C.T-4 : Genetic Algorithm. [From Lecture Slide]

68

Introduction to Evolutionary Computation:

Subfield of AI uses the concept of biological evolution to find optimal or near optimal solutions for a given problem.

* অনেকগুলো soln আছে। তার মধ্যে optimal or near optimal soln টা খুঁজে বের করবো।

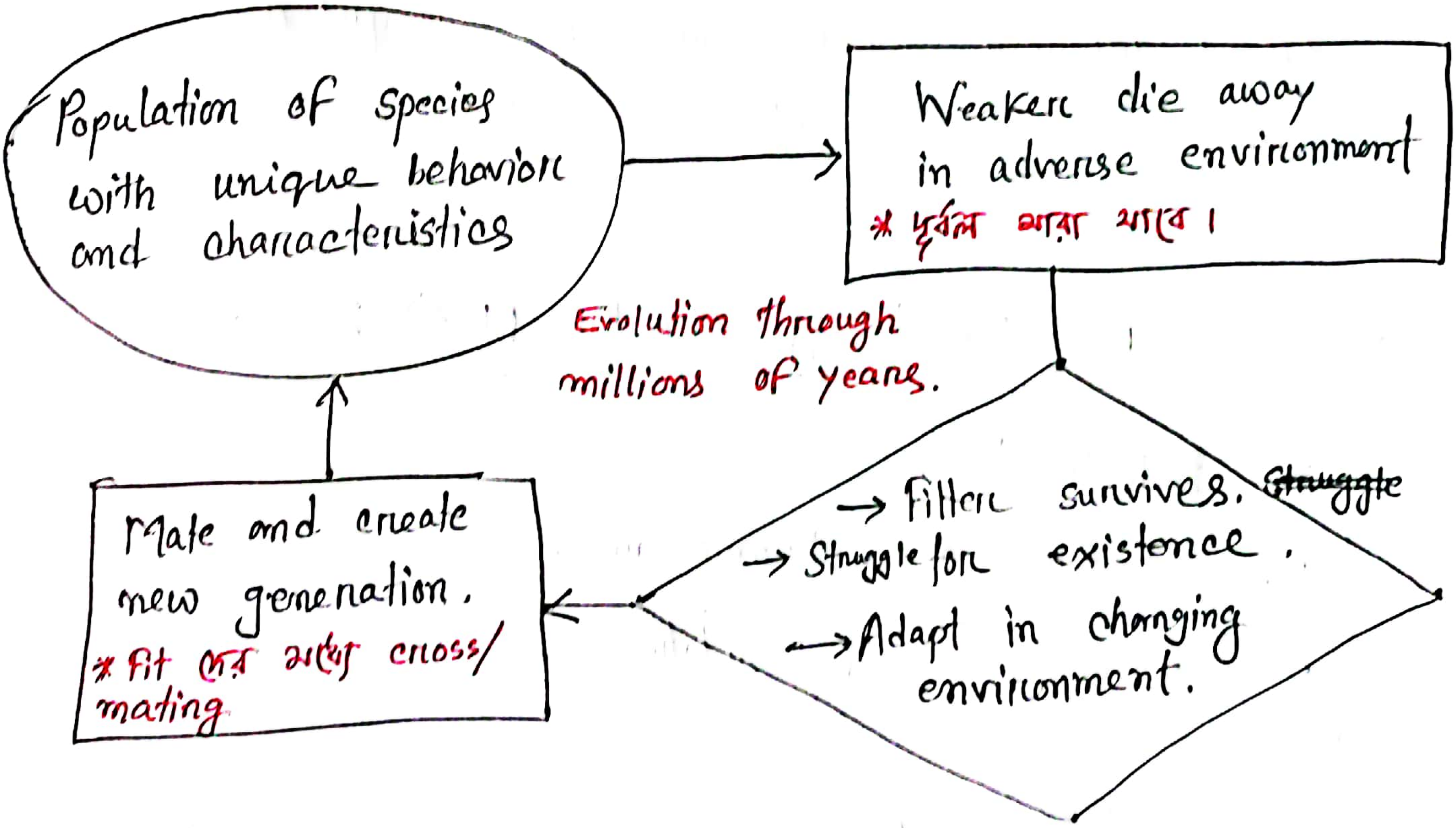


Fig: Evolution in the nature.

