23-S1-Q1

Q: TSP 12 city $< a_1\ a_2 \cdots a_{12}>$

recombination → hyper-recomb

① PMX : shade cells

② cycle ~

③ Edge. ~ → Node 1

Node 7

greedy approach : lowest cost

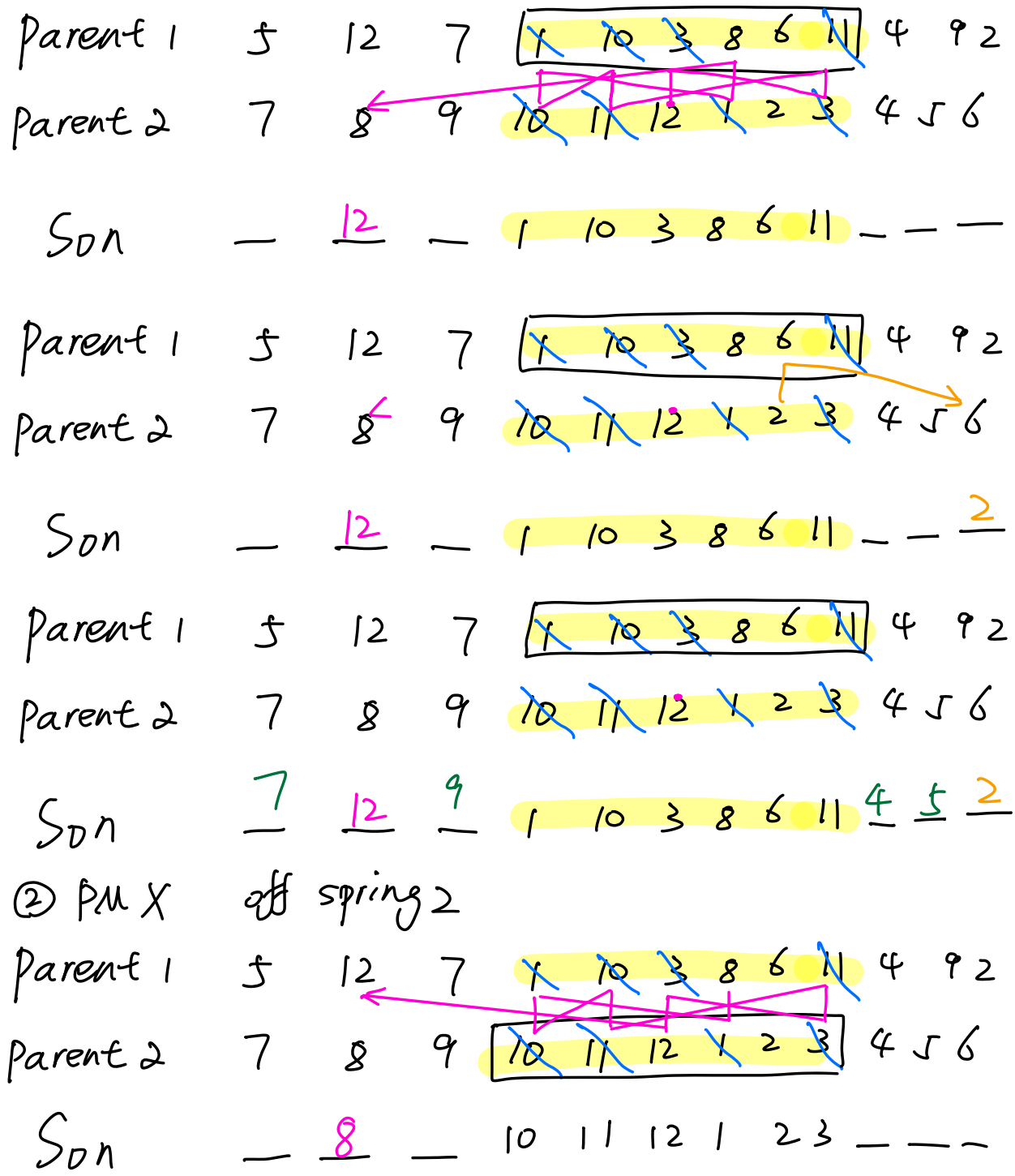
6→2 d_{ij} % : modulo

$d_{ij} = ((a_i + a_j) \% 5) + 1$

(a) two offspring

Parent 1	5	12	7	1	10	3	8	6	11	4	9	2
Parent 2	7	8	9	10	11	12	1	2	3	4	5	6

Solution ① PMX off spring 1



② PMX off spring 2

Parent 1 5 12 7 1 10 3 8 6 11 4 9 2

Parent 2 7 8 9 10 11 12 1 2 3 4 5 6

Son _ 8 _ 10 11 12 1 23 _ _ 6

Parent 1 5 12 7 1 10 3 8 6 11 4 9 2

Parent 2 7 8 9 10 11 12 1 2 3 4 5 6

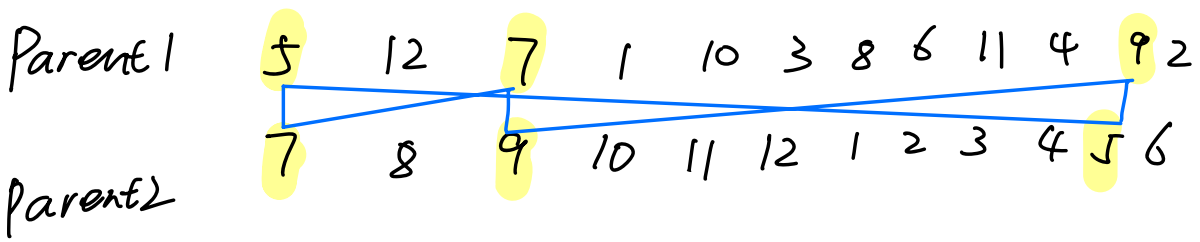
Son 5 8 7 10 11 12 1 23 4 9 6

③ After PMX

offspring 1 7 12 9 1 10 3 8 6 11 4 5 2

offspring 2 5 8 7 10 11 12 1 23 4 9 6

④ Cycle recombination: cycle 1



⑤ Cycle 2

Parent1 5 12 7 1 10 3 8 6 11 4 9 2

Parent2 7 8 9 10 11 12 1 2 3 4 5 6

⑥ Cycle 3

Parent1 5 12 7 1 10 3 8 6 11 4 9 2

