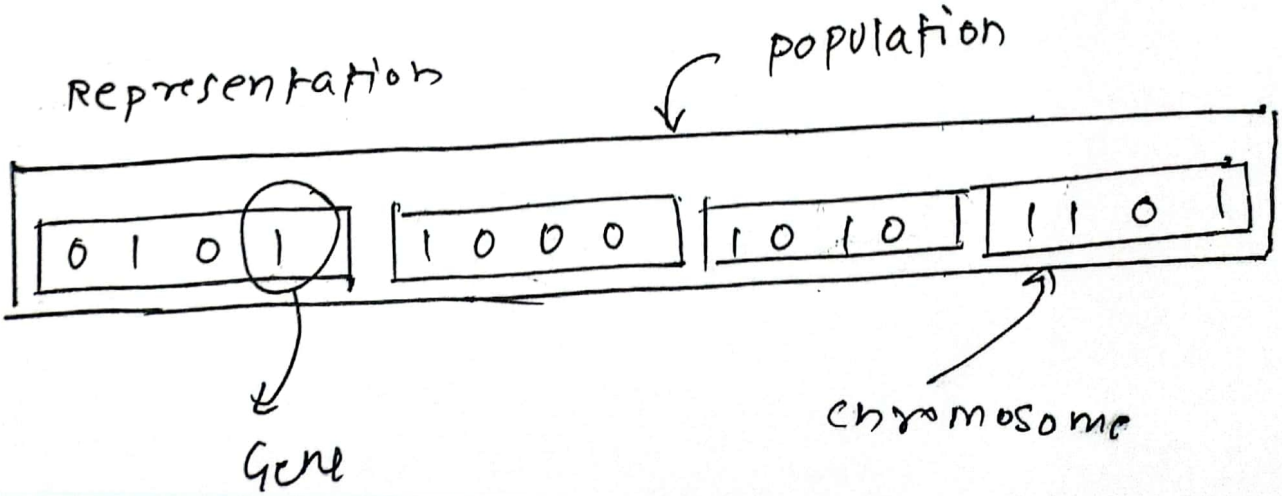


Q2) Example

$$f(x) = \frac{x^2}{2} + \frac{125}{x} \quad \text{where } 0 \le x \le 15$$

some of possible solutions without breaking constraints ($0 \le x \le 15$)

5, 8, 10 and 13



value encoding

Defining the initial population for function

$f(x) = \frac{x^2}{2} + \frac{125}{x}$ where $0 < x \leq 15$ is x is any discrete integer

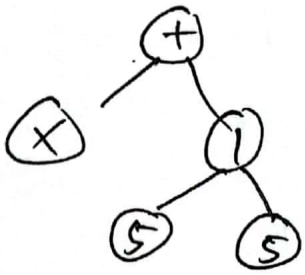
5, 8, 10, 13

5	8	10	13

Tree Encoding

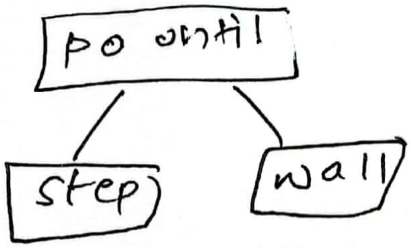
solution is encoded in binary tree

Chromosome A



(+ x (/ 5 4))

