Optimization Approach for Capacitated Vehicle Routing Problem Using Genetic Algorithm

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Abstract— Vehicle Routing Problem (VRP) is a combinatorial optimization problem which deals with fleet of vehicles to serve *n* number of customers from a central depot. Each customer has a certain demand that must be satisfied using each vehicle that has the same capacity (homogeneous fleet). Each customer is served by a particular vehicle in such a way that the same customer is not served by another vehicle. In this paper, Genetic Algorithm (GA) is used to get the optimized vehicle route with minimum distance for Capacitated Vehicle Routing Problem (CVRP). The outcomes of GA achieve better optimization and gives good performance. Further, GA is enhanced to minimize the number of vehicles.

Keywords: Capacitated Vehicle Routing Problem (CVRP), Genetic Algorithm (GA), Random Generation.

I. INTRODUCTION

The Vehicle Routing Problem (VRP) can be defined as the delivering goods to a set of customer with known customer demands through minimum vehicle distance routes, starting and ending with the same depot. VRP is a combinatorial optimization problem and belong to NP problem. The VRP plays a vital role in distribution and logistics. VRP is one of the difficult tasks in operation research.

A client direct arrangement and grouping randomized without repeating for solving the minimum distance [1]. An additional method is also used to change in genetic algorithm for solving the optimal route [2].Another approach for solving minimum distance which limits on capacity using two layer chromosomes in genetic algorithm [3]. By comparing various algorithm, GA gives the nearest optimal solution [5]. In this paper, an attempt is made by changing the mutation operators in GA which subsequently gives the minimum distance for vehicle.

This problem has many applications in real life such as collection of household waste, delivering goods, school bus routing and public transportation. In addition, there is a cost component associated with moving a vehicle from one node to another. These costs usually represent distance, travelling time, number of vehicles employed or a combination of these factors. The goal of this problem is used to discover the optimal route for set of vehicles to minimize total vehicle travel distance and services to all customer.

Both VRP and CVRP use the same approach but only difference is in CVRP is vehicle capacity limitation. But CVRP needs the information about customer demand is known in advance. VRP and CVRP are used to determine the optimization problem.

There are many different types of vehicle routing problem such as capacitated vehicle routing problem (CVRP), vehicle routing problem with time windows (VRPTW), open vehicle routing problem (OVRP), pickup and delivery vehicle routing problem (PDVRP) and periodic vehicle routing problem (PVRP).

The rest of the paper is organized as follows: Section 2 describes the problem of CVRP. Section 3 gives the preliminaries. Section 4 gives the GA in CVRP. Section 5 presents the experimental results of CVRP and conclusion are given in Section 6.

II. PROBLEM DESCRIPTION

CVRP can be described as follows: In distribution centre, there are n number of customer to provide goods and m number of vehicles to serve for the customer. The vehicle capacity is denoted by q. Each customer demand is denoted by L (I=1, 2, 3… n), L<q. The customer node numbered is i(I=1,2,...,n) and the number of vehicles for the distribution centre is k(k=1,2,…,m). d_{ij} is the distance from customer i to customer j. Each vehicle can be visited exactly once by the customer who all begin and end at the same depot and satisfy the constraints as vehicle capacity limitation, running distance and number of vehicles. x_{ijk} is the vehicle k from customer i to customer j or otherwise zero.

$$\text{Min } \mathbf{X} = \sum_{i=0}^{n} \sum_{j=0}^{n} \sum_{k=1}^{m} d_{ij}\, x_{ijk} \qquad (1.1)$$

$$\sum_{i=1}^{n} L \le q \qquad (1.2)$$

The mathematical formula described as: (1) the objective function is used to minimize the total running distance of vehicle; (2) represents the customer demand is not greater than vehicle capacity.