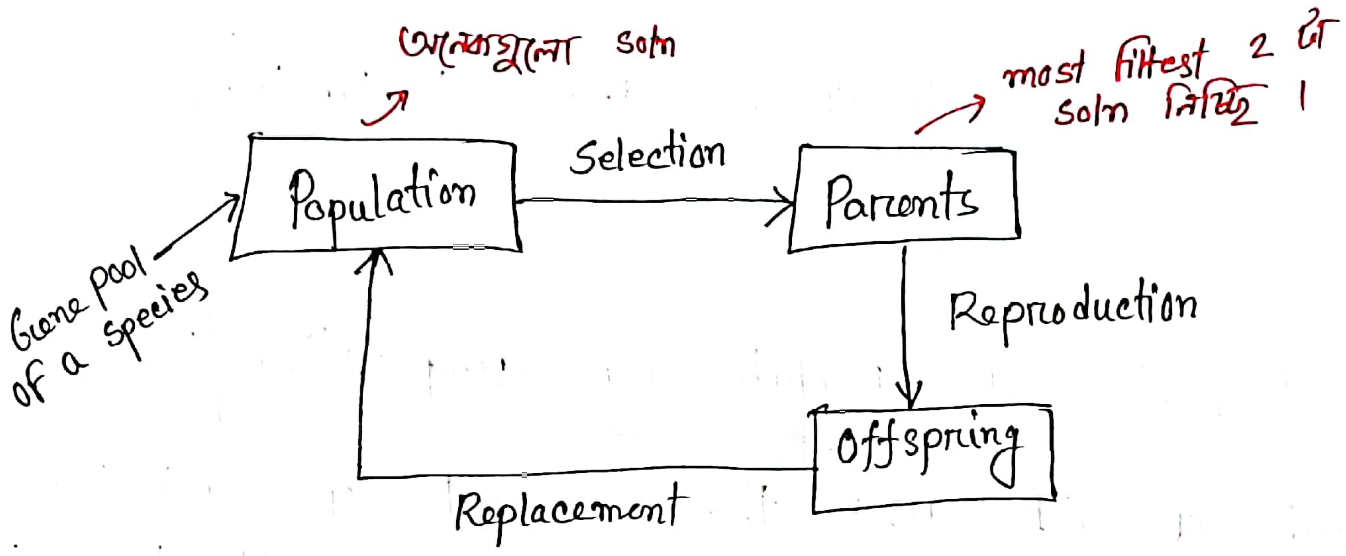


Fig: Evolutionary Computation.

* Population, gene, chromosome etc words have ~~differnt~~ different significances in computer science or genetic algorithm.

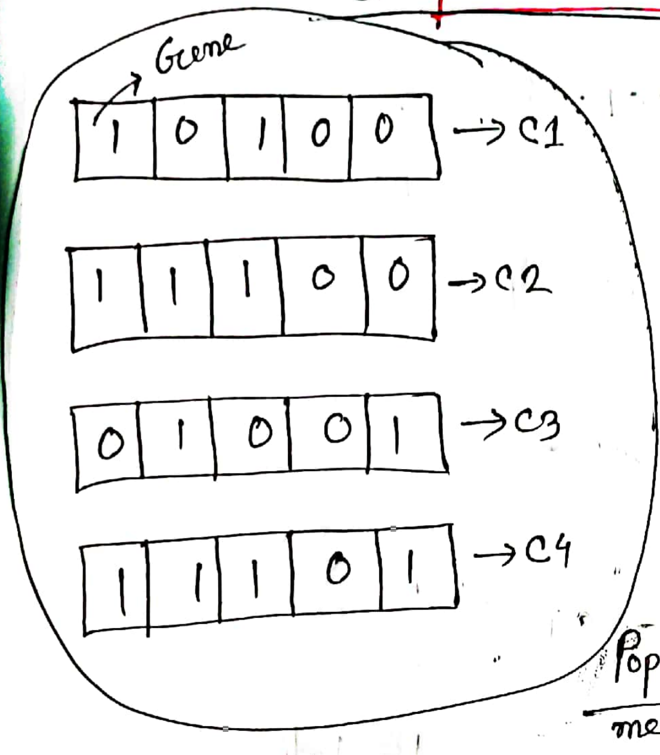
* Steps of Evolutionary Algorithm (EA):

1. Initialization.
2. Selection of chromosome.
3. Crossover and mutation.

* Genetic Algorithm is a kind of EA.

