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RESEARCH ARTICLE

AN APPROACH FOR VEHICLE ROUTING PROBLEM USING GRASSHOPPER OPTIMIZATION ALGORITHM AND SIMULATED ANNEALING

Sunil Boro and Santosh Kumar Behera

Student, Department of Computer Science and Engineering, Indian Institute of Information Technology, Pune, India.

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Abstract

This paper is focused on the study of the basic problem of the vehicle for reducing the cost factor and increasing efficiency of the solution. Features and constraint uses some capabilities of the algorithm used to modify it dynamically between the nodes and depot. This is demonstrated with a feasible schedule for every node and minimizes the total cost as much as possible. The analysis is based on the address of the given model and solution procedure. The purpose of this research paper is to provide examples of models and applications which include the profits, extensions and partitioned features. The objective is to minimize the traveled distance that visits every subset of nodes one after another while maximizing or satisfying a minimum collected profit from each visited node. The concepts of VRP are discussed in Section I and the issues discussed in paper are in Section VI. Section VI also contains the modeling aspects and constraints that can be used in solving VRP in this paper. Simulated annealing and grasshopper optimization algorithm are combined for solving vehicle routing problem as discussed in Section VII. This study investigates both the variants of algorithm for the clustering nodes and different methods for the generation of routes to overcome optimal VRP solution. In conventional grasshopper algorithm, shortest path for certain node that starts from center depot is calculated by means of local search algorithms. Few methods such as ant colony optimization and genetic algorithm are considered for the route optimization. We can compare the performance of these methods to solve the VRP. Therefore, performance of the proposed method is able to produce better solutions than the other methods which reveal a large number of benchmark experimental results and is very promising.

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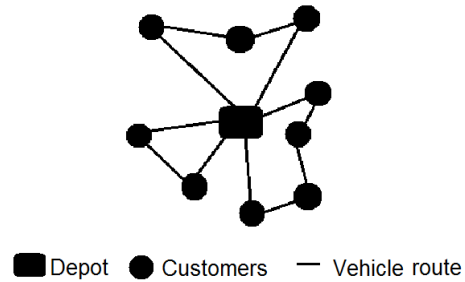
Introduction:-

Delivery of customer's goods and increased production needs to improve the modern logistics so that the products can be delivered more quickly and efficiently. However, the vehicle routing problem (VRP) has been in research for a long time in literature. Further, more new demands and solutions are growing every day in considerable demands on certain resources. The movement of customer's goods is the main objective of every industry that looks for optimal way for making transportation more efficient. Current researches concentrate on all the optimal algorithms

Corresponding Author:- Sunil Boro

Address:- Indian Institute of Information Technology, Pune, Maharashtra, 411048, India.

that are capable of finding high quality solutions in short period of time. To be applicable in real life, the problem instances are being characterized by vehicle fleets and thus affect modern logistics and distribution strategies.



The isolated Vehicle Routing Problem (VRP) generally looks for a set of routes at a minimal cost to find the shortest path and to minimize the number of vehicles for satisfying the demand of all the nodes. Exactly one location of each group in the consideration must be serviced. The VRP can be defined as the problem of designing least cost delivery routes from a depot to a set of geographically dispersed locations (customers) subject to a set of constraints. The isolated VRP is also classified as an NP-hard problem. However, the optimization problem of VRP deals with linear constraints and objective functions. It consists of multiple depots and few operational issues such as loading constraints for the specified models.

VRP is a supply of methods and approaches which aims to identify the minimal cost efficiency to fulfill all the nodes at its minimum cost from the start to end in the depot. The challenging approaches are dependent on the different capacities and costs of the vehicles. The optimization of VRP is essential to forward the goods to the final customers under the best conditions of cost and time. This real-life problem can be solved by various approaches and methods and are characterized by multiple capacities and multiple objectives.

Capacitated Vehicle Routing Problem (CVRP) is one of the variants of the vehicle routing problem where the development of modern logistics is to find optimal way from depot to nodes while also considering the capacity of vehicles which can reduce or increase the efficiency of products delivered. Capacity constraint is also optimized to reduce the cost of transportation of customer goods.

Vehicle Routing Problem with Time Windows (VRPTW) is generally (Non Polynomial hard) NP-hard problem. The main objective of VRPTW is to provide service to a given set of nodes within predefined time period and minimizing total cost. Also it should not violate capacity for each vehicle and other constraints. Some important methods used to solve the VRPTW are ant colony optimisation algorithm (ACO), genetic algorithm (GA) and evolutionary algorithms (EA).

