Vehicle Routing Problem: Wisdom of Crowds using Genetic Algorithms

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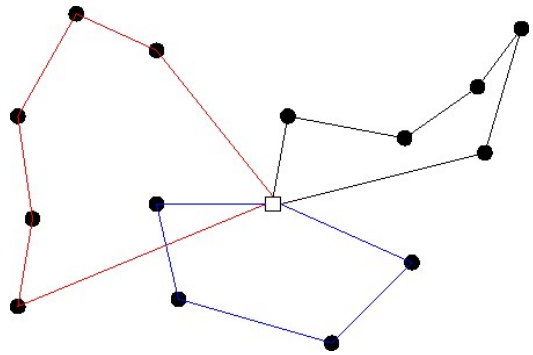
The Vehicle Routing Problem

First presented by George Dantzig and John Ramser in their 1959 publication, “The Truck Dispatch Problem”

A generalization of the Traveling Salesman Problem:

- There can be one more depots that serve a number of customers
- Each depot has one or more vehicles

The Goal is to minimize the distance traveled across all routes.

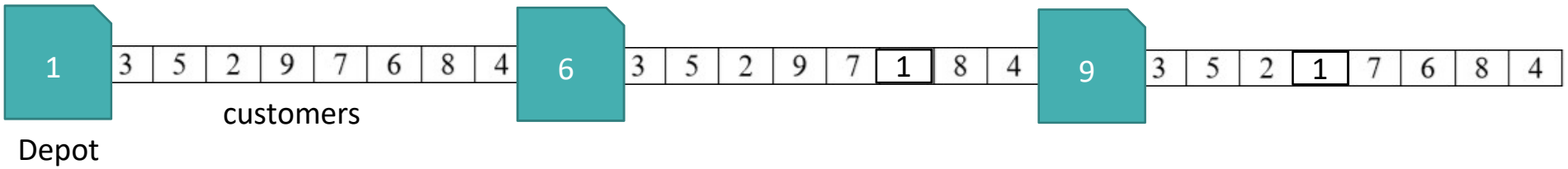


Approach – Genetic Algorithms

A population of chromosomes for the genetic algorithm were formulated as a list of depots represented as vertices with a list of customers, also represented as vertices.

Chromosome fitness is calculated as the total distance traveled across all depot's route.

3 Depots, 8 Customers per Depot



Route:
1,3,5,2,9,7,6,8,4,1

Route:
6,3,5,2,9,7,1,8,4,6

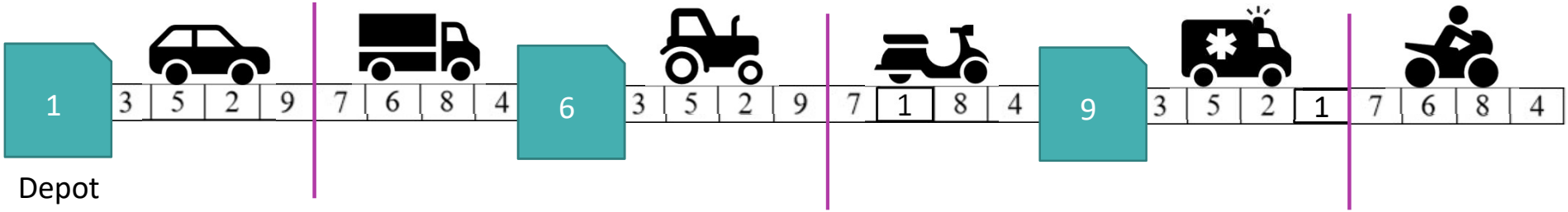
Route:
9,3,5,2,1,7,6,8,4,9

Chromosome Fitness= sum(Distance Traveled Per Route)

Approach – Genetic Algorithms

Vehicles were integrated into the formulation by redefining the fitness function.