[3] What is Gene, Chromosome, Population ? :

(1) Initialization of Population



Population

medium size হওয়া ভালো

→ first step of EA (GA)

→ six parameters are set before starting the algorithm.

1. No. of Genes per chromosome.
   ⇒ bit stream এ bit সংখ্যা।
2. The codes value.
3. The size of population per generation.
4. Crossover probability
5. Mutation probability.
6. Termination criteria and max. no. of generations.

* bit stream = chromosome/Individual.
* bit = Gene/Allele.
* Population = set of chromosome.

→ How to initialize population ?

→ What should be the population size.

* Three most widely used encoding of gene :

(i) Binary Encoding.

(ii) Real number encoding.

(iii) Permutation encoding.

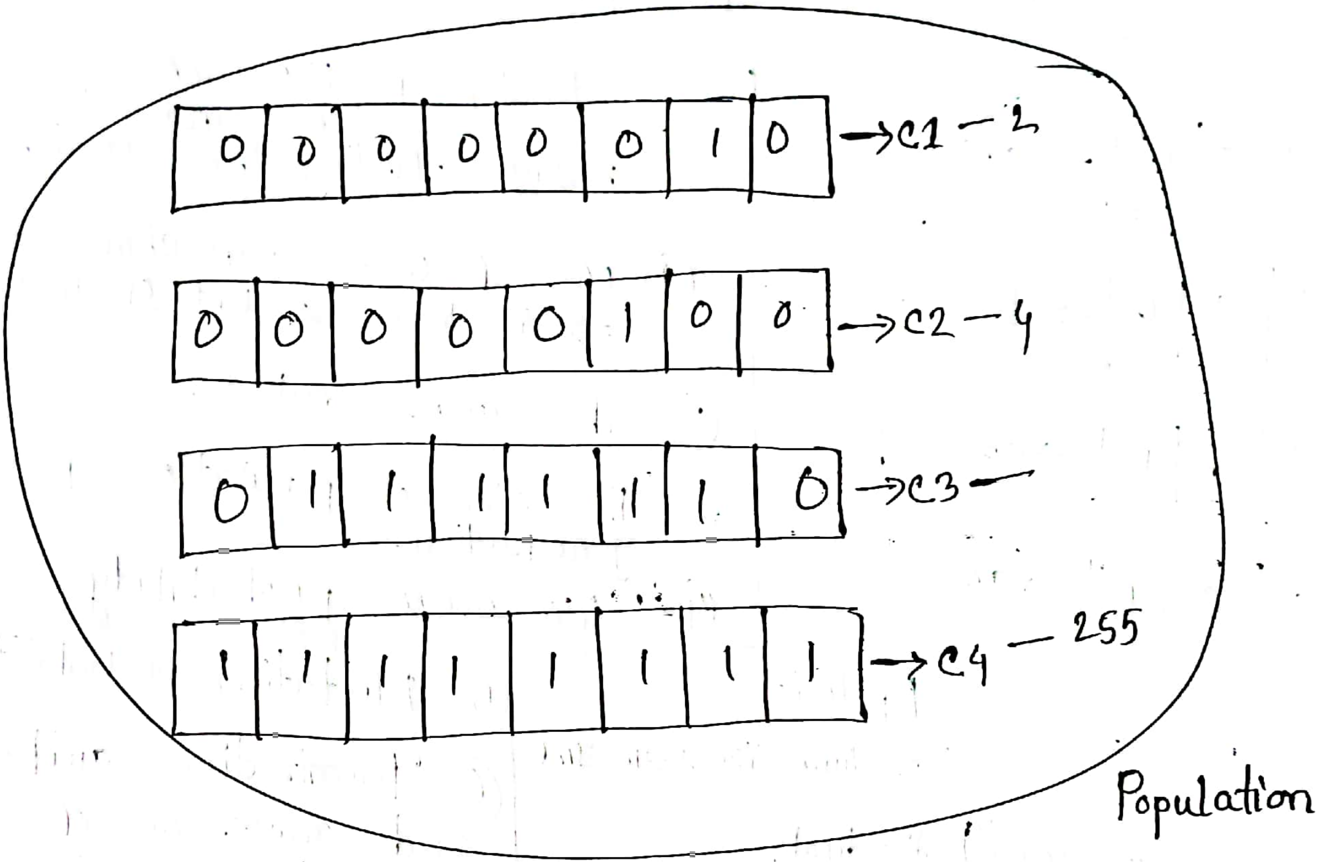
CS CamScanner

(i) Binary Encoding:

Example: $f(x) = x^3$; $0 \leq x \leq 255$

Maximize the fn value.

