Optimization of vehicle routing problem using artificial bee colony algorithm

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Problem Statement

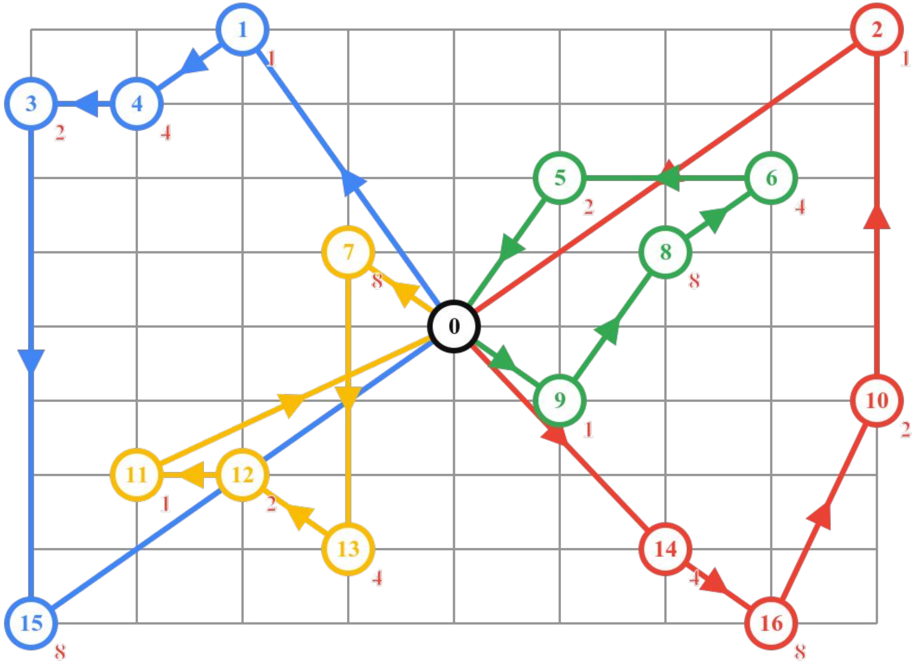
Capacitated vehicle routing problem(CVRP) is a combinatorial optimization problem which states as follows:

> “ *Find the optimal delivery routes for a set of vehicles to supply the set of customers with given demands minimizing the total cost of all the routes.* ”

Example

Number of vehicles: 4

Vehicle Capacity: 45



Computation complexity

Problem Size (Number of Nodes)	*Approximate Solution Time*
10	3 milli-seconds
20	77 years
25	490 million years
30	$8.4*10^{15}$ years
50	$9.6*10^{47}$ years