III. PRELIMINARIES

Genetic Algorithms have been inspired by the natural selection optimization mechanism. One general principle for developing an implementation of genetic algorithms for a particular real word problem is to make a good balance between exploration and exploitation of the search space. The most well-known operators in genetic algorithms such as reproduction, crossover and mutation Hence, this paper proposes the genetic algorithms to provide a random search technique and has good performance through experiment. The genetic algorithm steps are following:

1 Initial random population
2 Evaluate the fitness
3 Select the best chromosome to reproduce
4 Crossover operator process
5 Mutation operator process
6 Pick out the best individuals for new population
7 Continue until termination condition is false

A. Chromosome Representation

The chromosome of solution to the CVRP is based on the population size. Using population size, the random generation is made to find out the optimal route for minimum distance value. Chromosome is represented as a group of gene. Gene is encoded as numbers. For example,

Chromosome 1	1 3 4 2 5 8 7 6 9
Chromosome 2	1 2 5 4 3 6 7 9 8

Table 1: Representation of Genes

B. Fitness Function

The fitness function assigns a numeric value to each individual in the population. The fitness function is always problem dependent. In this problem, the fitness function is the total cost of minimum distance, i.e., the length of each chromosome. The fitness function calculates the total length of each chromosome and summarizes the minimum distance value. Obviously, the smallest value is the best one for CVRP.

Fitness value=100/Total distance

C. Selection Operator

The individuals are selected according to the fitness value to produce the next generation. This is done by using the Roulette Wheel Selection method. The selected new chromosome or individuals can be presented for the new population without any changes and then selected parents are crossed over to form new generation.

D. Crossover Operator

The crossover technique which is used in CVRP is Partially Matched Crossover (PMX). In the PMX operations selects the two chromosomes randomly and exchange the two-point crossover. Then, modify the gene value according to mapping relationship to the gene value in crossover section. For example, consider two parents as PMX follows:

P1=1 2 /3 4 5 6/ 7 8 9
P2=5 4/ 6 9 2 1/ 7 8 3

Here, exchange the P1 and P2 as two point crossover. Then, the new child generation as,

C1=1 2 /6 9 2 1/ 7 8 9
C2=5 4 /3 4 5 6/ 7 8 3

According to mapping relationship of new child C1 and C2 gene value in crossover zone as,

3 ↔ 6 ↔ 1
9 ↔ 4
2 ↔ 5

Then, new generation of PMX as,

M1=3 5 6 9 2 1 7 8 4
M2=2 9 3 4 5 6 7 8 1

E. Mutation Operator

After crossover, the strings are subjected to mutation. Mutation includes random change in new crossover chromosome. Interchange Mutation is used to select two random positions in new chromosome and those positions are interchanged. For example, new chromosome as,

A=2 4 5 1 3 7 6 8

And take two random exchange points are 2 and 6. After mutation of two gene as,

A1=2 7 5 1 3 4 2 8

IV. GA IN CVRP

A. CVRP Model

The main objective of CVRP is to minimize the total cost. Each vehicle has exactly visited once in a path. The customer demand is not exceeding the vehicle capacity. For example, there are 8 customers and 2 vehicles. The vehicle capacity is 8. The random generating customer number is 2 4 3 6 7 8 5 1.