Chromosme

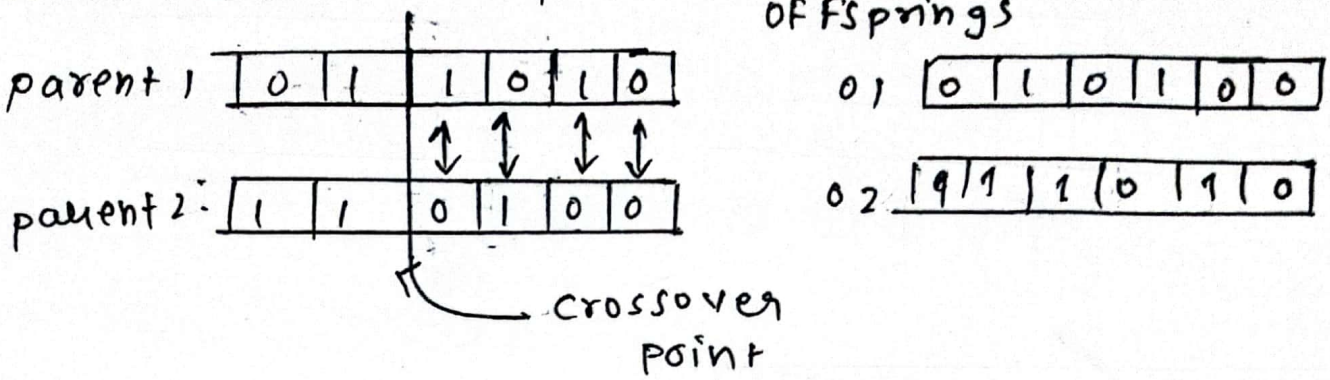


do-until step wall

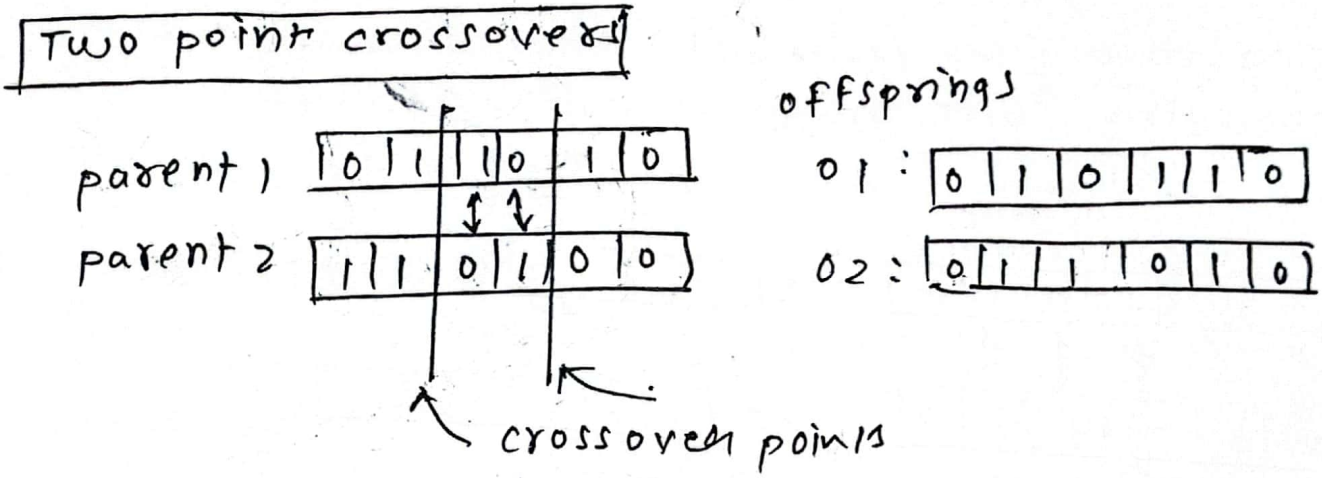
single point crossover

Cross-over Techniques

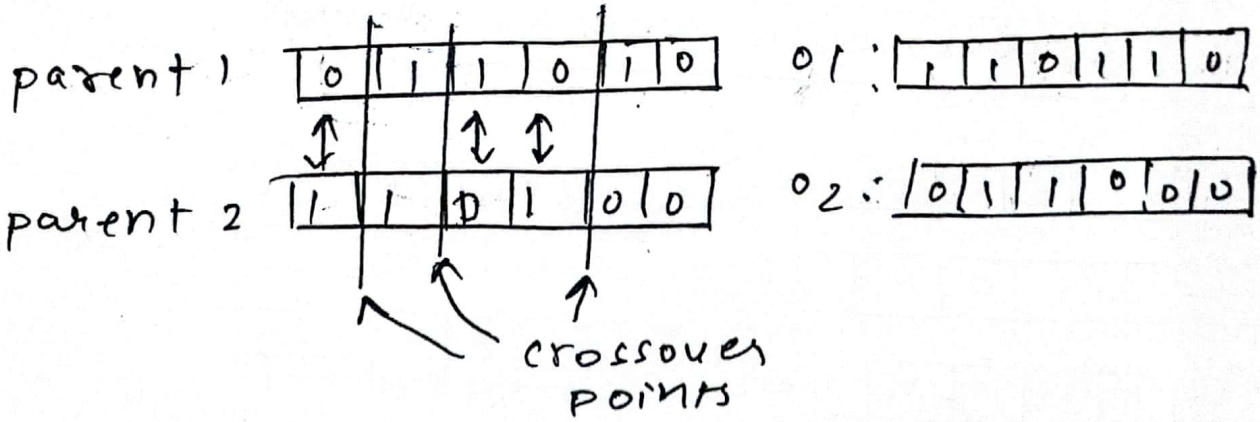
Singe-point Crossover



Two point crossover

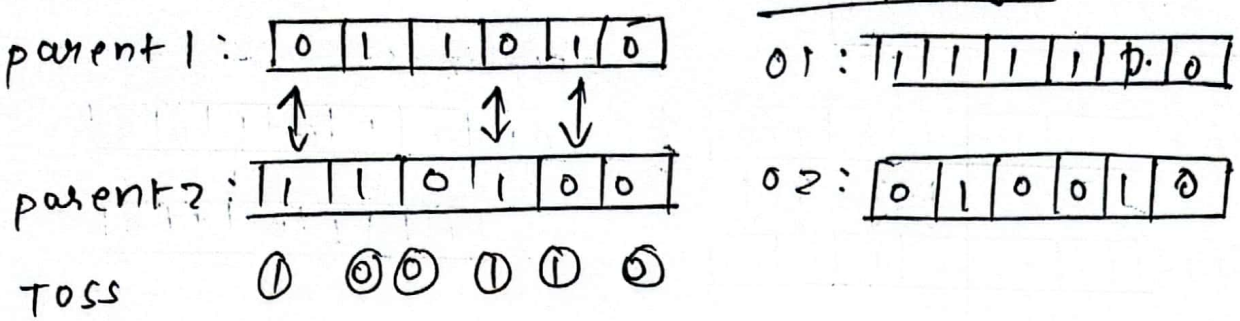


