AIFA: Genetic Algorithm

08/04/2025

Koustav Rudra

Travelling Salesman Problem

- A salesperson from city 1 must visit every month 8 other cities exactly once and come back to 1. Find his minimum distance tour using Genetic Algorithm given the following distance matrix.

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	0	12	22	15	21	21	15	21	21
C2		0	8	11	13	13	11	13	13
C3			0	16	18	18	16	18	18
C4				0	19	19	16	19	19
C5					0	14	19	20	20
C6						0	12	12	21
C7							0	22	13
C8								0	18
C9									0

TS Problem: Encoding

- Which encoding should be used?
- Permutation encoding
- Common in TS problems or Task Ordering problems
- Here each chromosome is a number string representing a position in a sequence

- Chromosome A: 1 5 3 2 6 4 7 9 8
- Chromosome B: 8 5 6 7 2 3 1 4 9

- What should be fitness function?

TS Problem: Fitness Function

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	0	12	22	15	21	21	15	21	21
C2		0	8/8	11	13	13	11	13	13
C3			0	16	18	18	16	18	18
C4				0	19	19	16	19	19
C5					0	14	19	20	20
C6						0	12	12	21
C7							0	22	13
C8								0	18/18
C9									0

Fitness Function = Maximize F = $^{1}/_{Distance}$

Chromosome	**Route**	**Total Distance Travelled (D)**	**Fitness Function ($F = {}^{1}/_{D}$)**
153264798	1-5-3-2-6-4-7-9-8-1	21+18+8+13+19+16+13+18+21	$F = {}^{1}/_{147} = 0.00689$
856723149	8-5-6-7-2-3-1-4-9-8	15+19+18+20+14+12+11+8+22	$F = {}^{1}/_{139} = 0.00719$

TS Problem: Crossover and Mutation

- Single Point Crossover
- One crossover point
- Copy first parent till crossover point
- Add number not present in offspring yet in sequence as present in second parent
- Parent1: 6 2 3 4 5 | 1 7 8 9
- Parent2: 4 5 3 6 8 | 9 7 2 1
- Child1: 6 2 3 4 5 | 8 9 7 1
- Child2: 4 5 3 6 8 | 2 1 7 9

- Order changing mutation: 6 2 3 4 5 8 9 7 1
- 6 2 3 4 5 8 9 7 1
- 6 2 8 4 5 3 9 7 1

TS Problem: Other Considerations

- Which selection scheme to use?
  - Roulette Wheel, Tournament, or Remainder Stochastic?
- Should Elitism be used?
- What should be the crossover and mutation probability?
- Are trade-offs achieved between selection pressure and population diversity?
- Convergence of the solution? – Stuck in local minima?

GA: Example 1

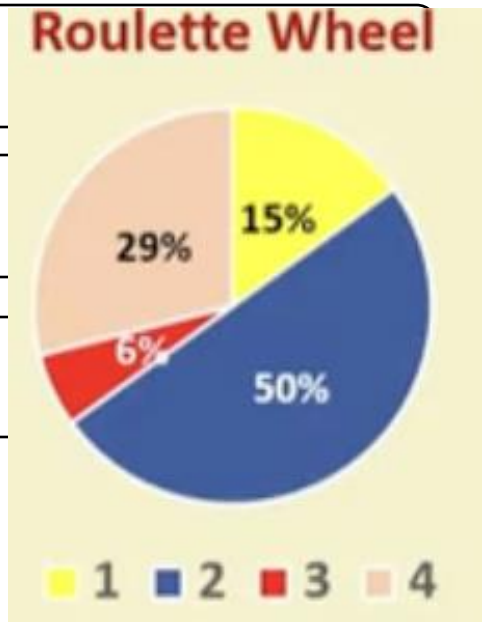
- Maximize $(x^2 + 1)$ over $\{0,1,\ldots,31\}$
- Representation: binary code e.g., 01101 for 13
- Chromosome length is 5 (11111 is 31)
- Population size: 4
- 1-point crossover
- Roulette Wheel Selection

Randomly generated initial population

1	01101	13
2	11000	24
3	01000	8
4	10010	18

GA: Example 1: Selection

String no.	Initial Population	X value	Fitness $f(x) = x^2 + 1$	Prob. $f_i/\sum f_i$	Exp. Count: f_i/f_{avg}	Actual Count
1	01101	13	170	0.15	0.60	1
2	11000	24	577	0.50	2.00	2
3	01000	8	65	0.06	0.24	0
4	10010	18	325	0.29	1.16	1
$sum \sum f_i$			1137	1.00		
$avg\ f_{avg}$			284.25	0.25		
$Maximun$			577			