3 Depots, 8 Customers per Depot, 2 vehicles per depot



Route: 1,3,5,2,9,1
+ 1,7,6,8,4,1

Route: 6,3,5,2,9,6
+ 6,7,1,8,4,6

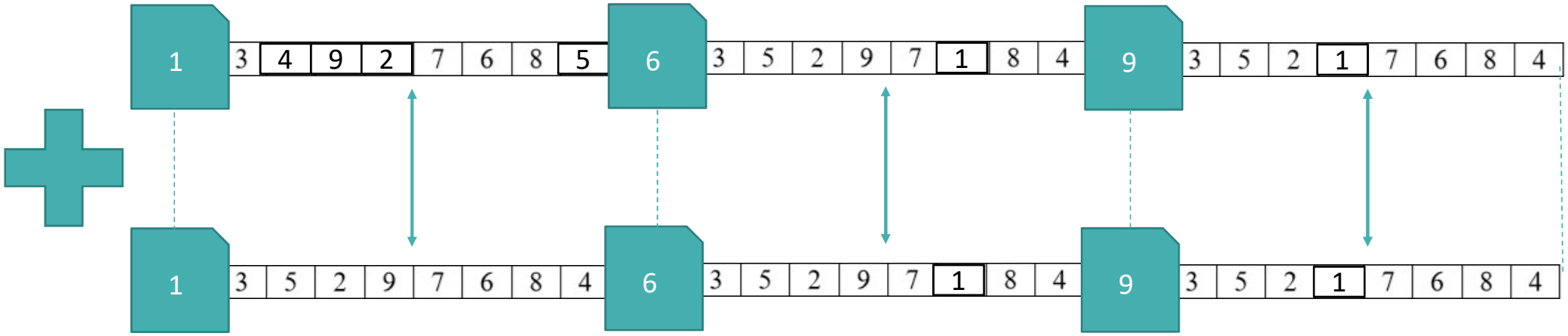
Route: 9,3,5,2,1,9
+ 9,7,6,8,4,9

Chromosome Fitness= sum(Distance Traveled Per Route)

Approach – Genetic Algorithms

An advance in the genetic algorithm's generation was defined as a sequence of crossover and mutation.

- These methods act on each route's customers separately agnostic of vehicle boundary lines.



Approach – Crossover Methods

Uniform

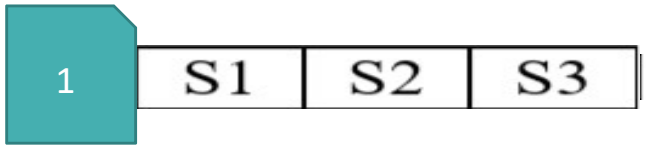
- Child is formed by randomly alternating alleles between the two parents.

Partially-Mapped Crossover (PMX)

- The parents are broken up into three sections of random length. The sequences S1 and S3 from parent 1 are copied to the child. S2 is formed by starting from S2 in parent 2 and leaping over genes that are already established.

Ordered Crossover

- The parents are broken up into three sections of random length. The sequence S1 from parent 1 and S3 from parent 2 are copied to the child. S2 is formed with the remaining alleles from parent 1.