Multi-point crossover



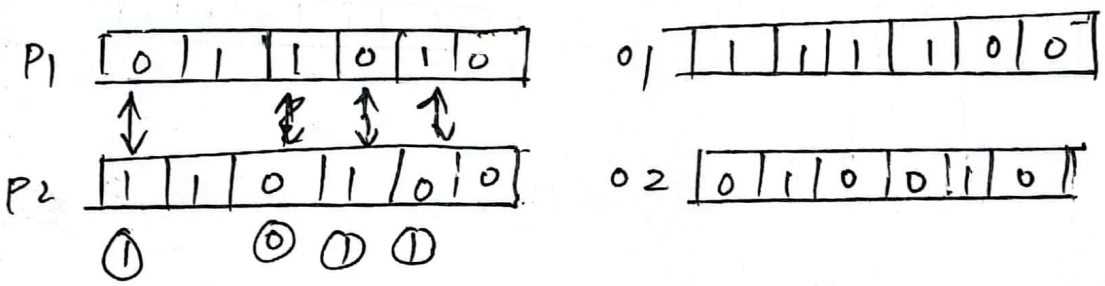
Uniform crossover

Each bit position of parents, toss a coin (let H=1 and T=0

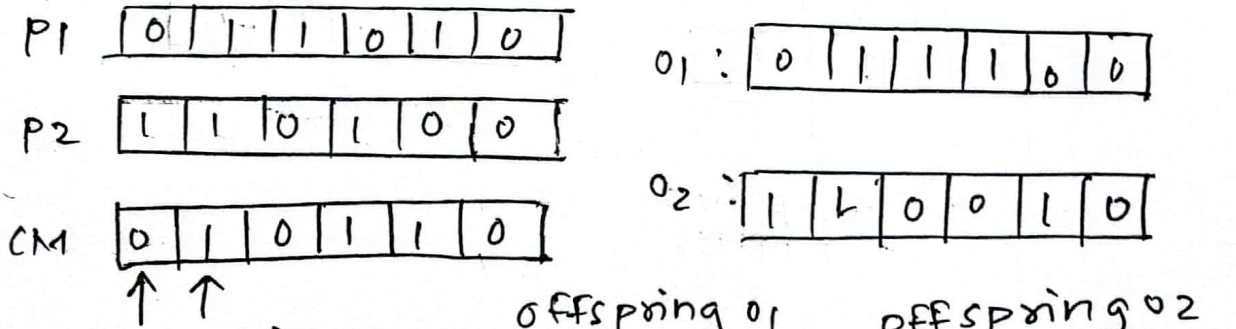


Half-uniform crossover

Toss a coin (let H=1 and T=0) only if the corresponding bits in P1 and P2 do not match