Parent2 7 8 9 10 11 12 1 2 3 4 5 6

⑦ Cycle 4

Parent1 5 12 7 1 10 3 8 6 11 4 9 2

Parent2 7 8 9 10 11 12 1 2 3 4 5 6

⑧ fix 1, 3 chang 2, 4

offspring3 5 8 7 10 11 12 1 6 3 4 9 2

offspring4 7 12 9 1 10 3 8 2 11 4 5 6

⑨ After Cirle

offspring3 5 8 7 10 11 12 1 6 3 4 9 2

offspring4 7 12 9 1 10 3 8 2 11 4 5 6

⑩ Edge : start with 1 & 7

⑪ offsprings

Parent 1	5	12	7	1	10	3	8	6	11	4	9	2
Parent 2	7	8	9	10	11	12	1	2	3	4	5	6

1	7	10	12	2
2	9	5	1	3
3	10	8	2	4
4	11	9	3	5
5	12	2	4	6
6	8	11	5	7
7	12	1	8	6
8	3	6	7	9
9	4	2	8	10
10	1	3	9	11
11	6	4	10	12
12	5	7	11	1

Choices	Element selected	Reason	Partial Result
1	1	offspring 5 start with 1	1
7 10 12 2	10	smallese d	1 10
3 9 11	9	~	1 10 9
4 2 8	2	~	1 10 9 2
5 3	3	~	1 10 9 2 3
8 4	8	~	1 10 9 2 3 8
6 7	7	~	1 10 9 2 3 8 7
12 6	6	~	1 10 9 2 3 8 7 6
11 5	5	~	1 10 9 2 3 8 7 6 5
12 4	12	~	1 10 9 2 3 8 7 6 5 12
11	11	only one	1 10 9 2 3 8 7 6 5 12 11
4	4	only one	1 10 9 2 3 8 7 6 5 12 11 4