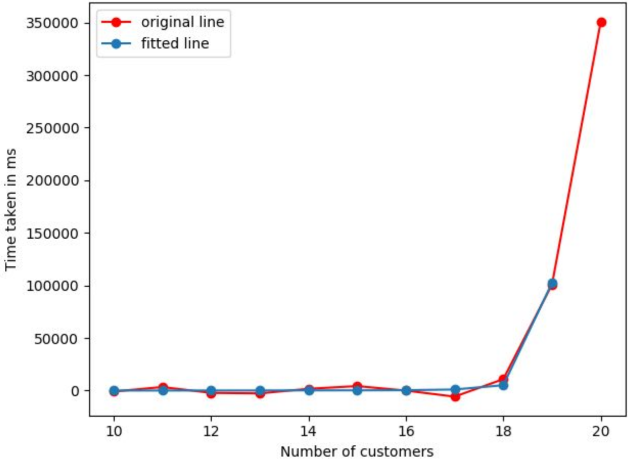
Software & Hardware

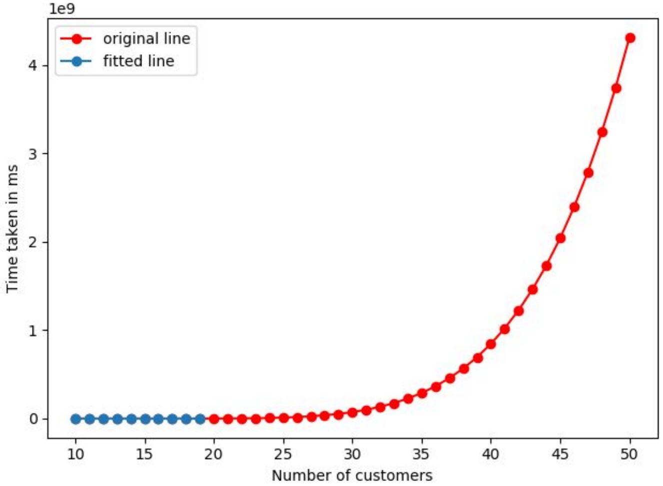
- **Software:**
  - Java
- **Hardware:**
  - Processor: Intel® Core™ i7-7500U CPU @ 2.70GHz × 4
  - RAM: 8 GB

Milestone 1

1. Finding dataset
2. Implementation of an exact algorithm

Milestone 1
(Optimized Exact algorithm)





Customers	Time taken(s)
10	5.0
11	12.0
12	29.0
13	51.0
14	146.0
15	209.0
16	238.0
17	273.0
18	5026.0
19	8447.0

Milestone 1 - Result

Nodes		Exact algorithm (Time Taken)	
Number of Nodes	**Optimal Answer**	**Brute Force**	**Optimized**
10	100	3 ms	5s
20	216	77 Years	4 Days
25	569	490 Million Years	122 Days
30	534	8.4xE15 Years	2 Years
50	741	9.7xE47 Years	136 Years

Milestone 2

1. Implement an approximate algorithm (Artificial bee colony algorithm)
2. Improve the performance of artificial bee colony algorithm

Artificial Bee Colony algorithm

- Artificial bee colony algorithm is based on the foraging behaviour of honey bees.
- Swarm intelligence algorithm.
- It’s a self organizing network.

Problem statement

There are 4 customers numbered from 1 to 4 and let depot be Node 0.

Distance Matrix

	0	1	2	3	4
0	0	2	31	4	12
1	3	0	12	4	5
2	5	9	0	10	11
3	3	2	12	0	4
4	13	7	10	8	0

Truck Capacity: 28

No. of trucks: 2

Demand

0	-1
1	12
2	8
3	20
4	9

Search Space

- Any combination of the nodes would be a potential food source.
- Possible food sources(states) in the above example with 2 trucks would be
  1. Truck1: 0 -> 1-> 2 -> 0; Truck2: 0 -> 3 -> 4 -> 0
  2. Truck1: 0 -> 1 -> 0; Truck2: 0 -> 2 -> 3 -> 4 -> 0

  Etc.

Phases

It is divided into 3 phases (3 types of bees):

1. Scout bees.
2. Employed Bees.
3. Onlooker Bees.

Scout Bee Phase

1. Scout bees are utilized to find the initial solutions
2. Scout bees go out and find FEASIBLE food sources.

   So according to the example:

   1. Truck1: 0 -> 3-> 4 -> 0; Truck2: 0 -> 1 -> 2 -> 0 ❌
   2. Truck1: 0 -> 1-> 4 -> 0; Truck2: 0 -> 2 -> 3 -> 0 ✅

3. The scout bee will find all solutions and save it in a queue.

Problem statement

There are 4 customers numbered from 1 to 4 and let depot be Node 0.