[$256 = 2^8$
8 bits.



* C4 → most optimal.
* C4 এখানে না থাকলে C3 near optimal.

CS CamScanner

② Selection of Chromosome

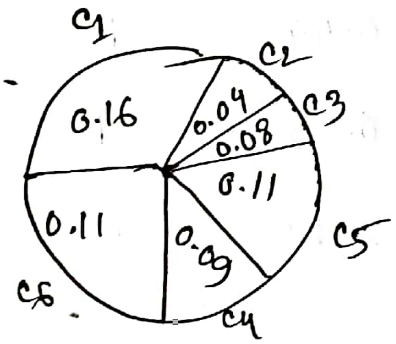
Parent Select করবো

→ Roulette wheel selection **
→ Rank Selection ***
→ Tournament selection **

3 types.

I Roulette Wheel selection :

→ Random selection of m chromosome from a big population (when fitness are not very different).



6 – Individual

Length of circumference ∝ fitness value

* i.e the probability of selection of a chromosome (for mating pool) is higher for larger fitness.

* Probability গুলোর মধ্যে যদি fitness খুব বেশি differ করলে, তখন Rank selection use করতে হবে।

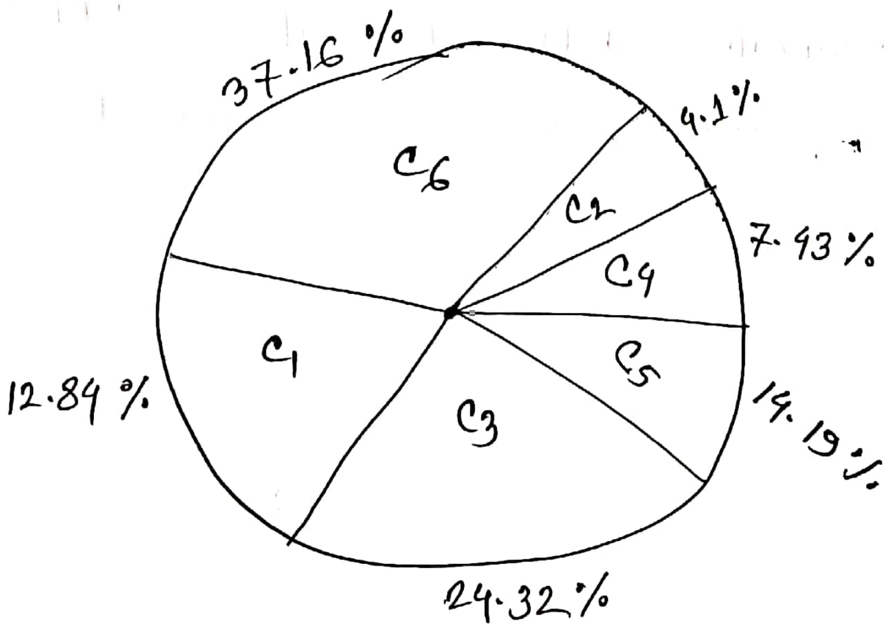
Example: Determine percentage of Roulette Wheel and Actual count for 6 chromosomes with fitness values of 19, 6, 36, 11, 21 & 55.

Soln:

Chromosome	Fitness, F	% of Roulette Wheel	Probability P_i	Expected Count $(P_i \times N)_{nd}$	Actual count
C1	19	12.84%	0.1284	0.1284 × 6 = 0.77	1
C2	6	4.1%	0.0405	0.243	0
C3	36	24.32%	0.2432	1.46	1
C4	11	7.43%	0.0743	0.44	1
C5	21	14.19%	0.1419	0.85	1
C6	55	37.16%	0.3716	2.23	2

$\sum F = 148$

C_1, $P_1 = \dfrac{19}{148} = 0.1284 \quad (P_i = P_1)$



এটা একেকজনের একেকরকম আসতে পারে।
0.46 → 1 নেয়া হয়েছে 0.5 এর কাছাকাছি হওয়ার জন্য।
এটা ইচ্ছা।
Just 6 মিলাতে হবে।