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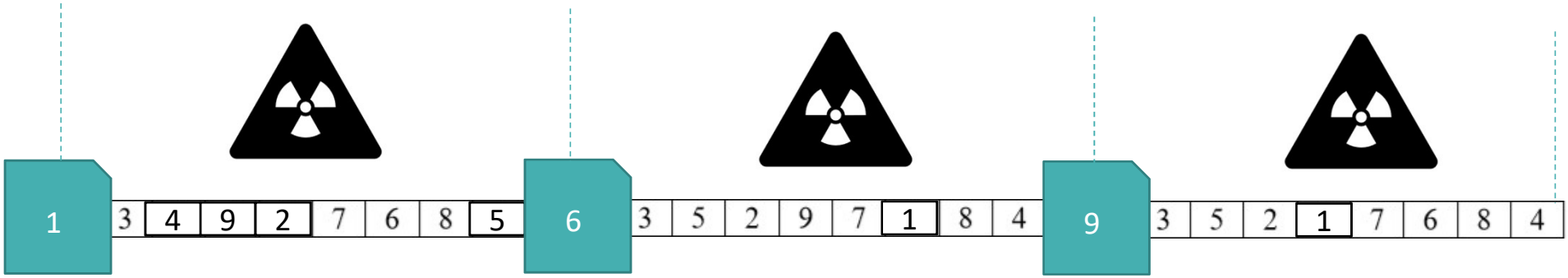
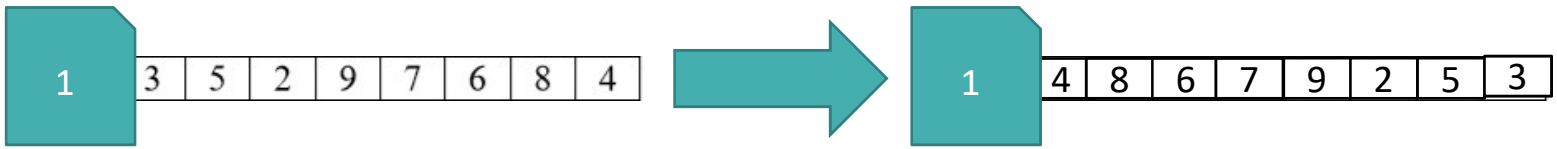


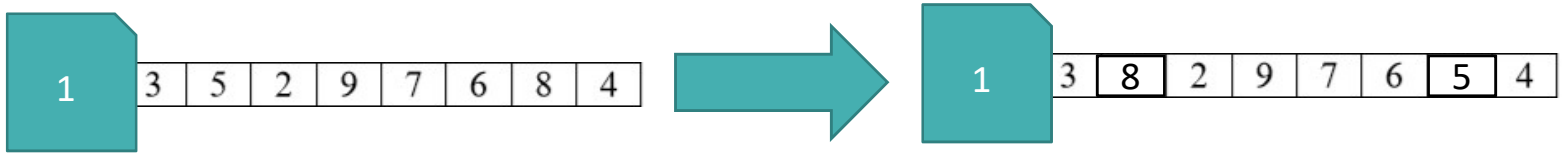
Approach – Mutation Methods

Reverse Sequence Mutation (RSM)



TWORS Mutation

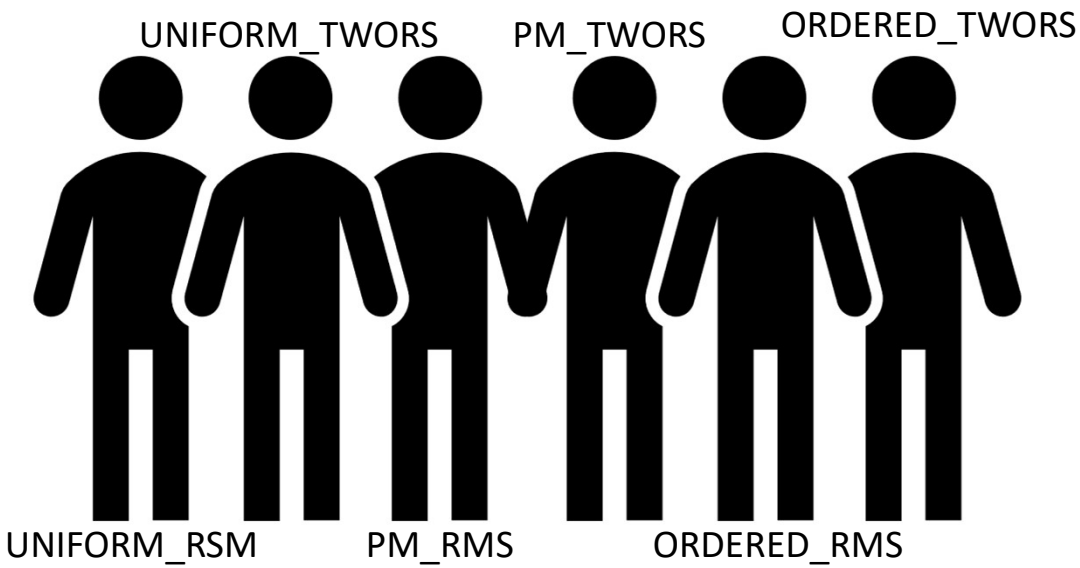
- Randomly swap two alleles



Approach – Wisdom of Crowds

A crowd was created from combinations of every implemented crossover and mutation methods.