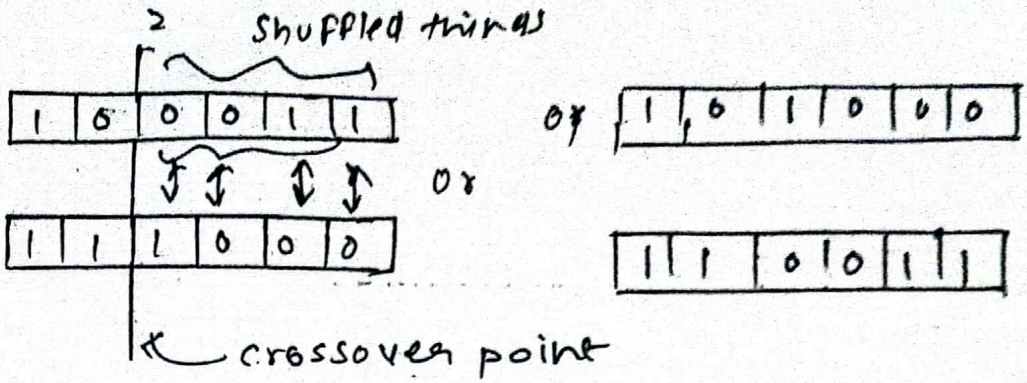


uniform crossover with crossover Mask (CM)



offspring O1	offspring O2
if CM = 0 then select P1 bit	if CM = 0 then select P2 bit
if CM = 1 then select P2 bit	if CM = 1 select P1 bit

shuffle crossover



Three parent crossovers

P1 | 0 | 1 | 1 | 0 | 1 | 0 |

P2 | 1 | 1 | 0 | 1 | 0 | 0 |

P3 | 1 | 0 | 0 | 1 | 0 | 1 |

combination (P1, P2, P3)

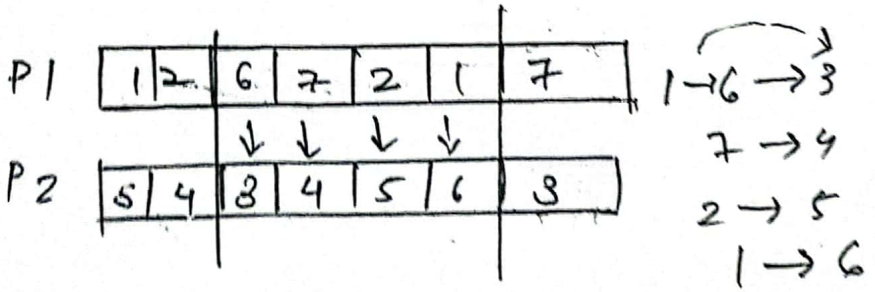
if P1 = P2 bit

then select P1 bit

if P1 bit != P2 bit

then select P3 bit

partially mapped crossovers



Replace offsprings with wherever 1 to 8

O1 | 8 | 2 | 6 | 7 | 2 | 1 | 4 |

O2 | 2 | 7 | 8 | 4 | 5 | 6 | 1 |

MUTATIONS - Genetic Algorithms

In each generation chromosomes undergo mutation and crossover and then selection to produce a better population whose candidates are near to desired solution.

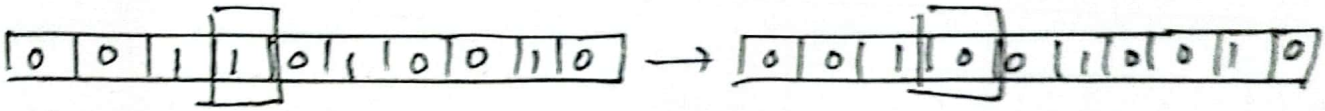
Mutation operator is a unary operator it needs only one parent to work on.

Select few genes from selected chromosome and apply desired mutation operator.

