Solution to Vehicle Routing Problem Using Genetic Algorithms

VISHNU MURTHY
Department of Computer Science and Engineering
GITAM University
Visakhapatnam, India – 530 045.

MANDA V ARUN KUMAR
Department of Computer Science and Engineering
GITAM University
Visakhapatnam, India – 530 045.

KONGARA JASWANTH
Department of Computer Science and Engineering
GITAM University
Visakhapatnam, India – 530 045.

ABHISHEK DUDI
Department of Computer Science and Engineering
GITAM University
Visakhapatnam, India – 530 045.

EVANA DINESH RAM
Department of Computer Science and Engineering
GITAM University
Visakhapatnam, India – 530 045.

Abstract—Vehicle routing problem is one of the most challenging areas of research in the field of combinatorial research. This problem is designing optimal set of routes for fleet of vehicles in order to serve a given set of costumers. Our project is mainly concerned about finding the optimized path between source and destination having several intermediate stages. We consider the problem in 2 regards: (a) Transportation View and (b) Personalized view. When coming to transportation, the goal is to maximize the income of the journey that is facilitating maximum people. The key objectives considered there is route constraint that limits the length of all feasible routes. When coming to the personalized view, a travel of a single person is concerned with the objectives like minimum cost, maximum mileage and so on. To implement this we are using GA which come under multi objective Optimization techniques (MOO). We choose to implement this because general conventional methods like heuristic search does searching sequentially, where are these methods are faster, parallel and even work on multiple objectives at a time and draw a feasible solution.

Keywords- Vehicle routing, Genetic algorithms, Multi objective optimization, traveling sales person problem

I. INTRODUCTION

The Vehicle routing problem (VRP) is a combinatorial optimization and integer programming problem seeking to service the number of customers with a fleet of vehicles. VRP is an important problem in the field of transportation, distribution and logistics. The Vehicle Routing problem (VRP) can be described as the problem of designing optimal delivery or collection routes from one or several depots to a number of geographically scattered cities or customers, subject to side constraints. The objective is to minimize the total distance travelled, travel time and minimize number of vehicles. The type of decisions involve assigning, routing and scheduling. Many methods have been developed for searching for good solutions to the problem, but for all but the smallest problems, finding global minimum for the cost function is computationally complex.

Solving VRP with traditional methods like branch and bound, dynamic programming and other methods have various disadvantages. Like dynamic programming is not feasible or more than 12 cities and whereas branch and bound give results to any number of cities but compared to new technologies it does not lead to better results. To combat this problem many techniques such as Genetic Algorithm, Ant Colony Optimization, Particle Swarm Optimization with Simulated Annealing, Differential Evolution, Harmony Search techniques are used. These methods lead to optimized results in polynomial time. The ant colony optimization algorithm (ACO) is a probabilistic technique for solving computational problems which can be reduced to finding good paths through graphs. A genetic algorithm (GA) is a search heuristic that mimics the process of natural evolution.

The Vehicle Routing Problem (VRP) is an NP-hard problem in combinatorial optimization studied in operations research and theoretical computer science. Given a list of cities and their pairwise distances, the task is to find a shortest possible tour that visits each city exactly once. Even though the problem is computationally difficult, a large number of heuristics and exact methods are known, so that some instances with tens of thousands of cities can be solved. VRP can be modeled as an undirected weighted graph, such that cities are the graph's vertices, paths are the graph's edges, and a path's distance is the edge's length. A VRP tour becomes a number of Hamiltonian cycles since for each vehicle few cities are allocated uniquely, and the optimal VRP tour is the shortest Hamiltonian cycles for the allocated cities for each vehicle accordingly. Vehicle Routing Problem can be implemented using different techniques such as genetic algorithm, Ant Colony Optimization, PSO with Simulated annealing etc., in less time. In this project we used Genetic Algorithm for this purpose.
We implemented the genetic algorithm on the dataset which consists of 53 cities and their corresponding cities.

The rest of the paper is organized as follows. Section II describes the literature survey. Section III describes the architecture flow. Result Analysis are performed in Section IV and Section V concludes the work and scope of the future work is discussed.