In this paper, simulated annealing and grasshopper optimization algorithm are combined for solving vehicle routing problem. The vehicle routing problem concept is decomposed and studied in depth so as to apply the grasshopper optimization model, in which one grasshopper is presented as vehicle and load all tasks. When all the nodes are classified, one grasshopper goes from a depot to all nodes and returns to depot. Then, grasshopper algorithm, which is used to improve genetic algorithm, can further overcome to the global optimal quickly. The proposed model can therefore obtain the optimal solution in a shorter period of time.

Mathematical Form:-

In this section, the mathematical formulations will be discussed. However, the nature-inspired algorithm used to solve this problem has been described in VRP model.

The optimization of basic VRP uses decision variable and binary variables to indicate the vehicle travels between two nodes for a solution. The formulation of movement of decision variables combines constraints and vehicle routes. The objective of the model is to minimize the total operating cost as well to optimize the solution procedure.

This mathematical formulation is expanded on a formula where customer is represented by a cluster of vertices, one for each depot. The isolated VRP is defined as: Let $G = (V, A)$ be a directed graph, where $\{V = \{0, \dots, n\}$ is the vertex set V , $i \neq j\}$ and A is the arc set. Vertex 0 and $A = \{(i, j): i, j$ represents the center depot and the remaining

vertices correspond to customers. A fleet of m vehicles of fixed capacity is further based at the center depot. The fleet size is a decision variable or is given a priority. Therefore, each node has a non-negative demand. Suppose position of each vehicle is denoted by X_i , V_i represent social interaction, i.e., path from certain node to neighboring nodes, G_i denotes remaining time required for completing the journey and T_i represent direction of next node. Then,

$$X_i = V_i + G_i + T_i$$

This is the basic formula for Grasshopper Optimization Algorithm which describes the behavior of grasshopper in environment. Then comes the probability function of Simulated Annealing algorithm which is used to select the right solution with help of probability of accepting.

$$P(X_i) = 1 - \exp(-\Delta E / kT)$$

It's Applications:

In order to reduce the complexity of the problem, all nodes must be visited. VRP can be related to cost and balance, node activity and few resource conflicts. Therefore, minimizing the number of vehicles, i.e., only one vehicle can be used for delivery at a particular place. However, the delivery of orders to customers is dispersed in a certain geographical region. Serving from a central distribution center can also be done reducing the capital reduction, i.e., the investment and fixed costs.

Vehicle routing problem (VRP) forms an integral part of supply chain management, which plays a significant role for productivity improvement in organisations through efficient and effective delivery to customers. The VRP is so widely studied because of its wide applicability and its importance in determining efficient strategies for reducing operational costs in distribution networks.

Issue in the Current Research:

In this section, we describe the issues and the evaluation method related to formulated research. By reviewing researches, we found that a considerable amount of some researches on VRP models and corresponding algorithms has been already proposed in the literature and developed the optimal vehicle routing solution procedure. Algorithms include such as An Ant Colony Optimization Algorithm [5], A Genetic Algorithm Approach [4], an adaptive Large Neighborhood Search (LNS)[5] and Simulated Annealing (SA) [8].

J. Gromicho, S. Haneyah and A.L. Kok have published a research article for solving a Real-Life VRP heuristically in combination with an exact algorithm. In their article, [1] they have formulated an algorithm to solve VRP with Inter-Route and Intra-Route Challenges. At the central depot if it gets request from two nodes at opposite sides of a region asking for delivery when only one vehicle is available at the depot, then the cost of transportation is high. However, no computational experiments are reported.

Literature Review:-

However, the literature of the Vehicle Routing problem is therefore very large. A number of variants of problems appeared in the literature.

Dantzig and Ramser (1959) raised the problem of transport, where it was considered as a generalization of the Traveling Salesman Problem. Then the first article in which the phrase "Vehicle Routing" appeared in 1972 is written by Golden Et Al.

David H. Marks and Robert Stricker (1971) then presented a model for routing public service vehicles. In 1987, Solomon then introduced constraints of time-windows into Vehicle Routing Problem (VRP). Further now, newly developed algorithms are used to solve VRP and finding optimal solution every way.

J. Gromicho, S. Haneyah and A.L. Kok (2012) have developed construction and improvement for VRP based on thorough study in the problem. In their publication they considered the Inter-Route and Intra-Route Challenges. In the paper, the use of intra-route is being discussed. Three challenges were discussed by [1] to solve VRP: (a) unmatched pickup and delivery, (b) case of central depot with some, and (c) priority of orders can be low and high.

Wan Amir FaudWajdi Othman, Syed SahalNazliAlhady and Haw Ngie Wong have solved the VRP [5], the authors presented with an ant colony algorithm for the exact solution of the VRP. They formulated the solution of finding the minimum number of vehicles required to visit all the respective nodes. Stopping criteria and four control

parameters were outlined in their research. Their overall performance of the VRP are successfully conducted and the promising solutions for instances are optimized within a short period of time frame in an efficient manner.