GA: Example 1: Mutation

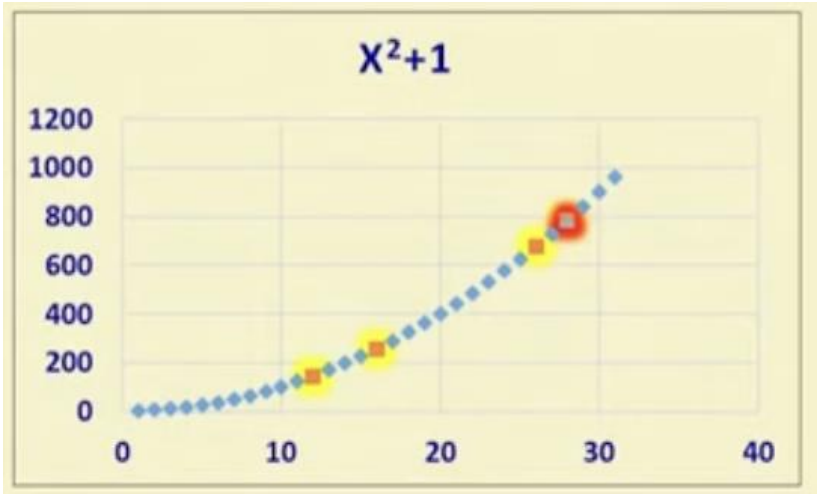
- Mutation probability: 1/5 = 0.2
- Generate random number for all 20 genes

String No.	Random numbers				
1	0.6787	0.7577	0.7431	0.3922	0.6555
2	0.7712	0.7060	0.1318	0.2769	0.0462
3	0.5971	0.8235	0.6948	0.3171	0.9502
4	0.3644	0.4387	0.3816	0.7655	0.7952

Genes in the above highlighted places are to be flipped 1/0 or 0/1

GA: Example 1

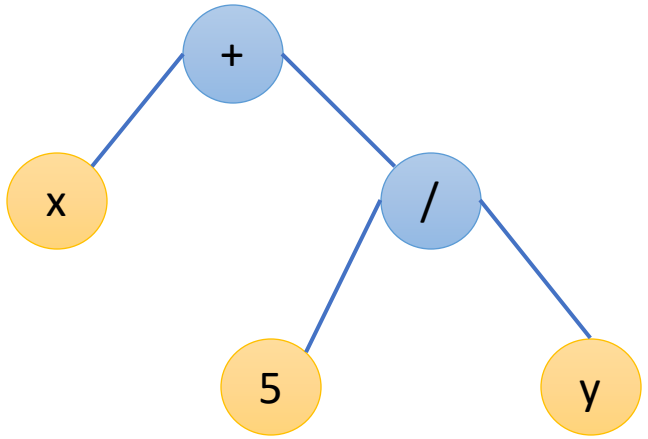
String no.	Offspring after Crossover	Offspring after Mutation	X value	Fitness $f(x) = x^2 + 1$
1	01100	01100	12	145
2	11001	11100	28	785
3	11010	11010	26	677
4	10000	10000	16	257
Sum				1864
Average				485
Max				785



Tree Encoding

- Used mainly for evolving programs or expressions
- Every chromosome is a tree of some objects, such as functions or commands in programming language

$(+x(/5y))$



Tree Encoding

- Tree encoding is useful for evolving programs or structures that can be encoded in trees

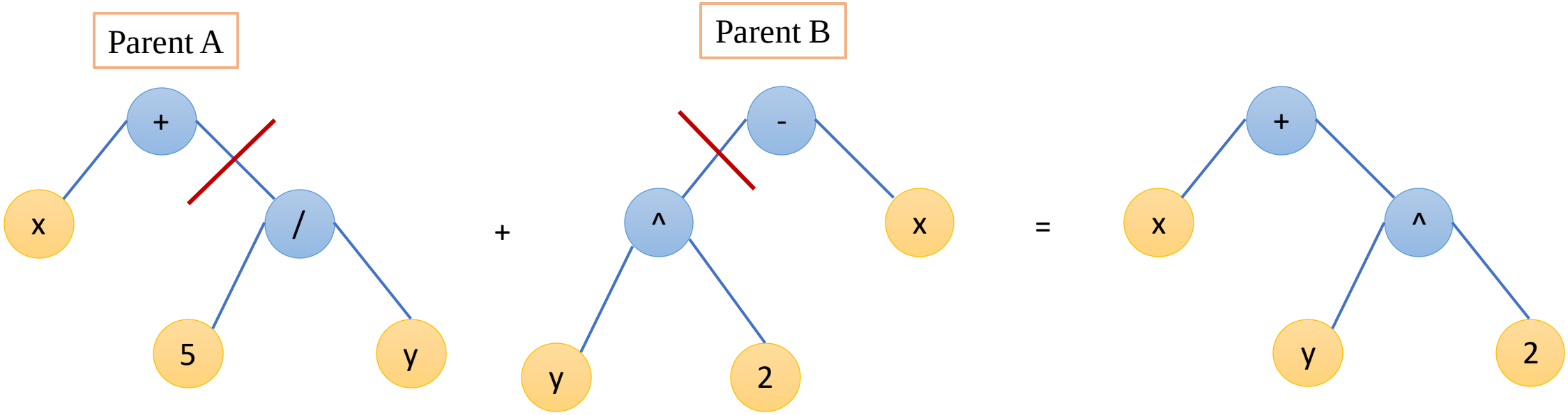
- Example of Problem: Finding a function that would approximate given pairs of values

- The problem:
  - Input and output values are given
  - The task is to find a function that will give the best (closest desired) outputs for all inputs

- Encoding:
  - Chromosomes are functions represented in a tree

Crossover and Mutation for Tree Encoding

- Tree crossover
  - A crossover point is selected in both parents
  - Parents are divided in that point and the parts below crossover points are exchanged to produce new offspring



- Mutation:
  - Changing operator, number
  - Selected nodes are changed

Thank You