II. LITERATURE SURVEY

The Vehicle Routing Problem (VRP) is an NP-hard problem in combinatorial optimization studied in operations research and theoretical computer science. Given a list of cities and their pair wise distances, the task is to find a shortest possible tour that visits each city exactly once. Even though the problem is computationally difficult, a large number of heuristics and exact methods are known, so that some instances with tens of thousands of cities can be solved. VRP can be modeled as an undirected weighted graph, such that cities are the graph's vertices, paths are the graph's edges, and a path's distance is the edge's length. A VRP tour becomes a number of Hamiltonian cycles since for each vehicle few cities are allocated uniquely, and the optimal VRP tour is the shortest Hamiltonian cycles for the allocated cities for each vehicle accordingly. VRP is a NP-Hard problem and has been extensively studied. In this context, there is a great interest in efficient heuristics to solve it. The VRP has received considerable attention over the last two decades and various approaches are proposed to solve the problem, such as branch-and-bound, dynamic programming, genetic algorithms, and ant colony optimization and so on. Vehicle Routing Problem (VRP) in one of the most renowned problems in contemporary operations research. Informally, the goal of the problem is the make an optimal route for delivery of packages to customers who have specified when they will be available to receive their packages, paying attention to vehicle and package size and so on. Interest in the Vehicle Routing Problem grew rapidly after World War Two, with the increase in postal traffic, and catalog ordering of goods from a remote retailer. It falls under a broader category of transportation problems, which also include fleet management, facility location, traffic assignment, air traffic control etc. Vehicle Routing Problem has a historical and theoretical background in the Traveling Salesman Problem, both of which address the problem of finding a minimal cost route (usually described as the shortest route in terms of distance) within a predefined set of points, given a set of constraints. Among the number of solving methodologies which were explored in this project, Genetic Algorithms was examined in greater depth, and a genetic solution to the Vehicle Routing Problem is proposed.

A. Selecting a Template (Heading 2)

The Traveling Salesman Problem (TSP) can be stated as: given a finite number of nodes (cities) and the cost of travel between them (typically a function of their geographical distance), find the cheapest way to visit all the nodes and return to the starting one. TSP traces its origin to the so-called Icosian Game, invented in the 1880’s by the Irish mathematician Sir William Rowan Hamilton, in which a player should find the way to visit all 20 points of a two-dimensional representation of an icosaedar, without visiting any point more than once. What makes Traveling Salesman Problem so interesting is the fact that it is NP-Complete (solvable in non-deterministic polynomial-time). This means that for n nodes, the time T it takes for a non-deterministic (brute force exhaustive search) method to solve the problem grows faster than any power of n. This in effect means that some form of a heuristic solution in needed. Examples of NP-complete problems include the Hamiltonian cycle (named after Sir Wiliam Rowan Hamilton and Traveling Salesman Problem.

![Figure 1: Solution to Hamilton's Icosian Game, courtesy of Wolfram Research](image)

The largest solved instance of the Traveling Salesman Problem is a tour of 15, 112 cities in Germany. The computation was carried out on a network of 110 processors located at Rice University and at Princeton University. The total computer time used in the computation was 22.6 years, scaled to a Compaq EV6 Alpha processor running at 500 MHz. The optimal tour has a length of approximately 66,000 kilometers through Germany. The problem can be applied to many industrial applications, such as microprocessor manufacturing, transportation and logistics problems and so on. Vehicle Routing Problem (VRP) is one of the most important topics in operations research. It deals with determining least cost routes from a depot to a set of scattered customers. The routes have to satisfy the following criteria (a) Each customer is visited exactly once (b) All routes start and end at the depot and (c) Sum of all demands on a route must not exceed the capacity of a vehicle.
VRP is closely related to TSP, as soon as the customers of the VRP are assigned to vehicles, the problem is reduced to several TSPs. Based on the following two criteria:

- Whether the vehicle is capacitated or uncapacitated (is there a limit on how many passengers or objects the vehicle can take at any given time)
- Whether it has one or more starting points (does the vehicle pick passengers or objects from a central location (i.e. a bus terminal, or a warehouse), or the pick-up can occur on a number of places).

Many-to-many problems with capacity constraints are typically the most difficult ones because pick-up and delivery locations must be located on the same line, and the pick-up point must precede the delivery location. Dial-a-ride Problem (DARP), also known as Stacker Crane Problem (SCP) comes in two flavors depending on whether the vehicle is allowed to leave objects on intermediate locations and later pick them up and deliver them. DARP arises in several practical applications [3] such as transportation of elderly or disabled persons, tele-buses and shared taxi services. Courier and Repair Services should be contrasted to the Traveling Salesman Problem with Time Windows with respect to that the service must not immediately follow the request. Instead, time windows would be specified by a central planner in order to minimize the route cost. Another specific of the Repair Services is that the service time is a significant portion of the total schedule time.