Problem description and modeling aspects:

This paper deals with the computation time required for VRP's, i.e., to find the optimal path for vehicles travel path in a smaller number of operations. In variety of e-commerce platforms, the delivery of products requires quick computational algorithms. VRP has a central depot from where the products are delivered to nodes at different places. We see this problem using a real-life example.

Food delivery service from a certain hotel over a region by small number of delivery-boys. Each delivery-boy can take few orders at once over a sector in the region. Now, if a delivery-boy gets order for over two nodes which are at opposite sides of the region, it's very hard to get delivery quickly.

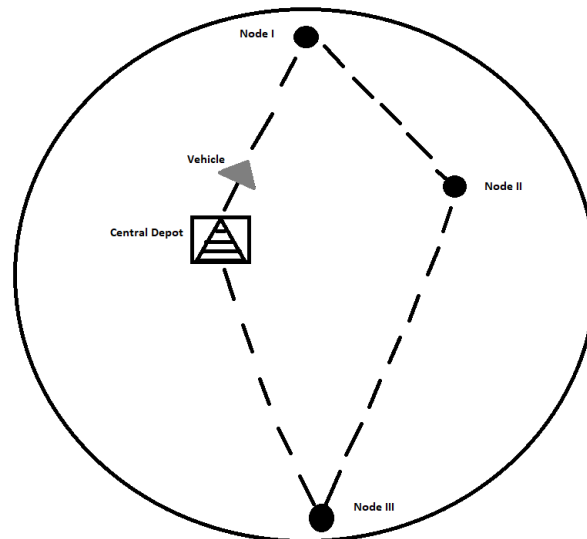


Figure 1:- Representation of first issue.

The vehicle a have to travel over almost two times the diameter (longest distance) as shown in *Figure 1*. This represents the first issue that is discussed in the paper. This causes unnecessary distance and time spent by the vehicle, ultimately increasing the cost of product and decreasing the quality of service. We introduce a time constraint which checks the time necessary for reaching one node to another. If any other vehicle can arrive at the depot and deliver the product earlier than the product is not given to the first vehicle. This requires simple time calculation algorithm which calculates the time required for each vehicle to complete the given task.

Second issue is about multiple visits to the same location by same vehicle or different vehicles on same journey. There are some such visits that can't be avoided but most of the visits maybe unnecessary.

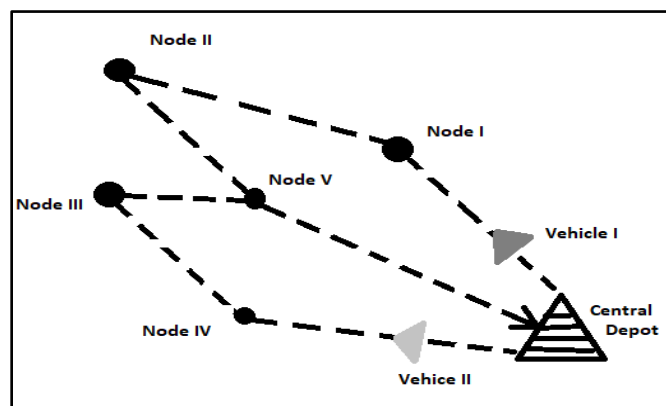


Figure 2:- Representation of second issue.

Also, if two vehicles are crossing each other at some node at same time, it is seen as un-optimized solution. This happens when products for one node can't be carried by single vehicle if it is carrying product for other nodes too. In *Figure 2* you can see the *Node V* is being visited twice by different vehicles. This can be minimized if one of the two vehicles would have carried all products of Node V itself.

Solution Approach:

This paper proposes a mixture of LNS heuristic approach and random solution optimization approach, for solving this problem. We solve the issues by adding constraints later. First, we check for the solution for optimizing VRP problem.

The solution for VRP optimization consists of different heuristic methods that are used in Simulated Annealing (SA) and Grasshopper Optimization Algorithm. We will be discussing these methods and how they are helpful.

- **Construction:** A random solution is first constructed over the model of VRP. Here the minimum path distance of each node from the depot is calculated which can be visited by different vehicles.

- **Local Search (LS):** We use some classic heuristics search methods such as 2-opt, relocate and exchange. These are used in the order as: 2-opt -> relocate -> exchange. 2-opt is the initial search method which inserts possible routes into the model. Then the path created by random solution it further optimized using Grasshopper algorithm. Then paths are relocated later if necessary or exchanged if other driver could do the job more efficiently. This is done till we get the best probability index in the Simulated Annealing method, which satisfies the optimal solution.

There are certain extra-functions that helps in solving for the two issues discussed in the paper. First issue says that if only one vehicle is at depot and the order is from very two opposite side of a region, then how to manage optimality. Second issue regards to multiple visit to same node by different vehicles or same vehicle in a journey. We describe the solution of the above problems now.