Vehicle1=depot-2-4-3-6-depot
Vehicle2=depot-7-8-5-1-depot

A. Flowchart for GA in CVRP

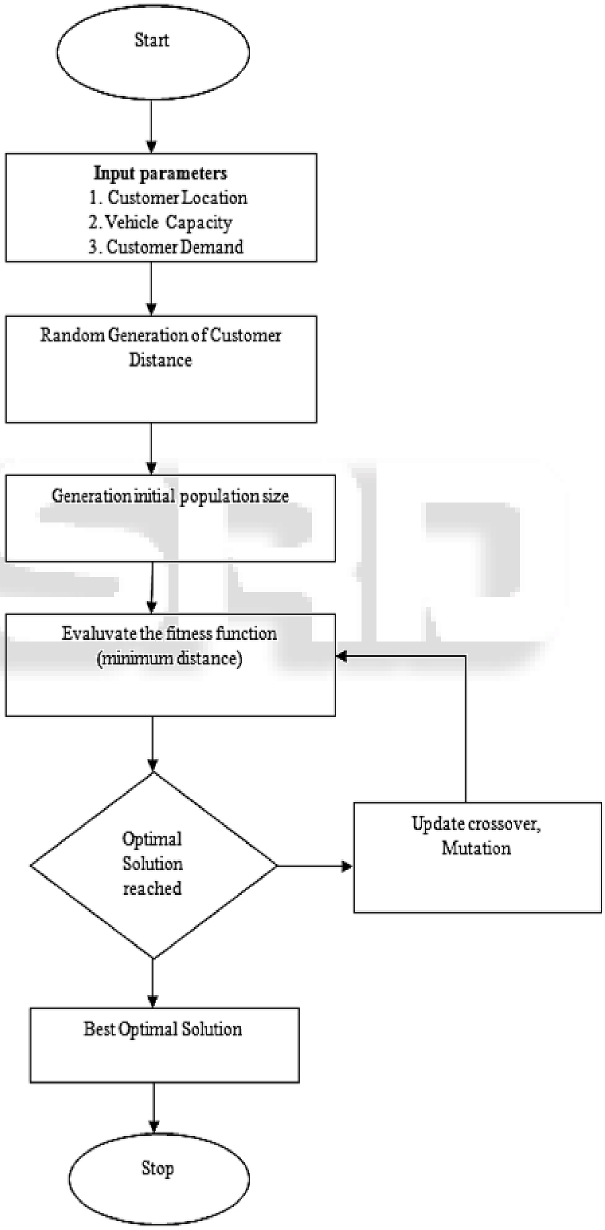

Fig. 1: Flowchart for CVRP in GA

V. EXPERIMENTAL RESULTS

GA is used in CVRP to get the nearest optimal solution. CVRP is implemented in MATLAB language and its program has easily developed language for random generation.

INPUT PARAMETERS
Number of Customers
Number of Vehicles
Customer Demand
Vehicle Capacity

Table 2: Input Parameters

Case1:
Test problem is to verify [1].
There are 8 customers and 2 vehicles in one distribution center. The loading capacity of each vehicle is 8t. The maximum running distance of vehicle is 50km per time.

Customer	1	2	3	4	5	6	7	8
Demand	1	2	1	2	1	4	2	2

Table 3: Customer Demand

The total running distance is 67.41km. But in this proposed paper, the total vehicle running distance is reduced as 43.94km.

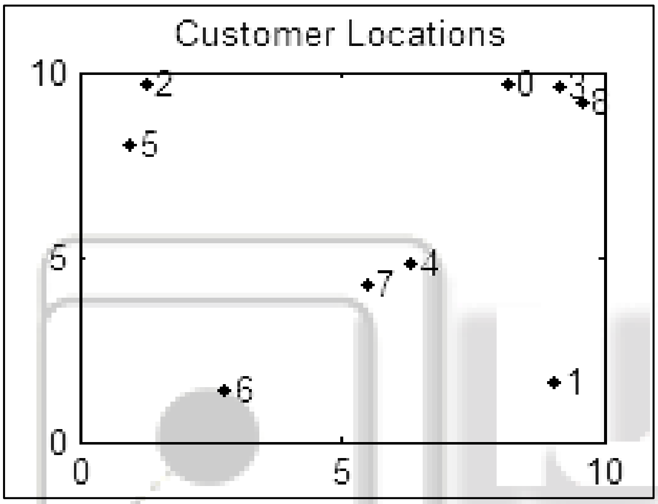

Fig. 2: Customer Locations

Distance Matrix is used to store the distance value of customer in random generation in the form of two-dimensional array.
The path of vehicle routing as,
Vehicle1=0-2-5-6-1-0
Vehicle2=0-7-4-8-3-0
Case2:
In this paper, another attempt is used to reduce the number of vehicles. Consider number of customers as 8 and number of vehicles as 3. The vehicle capacity limitation is 8t.