$d_{1,x} = ((1+x) \bmod 5) + 1$

x	$d_{1,x}$
7	4
10	2
12	4
2	4

x	$d_{10,x}$
3	4
9	1
11	3

x	$d_{9,x}$
4	4
2	2
8	3

x	$d_{2,x}$
5	3
3	1

x	$d_{3,x}$
8	2
4	3

x	$d_{8,x}$
6	5
7	1

x	$d_{7,x}$
12	5
6	4

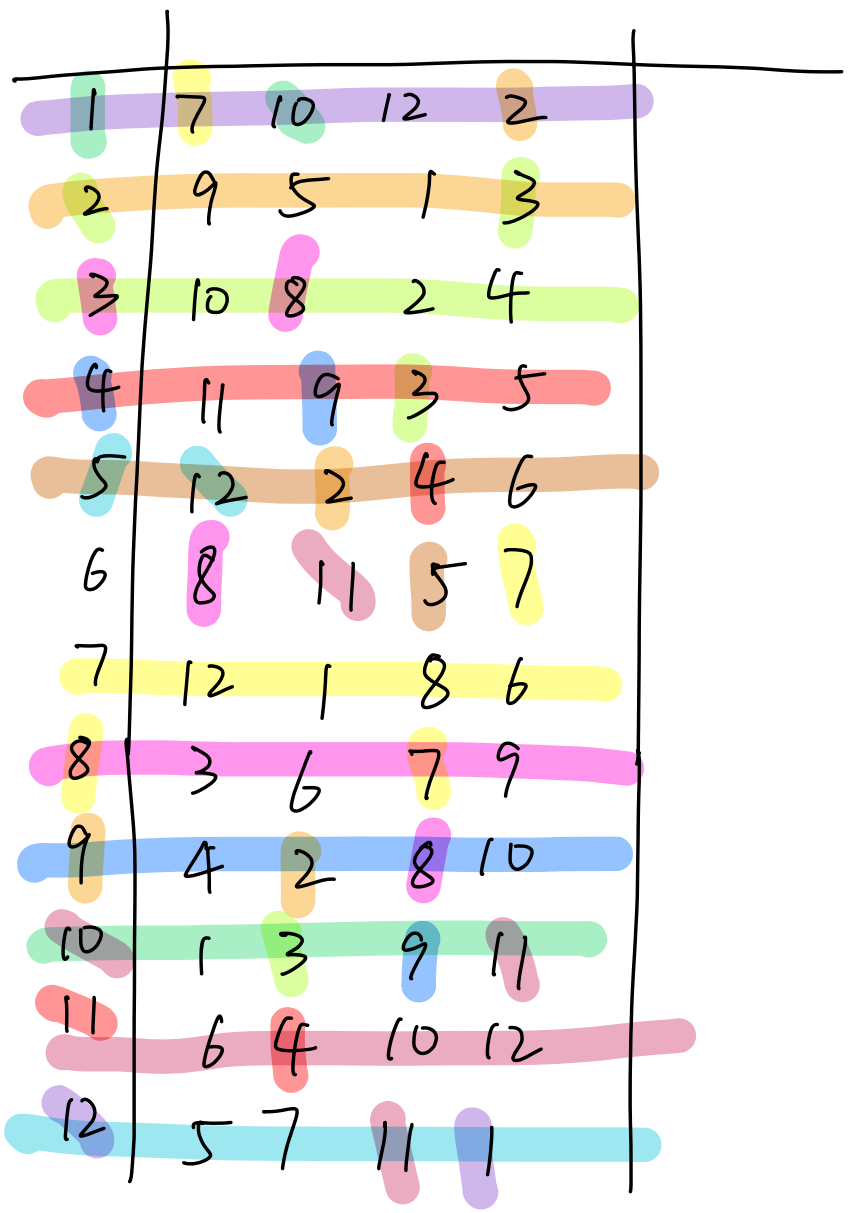
x	$d_{6,x}$
11	3
5	2

x	$d_{5,x}$
12	3
4	5

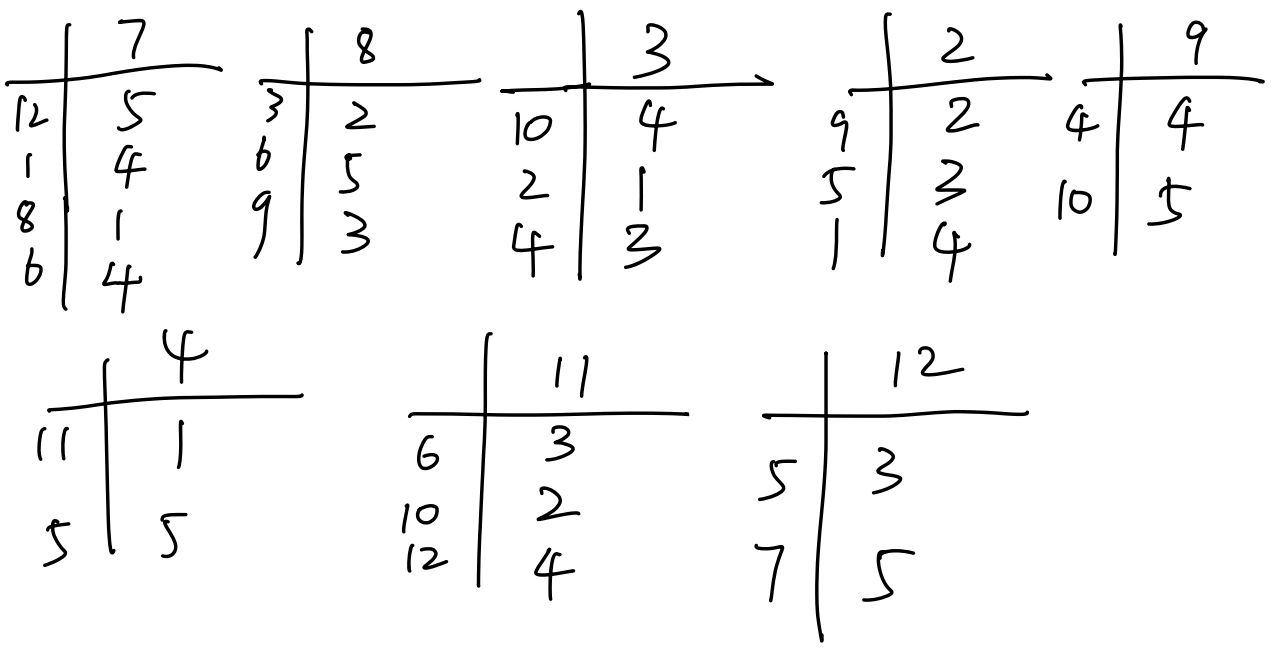
offspring5 1 10 9 2 3 8 7 6 5 12 11 4

⑫ offspring 6 : similar step!

skip



Choices	Element selected	Reason	Partial Result
7	7	offspring 6 start with 7	7
12 1 8 6	8	mini d	78
3 6 9	3	~	783
10 2 4	2	~	7832
9 5 1	9	~	78329
4 10	4	~	783294
11 5	11	~	7832941 1
6 10 12	10	~	7832941 1 10
1	1	only	7832941 1 10 1
12	12	only	7832941 1 10 1 12
5 7	5	~	7832941 1 10 1 125
6	6	only	7832941 1 10 1 1256


7
12 5
1 4
8 1
6 4
8
3 2
6 5
9 3
3
10 4
2 1
4 3
2
9 2
5 3
1 4
9
4 4
10 5
4
11 1
5 5
11
6 3
10 2
12 4
12
5 3
7 5

(13) cost computations

offspring1 7 12 9 1 10 3 8 6 11 4 5 2

offspring2 5 8 7 10 11 12 1 2 3 4 9 6

offspring3 5 8 7 10 11 12 1 6 3 4 9 2

offspring4 7 12 9 1 10 3 8 2 11 4 5 6

offspring5 1 10 9 2 3 8 7 6 5 12 11 4

offspring6 7 8 3 2 9 4 11 10 1 12 5 6