71

II Rank Selection :

Example: Determine percentage of Roulette wheel before ranking and after ranking SP [1.0, 2.0]

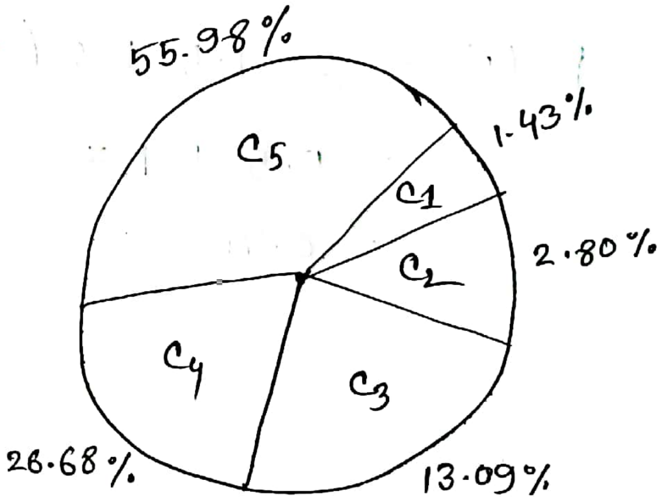
$\frac{1.0+2.0}{2} = 1.5$

Chromosome	C_1	C_2	C_3	C_4	C_5
Fitness Value	0.23	0.45	2.1	4.28	8.98

Soln:

(i) Before Ranking :

Chromosome	Fitness Value	% of Roulette Wheel
C_1	0.23	1.43%
C_2	0.45	2.80%
C_3	2.1	13.09%
C_4	4.28	26.68%
C_5	8.98	55.98%



min এর rank — 1.

(ii) After ranking :

Chromosome	Fitness value	Rank	New Fitness Value	% of Roulette wheel
C_1	0.23	1	0.5	10%
C_2	0.45	2	0.75	15%
C_3	2.1	3	1	20%
C_4	4.28	4	1.25	25%
C_5	8.98	5	1.5	30%