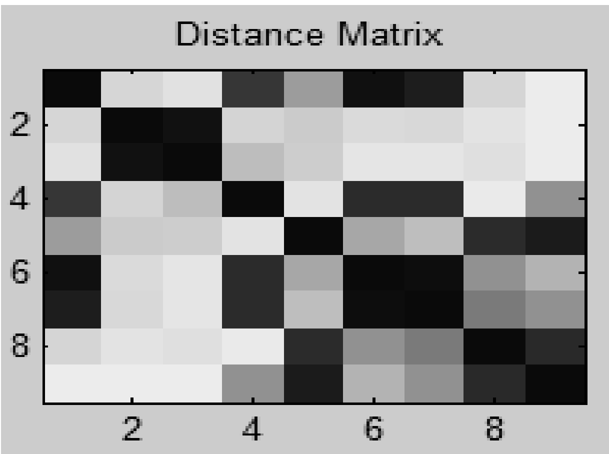

Fig. 3: Distance Matrix

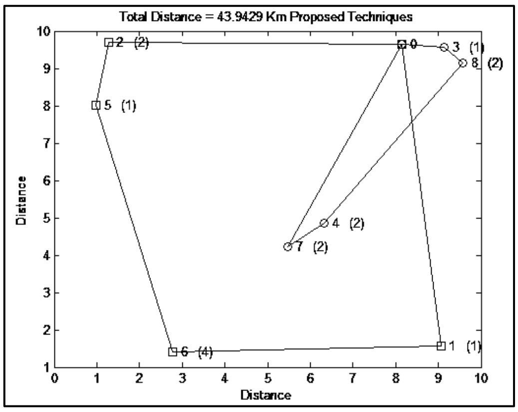

Fig. 4: Optimal route for vehicle

Customer	1	2	3	4	5	6	7	8
Demand	1	2	1	2	2	3	1	3

Table 4: Customer Demand

In existing system, three vehicles are used by the customer.

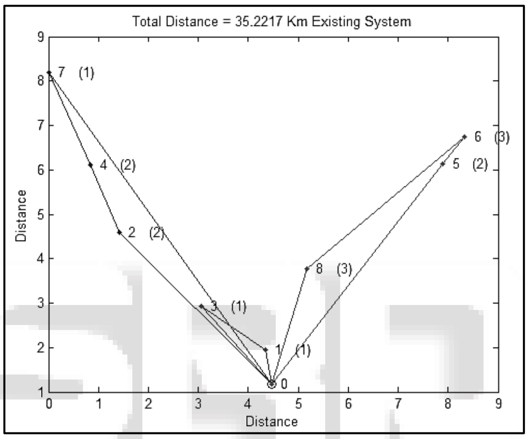

Fig. 5: Solution Method1

Vehicle1=0-8-6-5-0
Vehicle2=0-2-4-7-0
Vehicle3=0-3-1-0
The total running distance is 35.22km.
But in proposed system, number of vehicles is reduced. Each vehicle is checking the vehicle capacity. After completing vehicle capacity, its move to next vehicle, the best possible solution is follows:

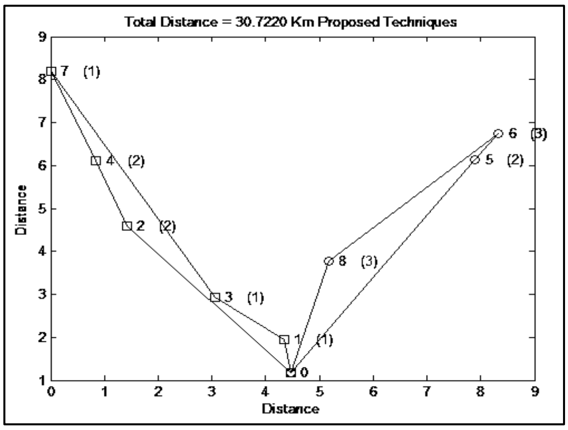

Fig. 6: Solution Method2

Vehicle1=0-8-6-5-0
Vehicle2=0-1-3-7-4-2-0
The total running distance is 30.72km.

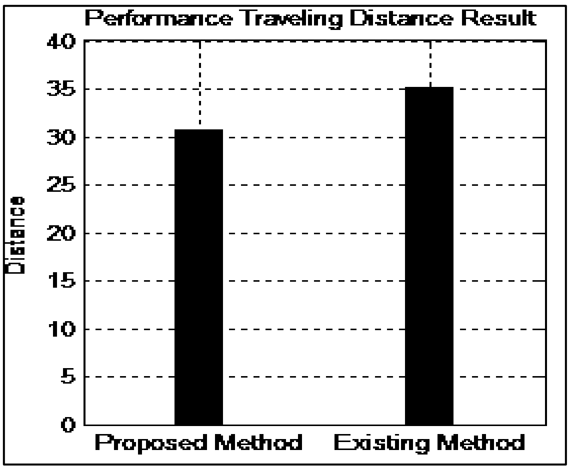

Fig. 7: Performance Travelling Distance

Judging from the two solution technique, solution method2 is better than solution method1.

VI. CONCLUSION

In this paper, GA is used to give the optimized solution in CVRP. Changes are made in population size and mutation operators and it gives the better optimal solution. It's clearly brought out in case1, the total distance is minimized by using interchange mutation operator. Further in case2, the number of vehicle is reduced by makes changes in genetic algorithm. The proposed system proves that GA is more efficient to find the optimal route for vehicles in CVRP.

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