Distance Matrix

	0	1	2	3	4
0	0	2	31	4	12
1	3	0	12	4	5
2	5	9	0	10	11
3	3	2	12	0	4
4	13	7	10	8	0

Truck Capacity: 28

No. of trucks: 2

Demand

0	-1
1	12
2	8
3	20
4	9

Employed Bee Phase

1. In this phase the employed bees go out and explore the food source's neighbourhood found by the scout bee.
2. Take candidate set found by scout bee
3. Explore the neighbourhood of that set for better solutions
4. Two ways to do that
   a. Swap operator
   b. BMX operator

Swap Operator

	Truck1					Truck2				Truck3			
Before Swap	0	1	2	3	0	4	5	6	0	7	8	9	0
After Swap	0	1	7	3	0	4	5	6	0	2	8	9	0

BMX Operator

	Truck1					Truck2				Truck3		
Solution	0	1	2	3	0	4	5	6	0	7	8	9	0
shuffled	0	~~5~~	2	3	~~0~~	1	~~4~~	9	0	~~6~~	8	7	0
BMX	0	2	3	1	0	4	5	6	0	9	8	7	0

Employed Bee Phase

1. How do we know that the new solution found is better than the previous one ?
2. We use a fitness function that determines

Fitness Function

$$f(x) = c(x) + \beta * p(x)$$

where,

$$p(x) = \sum_{i=1}^{N} d_i y_{ik} - q_k$$

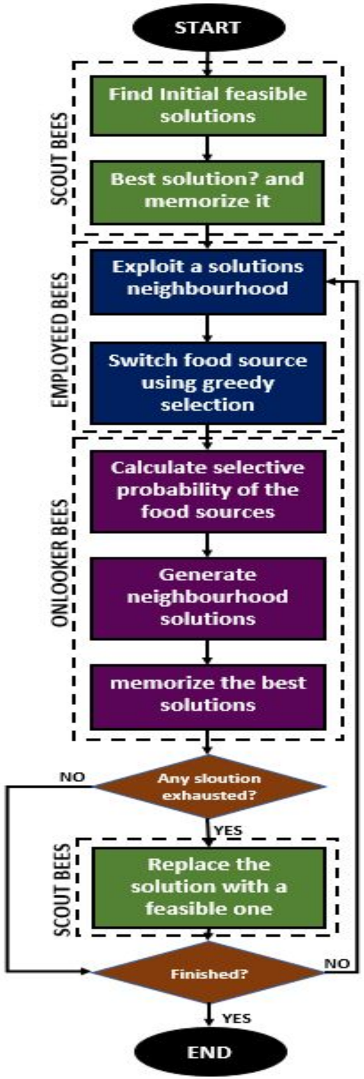
$$C(x) = \sum_{i=1}^{N} c_{i,i+1}$$

$$\beta = iteration\_index \times no\_of\_iterations$$

Onlooker Bee Phase

- The onlooker bees monitor the work that is performed by the employed bees
- After the employed bee phase all the employed bees come back
- And dance in front of the onlooker bees

Algorithm


START
SCOUT BEES
Find Initial feasible solutions
Best solution? and memorize it
EMPLOYEED BEES
Exploit a solutions neighbourhood
Switch food source using greedy selection
ONLOOKER BEES
Calculate selective probability of the food sources
Generate neighbourhood solutions
memorize the best solutions
Any sloution exhausted?
NO
YES
SCOUT BEES
Replace the solution with a feasible one
Finished?
NO
YES
END

Time taken

Nodes		Exact algorithm (Time Taken)		Approximate Algorithm (Swarm Size = 70) Iterations = 1500		
Number of Nodes	**Optimal Answer**	**Brute Force**	**Optimized**	**Approximate Answer**	**Avg. ans**	**Time Taken**
10	100	3 ms	5s	111	123	1000ms
20	216	77 Years	4 Days	224	231	1062 ms
25	569	490 Million Years	122 Days	654	671	1048 ms
30	534	8.4xE15 Years	2 Years	575	603	1125 ms
50	741	9.7xE47 Years	136 Years	884	925	1551 ms

Milestones

1. Milestone 1 ✅
   a. Finding dataset
   b. Implementation of an exact algorithm
2. Milestone 2 ✅
   a. Implement an approximate algorithm(Artificial bee colony algorithm)
   b. Improve the performance of artificial bee colony algorithm
3. Milestone 3
   a. Parallelize the artificial bee colony algorithm using GPU and CUDA
   b. Compare and contrast the run-time of all the implementations

Questions?

Thank you.