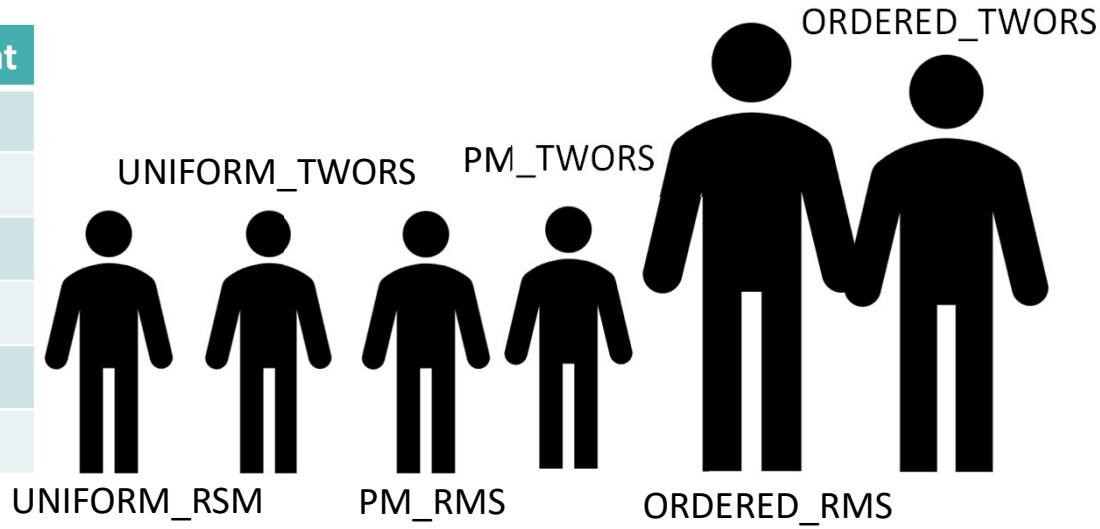
- Each genetic algorithm in the crowd shared:
  - population size
  - mutation probabilities
  - crossover probabilities
  - epoch thresholds



Approach – Wisdom of Crowds

Each algorithm ran agnostic of each other as a separate thread. Once all threads were completed, a predetermined set of weights was used to choose more of the best performing chromosomes from algorithms that historically performed better.

Crossover	Mutation	Crowd Weight
Uniform	RSM	0.05
Uniform	TWORS	0.05
PM	RSM	0.05
PM	TWORS	0.05
ORDERED_RSM	RSM	0.6
ORDERED_TWORS	TWORS	0.2