Vehicle routing and dispatching problems are topics of a great deal of ongoing research in the operations research community since the late fifties, reflecting VRP’s central role in distribution management. According to one classification, proposed by Fisher [4], vehicle routing methods fall into three categories:

- Simple heuristics based on local search and sweep, developed mostly in the ’60 and ’70.
- Mathematical programming based heuristics, which approximate VRP with generalized assignment and set partitioning problems.
- Exact optimization (K-tree, Lagrangean Relaxation) and artificial intelligence methods (Simulated Annealing, Tabu Search, Ant System and Genetic Algorithms).

The algorithm used in this project falls under the Genetic Algorithms category.

The two steps in our project are:

1. A comparative study of implementation of TSP using Branch and Bound, Genetic Algorithm and Dynamic Programming. We did this step to prove GA is more feasible approach compared to other two techniques in implementing TSP. As VRP is nothing but the multiple TSP, so implementing TSP effectively with GA in turn leads to efficient implementation of VRP as well.
2. Preprocessing the dataset so as to obtain the distance matrix.
3. Implementing TSP using GA.
4. Implementing VRP using GA.

III. PROBLEM ANALYSIS

The Vehicle Routing Problem (VRP) is an NP-hard problem in combinatorial optimization studied in operations research and theoretical computer science. In the Vehicle Routing Problem, a set of cities is given and the distance between each of them is known. In more formal terms the goal is to find the optimal distance with minimal length on a fully connected graph. Solving Vehicle Routing Problem by Dynamic Programming, Branch and Bound approach has disadvantage of exploring all paths. If there are n paths, by using Dynamic programming, O(n^2) time complexity exists. To combat this problem evolutionary Techniques such as Genetic Algorithm, Ant Colony Optimization, particle Swarm Optimization are developed. Evolutionary techniques are the latest trend in the field of computers which are inspired from the natural evolutions like behavior of ants in travelling in optimal path for fetching their food, working of genes and their inheritance to the future generation etc., These work excellently well in drawing the optimal results to any kind of the problem. Among them one is Vehicle Routing Problem. Solving Vehicle Routing problem using Genetic algorithm involves steps of population creation, fitness evaluation, cross over and mutation. Population was created as paths for Vehicle Routing problem. The paths with least cost is selected for cross over and mutation operation. The cross over technique used is 2 point cross over. Mutation involves simple exchange
of cities. The above mentioned operations are performed until termination condition is met.

**GENETIC ALGORITHM FOR SOLVING TRAVELLING SALESMAN PROBLEM**

1. N ← Read no of cities  
   Let it be 5
2. Pop Size ← Read the Population size  
   Let Popsize be 10
3. Read cost matrix. 
   
<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>10</th>
<th>20</th>
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<td>40</td>
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</tr>
</tbody>
</table>
4. Initialize population of size Pop Size  
   a. Chromosomes[i] ← call chromosome function
6. Initialize mutation percent, countsame ← 0
7. oldcost ← 0, iteration ← 0
8. While (count same < 100)
9. For i=0 to favored pop size do in steps of 1  
   cmother ← chromosome[i]
   a. Father ← select random chromosome from population  
   b. Perform cross over and mutation operation  
10. Sort the chromosome array  
11. Thiscost ← Chromosome[0].getCost();  
12. if (thiscost = oldcost)  
13. write cost, iteration, time of execution  
14. Stop

**IV. ARCHITECTURAL DIAGRAM**

![Architecture Diagram](image-url)

*Figure 3: An architecture diagram.*
V. RESULT AND ANALYSIS

<table>
<thead>
<tr>
<th>No. of Cities</th>
<th>Branch and Bound</th>
<th>Dynamic Programming</th>
<th>Genetic Algorithm</th>
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<tr>
<td>53</td>
<td>10657</td>
<td>-</td>
<td>7207</td>
</tr>
</tbody>
</table>

City Locations

Distance Matrix

Total Distance = 55,8406

Best Solution History

Total Distance = 55,8406, Iteration = 2543
VI. CONCLUSION AND FUTURE SCOPE

From the above observations it is observed that the Genetic Algorithm gives the best result for most of the times for our own created data set. We have taken into consideration the number of iterations and also the time taken for execution. Thus we can conclude that the Genetic Algorithm gives the best result for most of the problems. From the above observations it is observed that the Dynamic Programming gives the best result for most of the times but for only less number of cities. As the number of cities increases the output is not at all obtained. From the observations it can be observed that Genetic Algorithm gives a better result when compared to Dynamic Programming. Implementation of VRP using GA also gave better and optimal results.

In this paper, we implemented the VRP problem using Genetic Algorithm. In future we would like to explore our algorithms are working for well-known Vehicle Routing Problem data set. In future we would also like to solve Vehicle Routing Problem using many other evolutionary algorithms like Ant Colony optimization, particle Swarm Optimization and so on.

VII. REFERENCES