- **Time Calculation:** We introduce a time constraint that helps to determine the time required for a vehicle to deliver and return to depot. This calculation is based on Grasshopper algorithm in which the time for each grasshopper to return is calculated. The minimum time taking grasshopper is allowed to continue its journey (assigned as a vehicle). In case for first issue, the time required for the driver complete the journey to two opposite ends of a region is calculated. Also, the time required for any other driver reaching depot and delivering the good to one end is also calculated. If the answer is positive, i.e., the other driver can deliver good earlier to any one node, than the goods for that node is not dispatched with the available driver.

- For the second issue, we introduce a constraint that keep track if a node will be visited by a vehicle in a single journey or not visited. If node is visited then 'visit' is equal to 1. For nodes with 'visit' 1 are most likely to repel any other visits by other vehicle or same vehicle. Instead of visiting the same node the vehicle is made to take a different route instead of visiting the same node. But still if any other route cannot be taken than the vehicle may access the node.

Conclusion:-

The solutions to the approach for Vehicle Routing Problem is described and elaborated. We have described each section independently which is linked with the exact quality performances. The feasible solution to the formulation of optimal solution of the methods has been discussed.

Since, swarm intelligence optimization algorithm like the Grasshopper Algorithm is more efficient to find the optimal solution, the contributions to this approach enhances the objective value. We think our approach is productive for the knowledge of the problem and future works will find it good.

On the other hand, the model is complicated one but it solves very efficiently. Efforts are being made to make the model a simple one.

References:-

1. J. Gromicho, S. Haneyah*, A.L. Kok, "Solving a Real-Life VRP with Inter-Route and Intra-Route Challenges", Algorithmic R&D, ORTEC, P.O. Box 75, 2700AB Zoetermeer, Netherlands

2. G. Dantzig and J. Ramser, "The Truck Dispatching Problem," *Management Science*, Vol. 6, No. 1, 1959, pp. 80-91. DOI: 10.1287/mnsc.6.1.80
3. David H. Marks and Robert Stricker, "Routing for Public Service Vehicles", *Journal of the Urban Planning and Development Division*, 1971, Vol. 97, Issue 2, Pg. 165-178
4. Abdul Kadar M. Masum, Md. Faisal Faruque and Iqbal H. Sarkar, Vehicle routing problem using Genetic Algorithm. DOI: 10.14569/IJACSA.2011.020719
5. Wan A. F. Wajdi, Aeizaal A. AbdWahab, Syed Sahal N.A. and haw Ngie Wong, "Solving Vehicle Routing Problem using Ant Colony Optimization(ACO) Algorithm"
6. Suresh Nanda Kumar and RamasamyPanneerselvam, "A Survey on the Vehicle Routing Problem and Its Variants".<http://dx.doi.org/10.4236/iim.2012.43010>
7. ModhiLaftaMutar, BurhanuddinMohdAboobaider and AsaadShakirHameed, "Review Paper in Vehicle Routing Problem and Future Research Trend". *International Journal of Applied Engineering Research* ISSN 0973-4562 Volume 12, Number 22 (2017) pp. 12279-12283
8. TonciCaric and Hrvoje Gold, "Vehicle Routing Problem", In-Teh. Amir Hajjam El Hassani, LyamineBouhafs and AbderKoukam, Chapter 4 "A Hybrid Ant Colony System Approach for the Capacitated Vehicle Routing Problem and the Capacitated Vehicle Routing Problem with Time Windows".
9. Ibrahim A.A, Lo N., Abdulaziz R.O and Ishaya J.A., "Capacitated Vehicle Routing Problem", DOI: 10.5281/zenodo.2636820
10. Abdullahi A. Ibrahim, Rabiati O. Abdulaziz, A. Ishaya, Samuel O. Sowole. Vehicle Routing Problem with Exact Methods. e-ISSN: 2278-5728, p-ISSN: 2319-765X. pp 05-15
11. VeaceslavGhilas and Tom Van Woensel, "An adaptive large neighbourhood search heuristic for the Pickup and Delivery Problem with Time Windows and Scheduled Lines", URL <http://doi.org/10.1016/j.cor.2016.01.018>, 2016
12. Nabila Azi, Gendreau M. and Potvin, J., "An Adaptive large neighbourhood search for a Vehicle Routing Problem with Multiple Trips", DOI: 10.1016/j.cor.2013.08.016, 2010
13. S. MostaphaKalamiHeris, "Solving Vehicle Routing Problem using Simulated Annealing", Project Code: YPAP108, URL <http://yarpiz.com/372/ypap108-vehicle-routing-problem/> ypap108-vehicle-routing-problem.