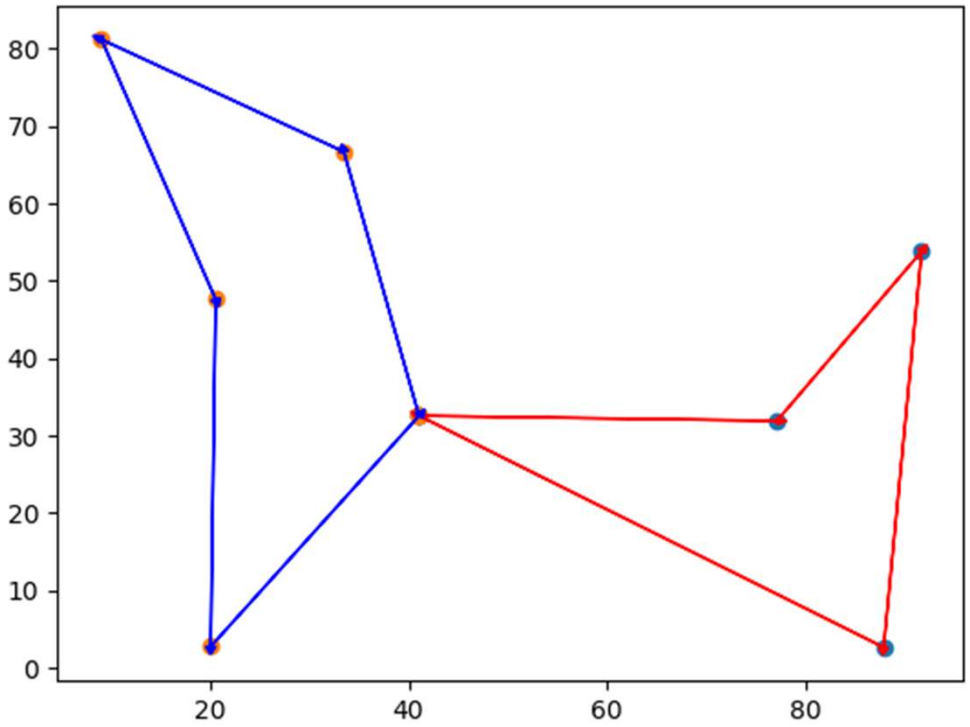
Approach – Wisdom of Crowds

Aggregation of the chromosome's solutions was done by surveying the adjacencies, or edges, of each allele.

The edges that occurred at least 3/10ths as frequent as the most frequent occurring edge were used in the final solution. This threshold value was referred to as the superiority threshold.

- If two or more edges were in the final solution with similar allele starting or end points, the edge with the highest frequency was chosen. If the frequencies were equal, the shortest edge was chosen.

Remaining unvisited vertices were chosen by selecting the closest unvisited vertex in distance to any vehicles route belonging to the same depot.



Results

Survey of 20 Tests (1 Depot, 20 Customers)

ALGORITHM	average result	average runtime	average comparison	tests better than average	Tests Surveyed	Percent Superior to Avg
GA_UNIFORM_TWORS	860.48	0.99	10.92	10	20	50%
GA_UNIFORM_RSM	874.73	1.02	25.17	4	20	20%
GA_PM_TWORS	871.60	1.00	22.03	6	20	30%
GA_PM_RSM	874.50	1.10	24.94	5	20	25%
GA_ORDERED_TWORS	862.47	1.18	12.90	8	20	40%
GA_ORDERED_RSM	866.80	1.00	17.23	5	20	25%
WisdomOfCrowds_GA	736.37	6.73	-113.20	19	20	95%
AVERAGE_FOR_ALGORITHMS	849.56	1.86	0	-	-	-

Survey of 20 Tests (19 Depots, 20 Customers)

ALGORITHM	average result	average runtime	average comparison	tests better than average	Tests Surveyed	Percent Superior to Avg
GA_UNIFORM_TWORS	16541.17	19.32	378.99	0	20	0%
GA_UNIFORM_RSM	16438.16	19.63	275.97	1	20	5%
GA_PM_TWORS	16520.75	19.43	358.56	0	20	0%
GA_PM_RSM	16496.21	18.64	334.03	0	20	0%
GA_ORDERED_TWORS	16431.53	19.41	269.35	2	20	10%
GA_ORDERED_RSM	16454.62	19.28	292.44	2	20	10%
WisdomOfCrowds_GA	14252.86	118.25	-1909.33	20	20	100%
AVERAGE_FOR_ALGORITHMS	16162.19	33.42	0	-	-	-

Findings

The Wisdom of Crowds solution performed better than the average of the genetic algorithms 97.5% of the time in tests surveyed.

Increasing epoch threshold, population size, crossover probability, or mutation probability improves each genetic algorithm's result at the cost of high runtime.

A lower superiority threshold yields a more optimal crowd solution at the cost of higher overhead during recombination.

Future Work

Run same tests with brute force solution to better understand how optimal the produced WOC solution is.

Implement a larger range of crossover methods and mutation methods from publications on genetic algorithms where order matters.

Isolate optimal hyperparameters through datamining a large number of tests.

Questions?

References

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