1. Bit Flip Mutation
2. Random Resetting mutation
3. swap mutation
4. scramble mutation
5. Inversion Mutation

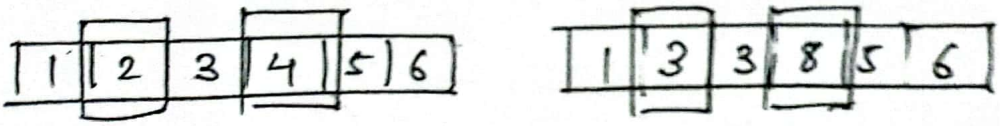
BIT Flip Mutation

we only use binary encoded GAs



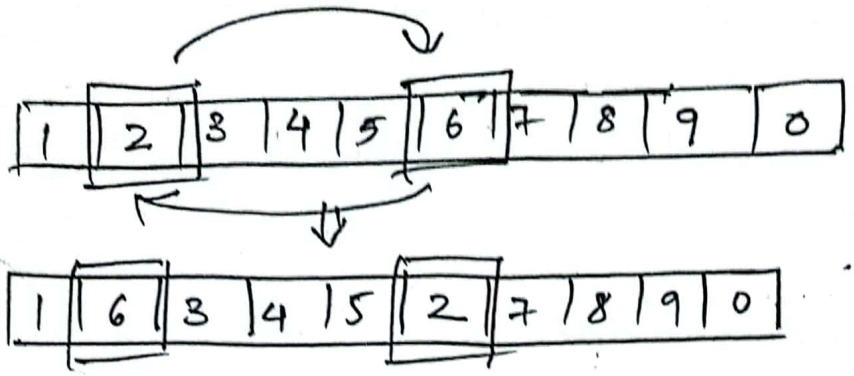
Random Resetting

only use integer representation

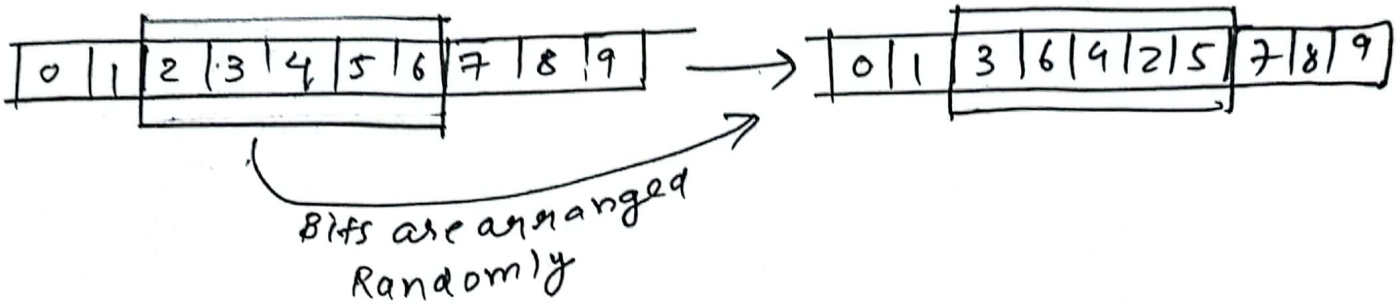


Swap Mutation.

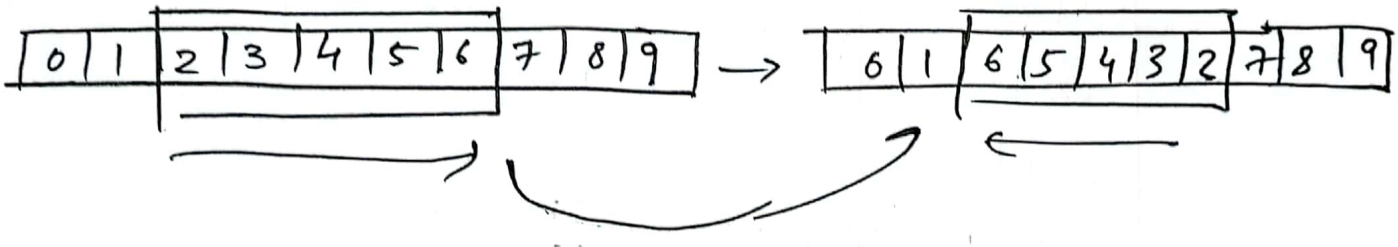
select two positions at random and interchange values



Scramble Mutation



Inversion Mutation



Solved Examples

Q1) consider the function of maximizing the function $f(x) = x^2$

$0 \leq x \leq 31$ Range :

Step 1: Select Encoding Technique

: Let's take Binary Encoding Technique.

1) use five binary integers numbers between 0 (00000) and 31 (11111)

objective $f(x) = x^2$

Step 2: select initial population

select any number of size.

Lets take population size 4 but we can take any no. by choice

string No	initial population (Randomly selected)	x value	fitness $f(x) = x^2$	prob	% prob	Expected count	Actual count
1	~~000~~ 01100	12	144	0.1247			
2	11001	25	625	0.5411			
3	00101	5	25	0.0216			
4	10011	19	181				
sum			1155				
Average			288.75				
maximum			625				

$$prob = \frac{F(X)}{\sum F(X)} = \frac{144}{1155} = 0.1247$$