(14) greedy compute for each offspring

offspring1 7 12 9 1 10 3 8 6 11 4 5 2

$d_{i,j}$ 5 2 1 2 4 2 5 3 5 5 3

sum 37

offspring2 5 8 7 10 11 12 1 2 3 4 9 6

$d_{i,j}$ 4 1 3 2 4 4 4 1 3 4 1

sum 31

offspring 3: 5 8 7 10 11 12 1 6 3 4 9 2

$d_{i,j}$: 4 1 3 2 4 4 3 5 3 4 2

sum: 35

offspring 4: 7 12 9 1 10 3 8 2 11 4 5 6

$d_{i,j}$: 5 2 1 2 4 2 1 4 1 5 2

sum: 29

offspring 5: 1 10 9 2 3 8 7 6 5 12 11 4

$d_{i,j}$: 2 5 2 1 2 1 4 2 3 4 1

sum: 27

offspring 6: 7 8 3 2 9 4 11 10 1 12 5 6

$d_{i,j}$: 1 2 1 2 4 1 2 2 4 3 2

sum: 24

offspring	Sum of $d_{i,j}$	
1	37	
2	31	
3	35	
4	29	
5	27	✓
6	24	✓

So we choose offspring 5 and 6

(b) Pros & Cons

Pros ① Greater Diversity of Solutions

② Potentially Faster Improvement

③ Combine three methods pros

(1) PMX often preserves relative order of substrings nicely

(2) Cycle crossover systematically passes certain "alleles" in cycles

(3) Edge ~ preserve adjacency information

Cons

① increased computational cost per Pair

② Risk of Overfitting to the crossover stage

③ complexity of Implement and tune