CamScanner

$$Fit(pos) = 2 - sp + 2(sp-1)\frac{(pos-1)}{(Nind-1)}$$

rank

$\boxed{\text{Non linear এর (ranking) ক্ষেত্রে, } sp\ [1.0,\ Nind - 1]}$

$$Fit(1) = 2 - 1.5 + 2(1.5-1)\frac{1-1}{5-1}$$

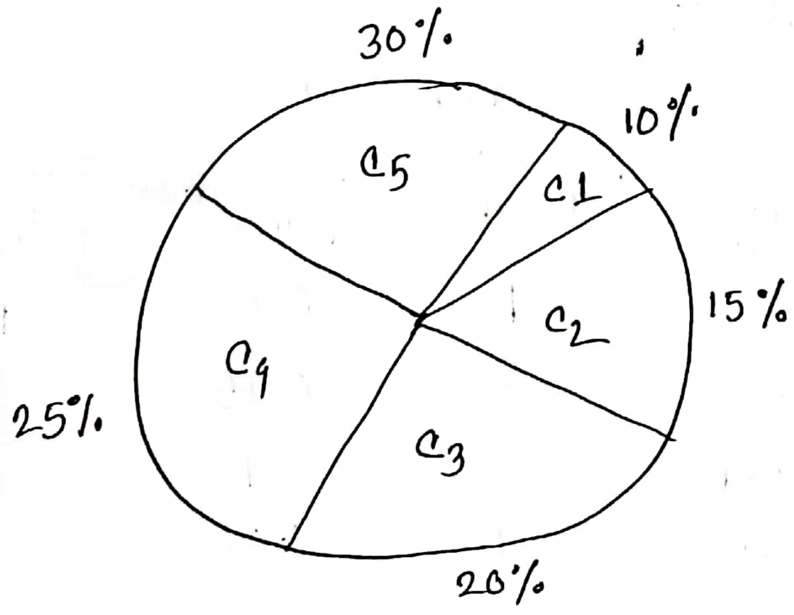
$$= 2 - 1.5 + 1 * \frac{0}{4}$$

$$= 0.5$$

$$Fit(2) = 2 - 1.5 + 2(1.5-1)\frac{2-1}{5-1}$$

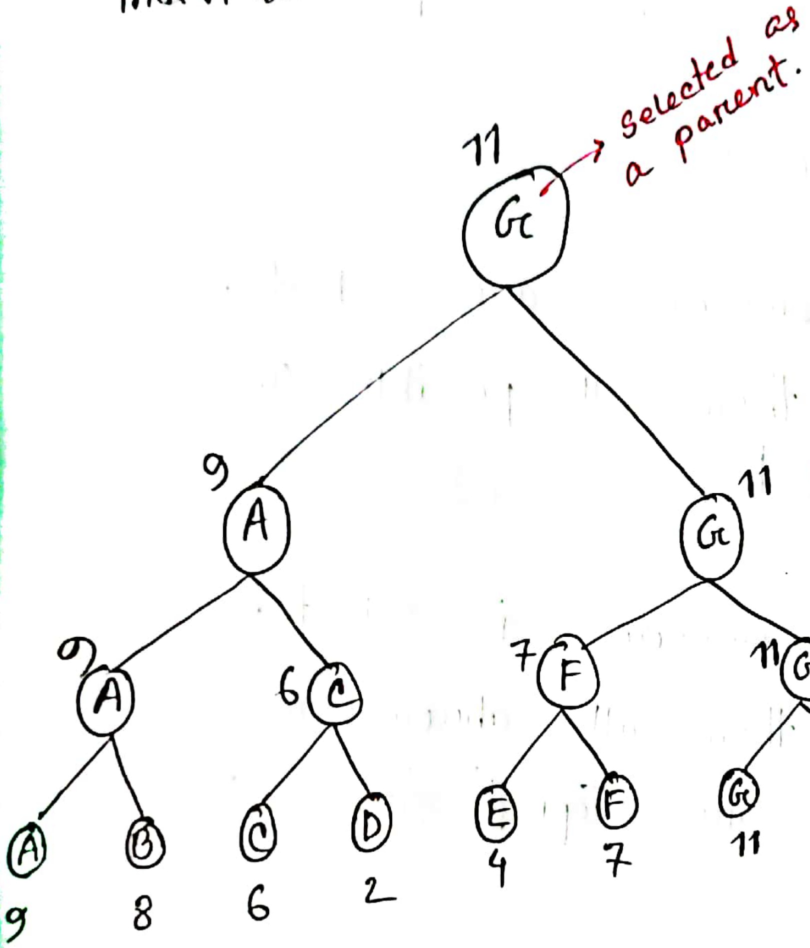
$$= 0.5 + 1 * \frac{1}{4}$$

$$= 0.75$$



Tournament Selection :

Group of K individuals randomly selected from a population of N individuals.



Algorithms :

① Select K individuals from the population and perform a tournament amongst them.

② Select the best individual from the K individuals.

③ Repeat process 1 and 2 untill we have the desired amount of population.

100 >> 8 ↓ K

* যদি 4 টা parent প্রয়োজন হয়, এই tournament টা 4 বার perform করতে হবে।

Crossover & Mutation :

* Crossover → Generation of offspring/child.
* Mutation → Change characteristic of next generation.

* Extreme case of crossover :

* Case-I : If all chromosomes are selected for mating then all possible offspring are generated.

* Case-II : If no chromosome is selected for mating then all chromosomes of parents are copied for next generation.

* **Drawback of crossover** : Crossover may stuck into local optima (global optima may be missed).

* Single-site Crossover.
* Two-site Crossover.
* Crossover Mask.

Math.

$P_1 \rightarrow 00|00$ (0)

$P_2 \rightarrow 00|01$ (1)

$C_1 \rightarrow 0001$ (1)

$C_2 \rightarrow 0000$ (0)

* এভাবে repeat হবে 0 আর 1 এর।
* যেখানে 4 bit এর max 1111 → 15.

CamScanner

~~Robiul Sir~~

Single-site Crossover (At point 5):

Example:

5

$P_1 \rightarrow$	1	0	0	1	1	0	0	1	0
$P_2 \rightarrow$	0	1	0	1	1	1	0	0	1

Strings before mating

5

$C_1 \rightarrow$	1	0	0	1	1	1	0	0	1
$C_2 \rightarrow$	0	1	0	1	1	0	0	1	0

Strings after mating

Two-site Crossover (At point 2, 5):

No change 2 5 No change

$P_1 \rightarrow$	1	0	1	0	1	0	0	1	0
$P_2 \rightarrow$	0	1	0	1	0	1	0	0	1

2 5

$C_1 \rightarrow$	1	0	0	1	0	0	0	1	0
$C_2 \rightarrow$	0	1	1	0	1	1	0	0	1

CS CamScanner

☐ Crossover Mask***:

$P_1 \rightarrow$	1	0	0	0	1	0	0	1	0
$P_2 \rightarrow$	0	1	0	1	1	1	0	0	1

Strings before mating.

$C_1 \rightarrow$	1	1	0	0	1	1	0	0	0
$C_2 \rightarrow$	0	0	0	1	1	0	0	1	1

Strings after mating

Mask	1	0	0	1	1	0	0	0	1

<u>C_1 generation:</u>   Mask bit $\rightarrow$ 1, P_1 bit copy paste
Mask bit $\rightarrow$ 0, P_2 " " "

<u>C_2 generation:</u>   Mask bit $\rightarrow$ 1, P_2 bit copy paste
Mask bit $\rightarrow$ 0, P_1 " " "

CamScanner

73.

Maximizing Function :

Example: Maximize the function $f(x) = x^2$ where the range of x is $[0, 31]$ and maximum number of generation is 3.

Soln: Step-1: Initialization. $[32 = 2^5 \rightarrow 5 \text{ bits}]$

00000, 00001, 00010, ... 11111

· Max no. of generation = 3

Step-2: Selection (1st Generation)

Randomly

Chromosome	Binary Encoding	Value of x	Fitness value $f(x) = x^2$
c_1	00101	5	25
c_2	10000	16	256 ~~196~~
c_3	01001	9	81
c_4	11100	28	784

$\sum f(x) = 1146$

CamScanner

Step-3: Crossover (2nd Generation)

Chromosome	Mating Pool	Crossover Point	offspring after crossover	x	$f(x)=x^2$
c_1	00101	4	00100	4	16
c_2	10000	4	10001	17	289
c_3	01001	2	01100	12	144
c_4	11100	2	11001	25	625

26/2/25

$\sum f(x) = 1074$

Mutation (3rd Generation)

Chromosome	offspring after crossover	offspring after mutation	x	$f(x)=x^2$
c_1	00100	00100	4	16
c_2	10001	10101	21	441
c_3	01100	01100	12	144
c_4	11001	11011	27	729

$\sum f(x) = 1330$

Ans: $c_4 \to 11011\ (27)$. [Near optimum]

CS CamScanner

4 Genetic Algorithm:

→ John Hollond 1975.
→ Random Search Algorithm.
→ Achieves optimum soln, of a problem with some constraints.

* Why GA ?

→ Easy to code and almost same procedure for many problems.
→ Provides many solutions.
→ Parallel processing can be used.

* Shortcomings / Disadvantages :

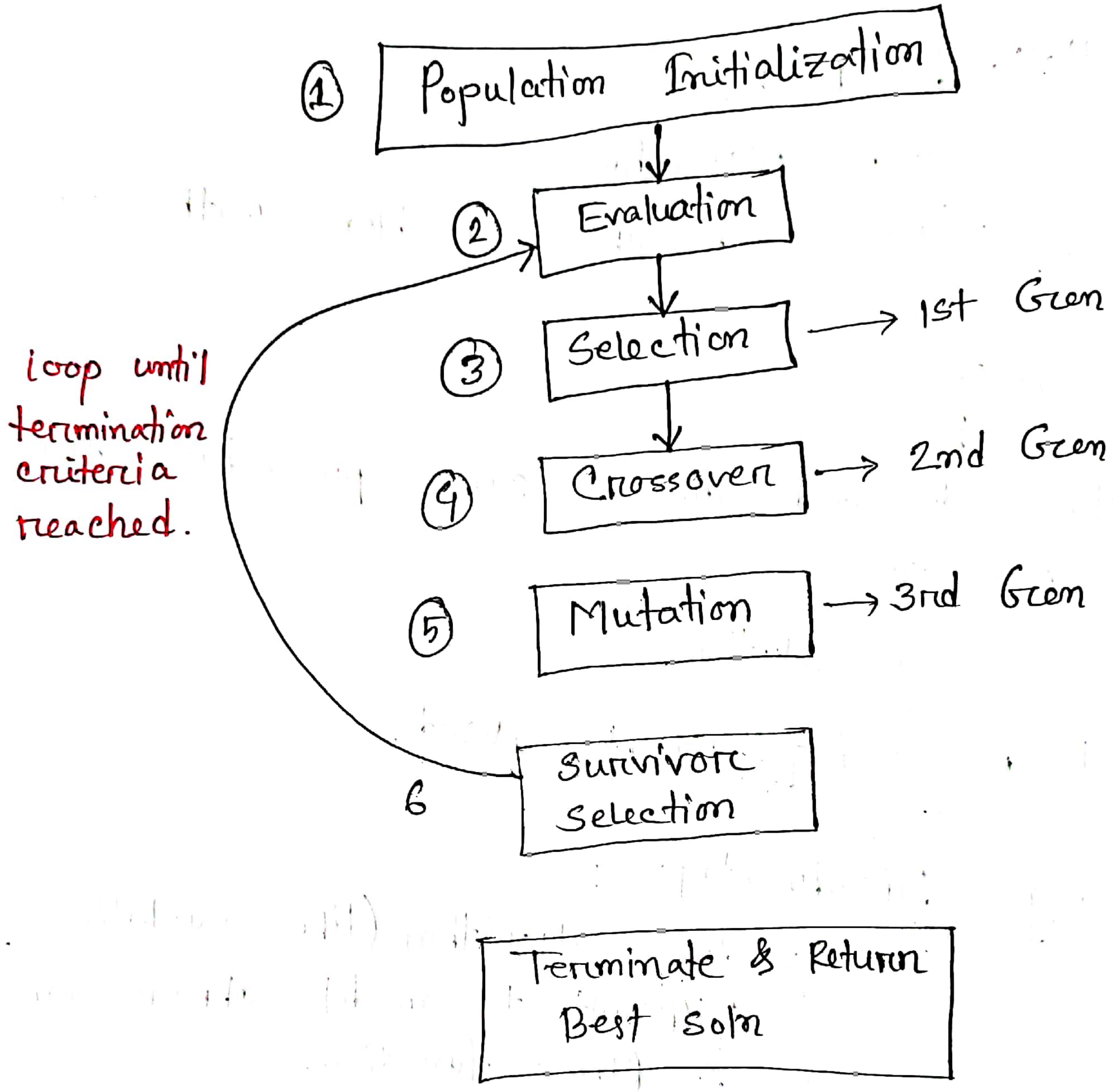
→ slow algorithm (like evolution).
→ Difficult to model chromosome & fitness function.

* Termination criteria of GA:

→ Maximum no. of generation.
→ Diversity minimum Level.
→ No change in fitness level.
→ Target fitness is achieved.
→ Change in Σfitness is very little.

CS CamScanner

Steps : 6 steps.



CS CamScanner

Genetic Algorithm example: Generate 3 chromosome each containing 12 bits. Apply single point and two crossover. Apply mutation generating random number r of [0,1] where $r < p$, $p = 1/12 = 0.0833$.

Soln: $c_1 \rightarrow$ 001 001 000 111
$c_2 \rightarrow$ 101101000011
$c_3 \rightarrow$ 110110010001

1 marks

$\boxed{c_1, c_2, c_3 \text{ (ইচ্ছামত)}}$

Single point crossover (At point 6)

$c1 \rightarrow$ 001 001 | 000111
$c2 \rightarrow$ 101101 | 000011
6

$ch1 \rightarrow$ 001001 000011
$ch2 \rightarrow$ 101101 000111

1.5 marks.

Two point crossover (2,6).

$c_1 \rightarrow$ 00 | 1001 | 000111
$c_2 \rightarrow$ 10 | 1101 | 000011
2 6

$Ch1 \rightarrow$ 00 1101 000111
$Ch2 \rightarrow$ 10 1001 000011

1.5 marks.

CamScanner

Mutation:

Random number generate করতে হবে।

$C_3 \rightarrow$	1	1	0	1	1	0	0	1	0	0	0	1
Randomly $\rightarrow$	0.5	0.6	<u>0.02</u>	0.9	<u>0.01</u>	0.33	0.45	0.62	~~0.77~~ 0.77	<u>0.031</u>	0.8	0.87

$C_3' \rightarrow$	1	1	1	1	0	0	0	1	0	1	0	1

Ans.